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इलाहाबाद विश्वविद्यालय

12th Annual Conference of Cognitive Science

12th – 14th December, 2025

Thank you note….

We extend our gratitude to the participants of the Twelfth Annual Conference of Cognitive Science.

The technical program consisted of keynote talks, oral presentations, poster presentations and a panel discussion. We thank the eminent cognitive scientists from India and abroad who travelled a long way to attend the conference. We thank all the participants who submitted their abstracts and had come here to share their work and interact with other researchers. We hope that the conference served as a meeting point for scientists facilitating academic networking and further research on different interesting domains and methodologies in Cognitive Science research.

I also thank all the members of the Organising Committee for the collective effort towards the conference. The faculty members and students of the Centre worked very hard for the Conference.

I would also like to take this opportunity to thank the University Administration for their support and encouragement for all our events. We are grateful to the Department of Science and Technology, Government of India for the generous support. We are also thankful to Tiden Technologies and Springer Nature for their support.

Best regards

B Kar

Prof. Bhoomika R. Kar

Head

Centre of Behavioural and Cognitive Sciences
University of Allahabad

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12th December, 2025 Friday

DAY 1

Venue: *Ishwar Topa Building, University of Allahabad*

09:30 - 10:30 **Keynote 1** *Chair: Narayanan Srinivasan*

Chandan J Vaidya (Georgetown University, USA): Adaptive Functioning in Neurodevelopmental Disorders: Role of Executive Function and Learning

10:30 - 11:00 **Inaugural Session**

11:00 - 11:30 **Tea Break**

11:30 - 13:00 **Oral Session 1: Executive Control** *Chair: Srikanth Padmala*

Aswini Madhira (University of Hyderabad) - Reactive, Not Proactive Suppression: Eye-Tracking Evidence for Attentional Control Strategy during Visual Search

Noel Tomy (CBCS) - Quasi-Periodic BOLD Patterns as Person-Specific Predictors of Sustained Attention Fluctuations

Adrija Chatterjee (IIT Kanpur) - Disentangling the Ego- versus Allo-centric navigation switching performance, and relating to Cortical Energy resource in Mild Cognitively Impaired Patients

Amora Tawar (University of Hyderabad) - Partner's L2 proficiency modulates Executive Control in a Joint Task

13:00 - 14:00 **Lunch**

14:00 - 15:30 **Oral Session 2: Language Processing** *Chair: Samar Hussain*

Pallab Basu (IIT Delhi) - Syntactic Expectations in Bengali: Probing Filler-Gap Dependencies Using BERT

Gauri Gunjyal (IIT Gandhinagar) - Processing of Emotional Expressions in Hindi L1 and English L2 Bilinguals

Madhavilatha Maganti (Krea University) - Body Parts and Early-Learned Verbs: Lexico-Semantic Networks in the Telugu and Hindi contexts

Prabhjapan Kaur (IIT Ropar) - Processing of gender-neutral forenames in Punjabi

15:30 - 15:45 **Tea Break**

15:45 - 16:45 **Keynote 2** *Chair: Bapi Raju*

Bharat Biswal (New Jersey Institute of Technology, USA): Toward Brain Connectomics: Examining Brain Connectivity During Rest and Movie Watching

16:45 - 18:15 **Poster Session 1**

18:15 - 19:15 **GB Meeting**

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13th December, 2025 Saturday DAY 2

***Venue:** Ishwar Topa Building, University of Allahabad*

09:00 - 10:00	**Keynote 3** **M Rosario Rueda (University of Granada, Spain):** Developing the Attentive Brain: Early foundations of Executive Attention Development	*Chair: Nandini Chatterjee Singh*
10:00 - 10:45	**Oral Session 3: Cognitive Development** **Tripti Verma** (CBCS) - Feedback and Reward Facilitate Shifts Between Cognitive Control Modes in Children **Kundal Kohli** (CBCS) - Investigating the relationship between Meta-control and Creative Thinking in Children	*Chair: Rashmi Gupta*
10:45 - 11:15	**Tea Break**	
11:15 - 12:45	**Oral Session 4: Inhibition** **Lalchhandama** (IIT Delhi) - Stop or not: Do we have conscious access to the decision to stop? **Indrajeet Indrajeet** (Edmond and Lily Safra Center for Brain Sciences) - Automatic Pause and Deliberate Stop mechanisms in the Basal Ganglia **Chahak Sanduja** (IIT Kanpur) - A Pause is sufficient for Stopping: Evidence from Computational Modelling of stop/continue Signal task **Ishita Singh** (IIIT Delhi) - Emotional Facial Cues modulate Visual Distractor Suppression	*Chair: Devpriya Kumar*
12:45 - 13:45	**Lunch**	
13:45 - 14:45	**Oral Session 5: Memory** **Dipti Singh** (IIT Roorkee) - Investigating the direct effects of Directed Forgetting on Emotional Associations **Sujatha Ramesh** (IIM Indore) - Traditional vs. AI Cognitive Offloading: A Pilot Study of the Effects on Text Comprehension and Retention **Raju Pooja** (IIIT Hyderabad) - Role of Familiarity on Event Transitions and Temporal Structure of Memory	*Chair: Shiv Kumar Sharma*
14:45 - 16:00	**Panel Discussion on Gaming and Cognition** **Nandini Chatterjee Singh** (Ashoka University), **Veeky Baths** (Cognitive Neuroscience Lab, BITS Pilani Goa Campus), **Shraddha Rawat** (Learning Designers Community)	
16:00 - 16:15	**Tea Break**	
16:15 - 17:45	**Poster Session 2**	
19:30 onwards	**Conference Dinner** Hotel Yatrik Lawns	

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14th December, 2025 Sunday DAY 3

***Venue:** Ishwar Topa Building, University of Allahabad*

09:00 - 10:00 **Keynote 4** *Chair: Ramesh Mishra*
Samar Hussain (IIT Delhi): Towards a Typology of Language Processing

10:00 - 11:30 **Oral Session 6: Language and Cognition** *Chair: Ark Verma*

Gaurja Aeron (IIT Gandhinagar) - Number-Feature and Noun Representation Distortion in Hindi Sentences

Pranab Bagartti (IIT Delhi) - Length and Modality impacts Subject drop: A Corpus study in Hindi

Nayana Raj (IIT Delhi) - The Temporal Dynamics of Visual Word Recognition: Morphological Priming in a Morphologically Rich Language

Sandeep Kour (Central University of Punjab) - Age and Structural Differences in Multilinguals: Effects on Attention and Cognitive Flexibility

11:30 - 12:00 **Tea Break**

12:00 - 13:00 **Oral Session 7: Motor Memory** *Chair: Krishna Prasad Miyapuram*

Manvi Joiya (IIT Gandhinagar) - Mechanisms Underlying Savings in Visuomotor Adaptation

Navya Bajpai (IIIT Hyderabad) - Temporal Dynamics of Sequence Learning: How Response–Stimulus Interval Shapes Chunking and the Implicit–Explicit Transition

Naman Payasi (IIT Delhi) - Eyes do not lie: Testing whether Eye-tracking can be used to detect Mind-Wandering and Mind-Blanking

13:00 - 14:00 **Lunch**

14:00 - 15:00 **Oral Session 8: Music, Motivation, and Cognition** *Chair: Jay Prakash Singh*

Arijit Bhattacharya (Ashoka University) - Music, Mood, and Mind: Functional Modeling of Structure-, State- and Trait-Based Modulation of Emotion

Aditi Jha (IIT Gandhinagar) - Neural Coding of Auditory Features during Music Perception and Imagery

Harish Sinai Velingkar (AITD) - Understanding Consumer Attention: An EEG Study on Visual Appeal and Taste of food

15:00 - 16:30 **Poster Session 3**

16:30 - 17:15 **Industry Talk**
Parag Amodkar & Spandan Raha, Tiden Technologies

17:15 - 18:00 **Valedictory**

DAY 1 **12th December 2025**

Keynote 1 **Chair: Narayanan Srinivasan**

Adaptive Functioning in Neurodevelopmental Disorders: Role of Executive Function and Learning

Chandan J Vaidya

Georgetown University, USA

Adapting to real-world demands of daily life is a primary task of development. Despite normal intelligence, adaptive functioning varies greatly among children and adolescents with neurodevelopmental disorders. There are at least two ways we adapt to environmental demands, by using processes for controlling attention, actions, and emotions, termed executive function, and by building concepts that we learn across experiences. I will present our recent studies, published and ongoing, that attempt to gain insights at the behavioral and neural level, into these two processes. Regarding executive function, problems with executive function co-occur with core symptoms of most psychiatric and neurological disorders of developmental origin, all of which affect adaptive functioning. Our studies aim to identify brain regions, circuits, and networks that may support a mechanistic role in how executive function, psychopathology, and adaptive functioning may be related, across disorders. Using data-driven approaches, we find that behaviorally, three distinct profiles of strengths and weaknesses in executive function explain individual differences across childhood psychiatric disorders such as autism, attention deficit disorders, mood disorders as well as in one neurological disorder, epilepsy. We find that frontoparietal and the salience networks and select functional connections between them, are important in differences in executive function profiles as well as in how psychopathology may affect real-world adaptive functioning. Regarding learning, new work examines links between cognitive inflexibility and concept learning, particularly in autism, testing the hypothesis that computationally-derived learning biases, whether towards generating prototypes or exemplar-specific information, explain differences in behavioral flexibility and in turn, adaptive functioning. We find that specific medial prefrontal and parietal regions are particularly important in these learning differences. Finally, I will end with some preliminary findings regarding response to treatment for executive dysfunction.

Reactive, Not Proactive suppression: Eye-Tracking Evidence for attentional control strategy during visual search

Pratyoosh Sharma, Aswini Madhira*, Ramesh Kumar Mishra

Centre for Neural and Cognitive Sciences, University of Hyderabad

Introduction

Goal-directed behaviour critically involves both enhancement of target and suppression of distractors. While efficient goal-directed behaviour relies on anticipation, it remains unclear whether such anticipation extends beyond target enhancement to the suppression of distractors. The present study investigated whether suppression of a salient distractor can be initiated proactively at an anticipated location, using a mental rotation task combined with a feature search paradigm (Gaspelin & Luck, 2018). According to Braver's dual mechanisms of control framework (2012), cognitive control operates proactively—preparing the system to resist distraction before it occurs—or reactively—engaging suppression after distractor detection. We tested whether rotation cues indicating the location of potential distractors would elicit proactive suppression, as measured by anticipatory eye movements. We hypothesised that proactive suppression would manifest in reduced fixations to anticipated distractor locations before search array onset, whereas reactive suppression would only emerge after array presentation.

Methods

Sixty university students (n = 30 per experiment) completed two experiments. In experiment 1, participants performed 480 trials (plus 20 practice trials), each beginning with a 500 ms fixation cross, followed by a 500 ms preview of the search array (square being the target shape among non-target shapes: diamond, hexagon, and pentagon). In 75% of trials, a salient distractor (SD) appeared in red, with the remaining non-salient distractors (NSD). After a 500 ms rotation cue (indicating angle and direction of rotation of the search array: 0°, 90°, 180°, 270°) and a 1000 ms blank screen, participants viewed the rotated search array for 2000 ms and identified the line orientation within the target. In experiment 2, cue congruency was manipulated. In 25% of 600 trials (plus 20 practice trials), actual rotation differed from the cue (Incongruent trials). Eye movements were tracked to measure fixation proportions to targets, SDs, and NSDs during preview, blank, and search intervals. Participants with a minimum accuracy of 80% were included.

Results

In Experiment 1, reaction times were faster when distractors were present than absent, indicating suppression (t(29) = 3.05, $p < 0.01$). This shows that participants could resolve competition from SDs during active search, yielding a significant speed advantage. However, anticipatory fixations on the blank screen did not differ between SDs and NSDs. Repeated-measures ANOV As on fixation proportions revealed significant main effects of object-type (Target, SD, NSD), time-window (100ms - 400ms), and interaction effects, across preview (object-type: F(2,58) = 160.46, $p < 0.001$; time-window: F(6,174) = 146.66, $p < 0.001$) and blank screen (object type: F(2,58) = 69.74, $p < 0.001$; time-window: F(6,174)= 45.61,$p < 0.001$). The preview screen showed attention capture by SD compared to NSD t(29)= 7.95, $p < 0.001$. But it did not reflect in anticipatory suppression during the blank screen. During the search array, while participants fixated significantly more on targets than distractors F(2,58) = 689.21, $p < 0.001$, they also showed reactive suppression indicated by fewer fixations to SDs than NSDs t(29) = 3.91, $p < 0.001$. Thus, suppression-related benefits emerged only after the search array was introduced, not during earlier viewing phases.

Experiment 2 examined whether cue congruency could facilitate proactive suppression. RT's were faster on congruent versus incongruent trials (F(1,29) = 23.37, $p < 0.001$), and distractor presence continued to reduce RTs (F(1,29) = 6.37, p = 0.017), confirming suppression. The congruence effect indicates that cues successfully oriented participants toward likely target locations. However, fixation patterns during preview and blank intervals did not differ between SDs and NSDs, irrespective of cue congruency. Contrarily, RM ANOV A on search array fixations showed significant main effects of object type F(2,58) = 275.34, $p < 0.001$, time-window F(6,174) = 151.61, $p < 0.001$ and congruency F(1,29) = 277.83, $p < 0.001$), with targets receiving significantly highest fixations, NSDs intermediate, and SDs lowest—particularly on congruent trials—indicating reactive suppression during active search. This reinforces the finding from Experiment 1 that suppression is implemented after stimulus onset rather than proactively during pre-search intervals.

Discussion

We examined whether proactive or reactive suppression of salient distractors would occur in a mental rotation task with anticipatory cues. Across both experiments, participants consistently demonstrated reactive suppression, triggered by search display onset, rather than proactive suppression. The proportion of fixations toward SDs during preview and blank intervals were similar to NSDs, indicating that reactive suppression emerged only during the search array. Experiment 1 aligns with the finding that attentional capture by salience often overrides anticipatory control (Theeuwes, 2010). Experiment 2 showed that congruent cues improved reaction times but did not elicit anticipatory suppression, reinforcing the dominance of reactive mechanisms when spatial predictions are brief or uncertain. Together, these findings show that the visual system appeared biased towards target enhancement over anticipatory distractor suppression.

While participants engaged attentional control effectively during search, cue-based anticipation was insufficient to suppress distractors before they appeared. They adopted a reactive strategy, waiting for the complete search array before applying suppression templates. While these results attest to the updated account of signal suppression that preliminary attentional capture motivates learning to suppress distractors (Gaspelin et al., 2025), it probes into when such suppression occurs. In conclusion, these findings highlight the limits of proactive distractor suppression and underscore the interplay between anticipatory and reactive control in complex visual tasks.

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Quasi-Periodic BOLD Patterns as Person-Specific Predictors of Sustained Attention Fluctuations

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Introduction

The ability to sustain attention is fundamental to human cognition but inherently unstable, fluctuating from moment to moment. A central challenge for cognitive neuroscience is identifying reliable neural markers to track these dynamic changes within an individual. While static, time averaged functional connectivity models have successfully predicted stable, trait-level differences in attention, they are largely insensitive to real-time variations in cognitive performance that occur intra-individually. Infra-slow Quasi-Periodic Patterns (QPPs), recurring, stereotyped spatiotemporal sequences of brain activity, represent a promising class of dynamic neural events that may overcome this limitation.[2]

Characterized by alternating periods of activation and deactivation in large-scale networks like default mode network (DMN) and dorsal attention networks, QPPs may provide a more sensitive window into ongoing cognitive processes.[1,2,3] We assume QPPs reflect intrinsic transitions between internally and externally oriented brain states, and should provide a more direct window into the brain's real-time fluctuations in attention and arousal than static functional connectivity.

An open question is whether intra-individual variations in QPP can reliably predict moment-to moment cognitive performance. This study aimed to investigate whether fluctuations in QPP derived brain metrics could serve as individualized biomarkers of sustained attention, testing their predictive power against conventional static connectivity measures.

Methods

Thirteen healthy adults performed a continuous visual Metronome Response Task (vMRT) for approximately 50 minutes while undergoing functional magnetic resonance imaging (fMRI).[4] vMRT requires sustained focus to maintain rhythmic tapping, providing a robust measure of attentional stability.[4] Data was acquired on a 3T scanner (TR = 1000ms, 3 mm isotropic voxels). The natural logarithm of reaction-time variability (logRTV), calculated for each 4.5-minute task block, served as the primary behavioral index of sustained attention, with higher values indicating poorer performance.

Following preprocessing with fMRIPrep, QPPs were detected from network-level time series (derived from Yeo 7-network parcellation) using a 20-second sliding window correlation algorithm. All time series were temporally bandpass-filtered to 0.01–0.1 Hz to isolate infra-slow fluctuations known to drive quasi-periodic activity and to remove higher-frequency noise. From these, we derived inter-network anti-correlation metrics (e.g., DMN–SOM (Somatomotor), DMN DAN (Dorsal Attentional Network)) reflecting the amplitude of network transitions within the quasi-periodic cycle, and whole-network time series (NetTS) inter-network anti-correlation metrics. The predictive power of QPP-derived metrics was compared against NetTS-derived metrics.

The predictive value of QPP vs static metrics was assessed with linear mixed-effects models (LMMs) (DV = logRTV; fixed effects for both predictors). Participant-specific random intercepts were included to model baseline differences. To test for stable, person-specific QPP-performance relationships, a second model added participant-specific random slopes for the QPP metric, with significance evaluated via a likelihood-ratio test. Finally, a whole-brain, FDR-corrected edgewise connectivity analysis identified specific functional connections whose modulation by QPPs was most strongly associated with performance.

LMMs were used to compare QPP and NetTS-based predictors within a unified framework that accounts for repeated measures nested within participants. Because both predictors share identical data structure and noise characteristics, any statistical limitations (small N, noise) apply equally, making their relative predictive strengths directly comparable.

Results

Block-wise correlational analyses revealed that QPP-derived metrics were consistently superior predictors of performance. Notably, the QPP-derived metric for the DMN–SOM anti-correlation exhibited robust positive correlation with logRTV ($r = 0.401$, $p < 0.001$), substantially stronger than the corresponding NetTS metric ($r = 0.341$, $p < 0.001$). Similar results were found for DMN-DAN.

LMMs further confirmed these findings. In a model including both predictors, the DMN–DAN QPP metric was a significant positive predictor of logRTV ($\beta = 0.462$, $p < 0.001$), while NetTS metric for the same was not. Similar results were found for DMN-SOM and DMN-VAN (Ventral attention network) after FDR correction. A likelihood-ratio test indicated that inclusion of QPP predictor significantly improved model fit over a model containing only NetTS predictor ($\chi^2(3) = 21.29$, $p < 0.001$).

The most novel finding was that the QPP-performance relationship was a stable, person-specific characteristic. The DMN-SOM QPP metric exhibited significant participant-specific random slope variance (σ2 slope = 0.116), indicating reliable inter-individual variability of this brain-behavior relationship's strength. A model incorporating this random slope provided a significantly better fit to data than a random-intercept-only model (LRT $\Delta\chi 2$ =12.93, FDR-corrected q = 0.002).

Finally, edgewise analysis identified a plausible neural mechanism for these effects, revealing that QPP-driven modulation of functional connectivity between left primary somatosensory cortex (S1 trunk area) and left dorsolateral putamen was significantly associated with attentional performance (t(12)=8.72, FDR-corrected q=0.0466), with Cohen's d = 2.42.

Discussion

Our results provide converging evidence from correlation, mixed-effects modeling, and fine-grained edgewise analyses that infra-slow QPP dynamics, derived from temporally bandpass-filtered BOLD signals, capture intra-individual fluctuations in sustained attention more sensitively than static FC. This likely reflects QPP's ability to represent temporally structured, large-scale network transitions relevant to ongoing task performance.

Importantly, we show that QPP-performance link is idiosyncratic; unique "neural signature" in QPP expression relates to attentional variability. Moving beyond the group-average approach, this opens a path toward individualized neurocognitive profiling.

The identification of a specific cortico-striatal connection associated with performance suggests a possible mechanism: QPPs may modulate motor and sensory integration circuits that directly influence rhythmic coordination in the vMRT. Such mechanisms could be targets for brain stimulation protocols aimed at enhancing sustained attention in both healthy individuals and clinical populations (e.g., ADHD, TBI).

Beyond attentional research, this study demonstrates a methodological framework for linking dynamic, temporally structured neural events to real-time behavioral fluctuations. This could be applied to other cognitive domains like memory, language processing, decision-making, where moment-to-moment variability is both substantial and theoretically important.

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Disentangling the Ego-versus Allo-centric navigation switching performance, and relating to cortical energy resource in mild cognitively impaired patients

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Introduction

Spatial awareness is the first domain affected in MCI[a], a transitional state between normal ageing and dementia with conversion rates as high as 64% within two years[b]. Navigation relies on two distinct computations: egocentric (self-centred representations) and allocentric (world-centred representations), as well as the flexibility of switching between them for optimal navigation. Traditionally, it was believed that the brain's spatial map is coded based on an allocentric frame involving the hippocampus and neighbouring regions. Research shows that primary upstream regions, such as the post rhinal cortex, contain egocentric boundary cells, while

downstream processing regions, including the parasubiculum and medial entorhinal cortex, contain conjunctive EBCs and head direction (HD) cells[c][d]. This implies that HD cells are necessary for encoding the spatial context of an incident by converting egocentric sensory data into an allocentric map. The reverse process—transforming stored allocentric codes back into egocentric viewpoints—enables the reconstruction of first-person perspectives during retrieval[e]. Since episodic memory loss is an early sign of Alzheimer's disease (AD), this frame switching that occurs during encoding and retrieval can be used as a cognitive indicator[f].

Our research investigates, through a real-world spatial navigation paradigm, how switching differs in the healthy and MCI cohorts. Since increased stress or mental load can aggravate cognitive and memory decline[g], we introduce an additional working memory task (Digit numbering task, DNT) with navigation, to strain cognitive resources and observe its impact on switching. We simultaneously recorded electroencephalographic signals and administered a passive auditory mismatch negativity paradigm to understand the mismatch negativity (MMN) as a proxy for cognitive resource availability.

Our specific hypothesis was to test how high cognitive load affects performance in switching between egocentric and allocentric frames of reference during navigation, and how cognitive resource availability (measured via EEG/MMN) relates to behavioural performance in MCI vs. healthy controls.

Methods

Participants: 24 older adults (14 male, 10 female), age >55 (M=69), divided into 11 with Mild Cognitive Impairment and 13 healthy controls based on MMSE scores (Healthy: MMSE>22/30).

Baselining: Baseline cognitive measures included the Reference Frame Proclivity Test (RFPT), which classifies individuals by their preferred intrinsic spatial reference frame during navigation (Egocentric=13, Allocentric=11), and a working memory load profile from the Digit Numbering Task, capturing each participant's lower and upper thresholds (High: M=6, SD=1.71 Low: M=4, SD=1.28).

Task: Participants completed 5 trials of a real-world navigation task, conducted while seated on a wheelchair, with combined conditions of Working memory (WM) load (Digit Numbering Task: 2 high, 2 low, and baseline) and two levels of navigational load (based on the number of turns). Participants reported the direction of the home(egocentric) and direction home with respect to a landmark in every trial(allocentric), taken on an angle meter app. A passive auditory Mismatch Negativity (MMN) paradigm was presented during each trial.

During navigation, participants listened to digit sequences they had to recall at trial end, while auditory oddball tones elicited mismatch negativity (MMN) responses recorded with an 11-channel portable EEG system.

For each trial: DNT accuracy was computed as the percentage of correctly recalled digit sequences in order. Egocentric and Allocentric angle error was calculated by computing the difference between actual angle and angle reported by participants.

Switching was defined by comparing each trial's better-performing spatial frame (egocentric vs allocentric pointing accuracy) with the participant's intrinsic proclivity; a mismatch indicated a switch (coded 1), while a match indicated no switch (coded 0).

EEG data were preprocessed: it was filtered with a zero-phase FIR filter having a 0.5–40 Hz passband (pop_eegfiltnew, filter order = 9000) and analyzed for event-related potentials using

EEGlab toolbox, with MMN waveforms derived by subtracting responses to standard minima tones from deviant minima tones in the 100–400 ms post-stimulus. In this study, we report the ERP difference between deviant and standard from the central region (Average of electrodes: C3, C4, Cz).

Results

From behaviour: We first constructed a logistic regression predicting switching (binary outcome) from the WM load, navigational load and diagnosis group. MCI status was associated with reduced likelihood of switching (β=-1.869, p=0.02).

Model predictions closely matched observed distributions (Healthy: predicted=0.593, observed=0.583; MCI: predicted=0.29, observed=0.38), indicating that WM load and diagnosis robustly capture individual differences in frame switching. Notably, switching patterns varied across WM load: under high load, MCI participants switched more frequently, whereas under low load, healthy participants showed higher switch rates. This WM load × group interaction was able to significantly predict switching behaviour (β = 2.46, p = 0.009).

From the MMN task: ERP amplitudes in central regions were more negative in MCI (p=0.002)

than Healthy as well as control trials, and predicted switch behaviour in a separate model (β= 1.168, p=0.011). Predicted switch probabilities from the ERP-based model again aligned with observed switching across groups (Healthy: predicted = 0.51, MCI: predicted =0.26), further validating our neural measure as a predictor of behavioural flexibility. Behavioural (switching, working memory) and neural (ERP) measures independently and jointly captured navigation flexibility, highlighting their potential as sensitive indicators of cognitive impairment. *A predictive model based on switching and other significant behavioural features achieved 71.43% sensitivity and 77.78% specificity with an 80:20 train–test split.*

Discussion

Switching in spatial navigation has typically been studied by comparing performances between egocentric and allocentric, vice versa, or via learning in one frame and testing in the other, through tasks conducted in VR or lab-based settings. In contrast, our research emphasizes participants' intrinsic frame preference and examines switching in a real-world environment, thereby enhancing ecological validity.

Larger negative MMN deflection in MCI participants, over the central region[h], compared to healthy controls, suggests greater engagement in the auditory task. This likely reflects poor attentional filtering[i] and appears to be compensated by less frequent costly switching and reflected in poorer DNT performance. Interestingly, under high load, we observed the opposite trend, with MCI participants showing a higher frequency of switching. Whether this mechanism reflects compensatory resource optimization or cognitive dysregulation due to loss of maintenance of stale navigation strategies can be evaluated by further examining the extent of errors in task performances during frame of reference switch.

Limitation: Observed switching is from an intrinsic to a non-intrinsic frame, and whether a preferred frame drives directional switching should be examined further.

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Partner’s L2 proficiency modulates executive control in a joint task

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Introduction

Joint action refers to the coordination of actions performed between two individuals while the same goal is shared. This depends on action co-representations, predictions and adaptations as cognitive mechanisms (Sebanz et al., 2006; Vesper et al., 2017). Such coordination depends on adapting to the partner’s unique characteristics, including their linguistic backgrounds. This is especially relevant in bilingual contexts where second language proficiency is shown to modulate executive control (Green & Abutalebi, 2013). However, the influence of partner’s proficiency on executive control in joint contexts remains to be explored.

In this study, we investigate the effect of the task partner’s L2 proficiency on executive control performance during a joint setting. The present study investigates the influence of the task partner’s linguistic profile on the control exerted by the participant in a shared context i.e., joint flanker task. Participants responded in turns and their performance across switch-stay and congruency conditions was analysed.

Methods

Ninety Telugu-English bilinguals (mean age = 23.6, SD = 3.9) were recruited as participants. L2 proficiency was calculated using LexTALE ((Lemhöfer & Broersma, 2012), the Language and Social Background Questionnaire (LSBQ) (Anderson et al., 2017), and semantic and verbal fluency. A composite score was calculated for each (Ma et al., 2017) and were classified as either high or low L2 proficient. The pairs for the experiment were: low-low, high-low and high-high. Before the experiment began, participants had to converse with each other for 10 minutes to gauge each other’s proficiency. They then performed the joint flanker task while being seated next to each other. Trials were divided based on stimuli colour, and were randomised.

Results

Repeated measures ANOVA was performed on reaction time data. Trial type (congruent, incongruent), switch condition (switch, stay) and participant proficiency (high, low) were considered as factors. (Here, stay trial: participant’s trial being preceded by their own; switch trial: participant's trial being preceded by their partner's).

In the high-low group, main effect of trial type was significant, $F(1, 12) = 31.70$, $p < .001$, $\eta^2 = .725$. Faster responses were observed in congruent trials ($M = 469.51$ ms) than incongruent trials (508.38 ms). Main effect of switch condition was also observed, $F(1, 12) = 5.62$, $p = .035$, $\eta^2 = .319$, with responses faster in the switch trials ($M = 481.10$ ms) than stay trials (M=496.78 ms). The interaction between proficiency and switch condition was significant, $F(1, 12) = 6.47$, $p = .026$, $\eta^2 = .350$. Pairwise comparisons indicated faster response of low proficient participants in the switch trials ($M = 488.21$ ms) than stay trials ($M = 517.82$ ms). This trend was not observed in the high proficient participants.

In the low-low and high-high groups, main effect of trial type was significant (LPLP: $F(1, 12) = 24.41$, $p < .001$; HPHP: $F(1, 12) = 18.46$, $p < .001$), indicating a flanker effect. No other effects were significant.

Discussion

Results show that language proficiency of one's partner has a modulatory effect on their executive function during tasks with shared actions. Flanker effect was seen with slower responses on the incongruent trials, confirming successful conflict monitoring and inhibitory control.

In high-low pairs, a kind of reverse switch cost was found where low proficient participants performed better in the switch condition compared to the stay condition, whereas high proficient participants maintained a uniform performance across conditions. This means that the low proficient participants were being affected by the presence of their partner more than their high proficient counterparts and could be considered to be more flexible in adapting to their surroundings. A high proficient partner might have induced increased adaptive strategies, whereas a lower proficient partner might have led to task automatization. In cases where similar L2 proficient participants were paired, no such effect was seen, suggesting that performance was driven by task demands and not partner proficiency.

This suggests that linguistic asymmetry can induce adaptive control mechanisms and may influence cognitive flexibility in social settings.

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Syntactic Expectations in Bengali: Probing Filler–Gap Dependencies Using BERT

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Introduction

Natural language syntax is fundamentally hierarchical rather than merely sequential (Chomsky, 1957; Everaert et al., 2015). While recurrent neural network (RNN) language models, particularly LSTMs, have demonstrated impressive performance in terms of perplexity and down- stream NLP tasks, questions remain about the extent to which these models acquire deeper syntactic generalizations. Notably, Wilcox et al. (2018, 2019) showed that state-of-the-art LSTM models appear to capture aspects of English filler-gap dependencies and even demonstrate sensitivity to certain syntactic island constraints (Ross, 1967), which traditionally pose barriers to long-distance dependency formation. Building on this line of inquiry, the present study investigates filler–gap dependency representations in Bengali using BERT, a transformer-based model differing from RNNs in architecture and training. We assess whether BERT shows evidence of active dependency formation—a psycholinguistically motivated process where comprehenders anticipate gap sites (Fodor, 1978; Crain and Fodor, 1985; Stowe, 1986). Using three pre-trained Bengali BERT models and a masked prediction task, we explore their sensitivity to filler–gap dependencies in a low-resource setting, shedding light on hierarchical generalization and predictive processing in transformers.

Methods

Bengali allows embedded clauses both pre- and post-verbally, typically marked by clause-final *bole* or clause-initial *je*, respectively (Dasgupta, 2007). Filler-gap dependencies from the main clause can be resolved either within it or in an embedded clause, regardless of the latter's position. These features make Bengali well-suited for studying locality in filler-gap resolution. Drawing on the experimental framework proposed by Chacón et al. (2016), we systematically exploited the structural variability of Bengali to design a 2×2 factorial experiment. The design crossed two factors: (i) the type of Wh-expression—either an argumental wh-phrase bearing accusative case or an adjunct wh-phrase (e.g., when, where); and (ii) the position of the embedding verb—either preceding (matrix-verb-first) or following (embedded-verb-first) the embedded clause. In each stimulus sentence, a potential gap site was replaced with a [MASK] token to enable masked language modeling. Each of the four resulting conditions included 25 items, yielding a total of 100 constructed stimuli. We conducted two computational experiments to examine how lexical and structural factors influence the predictability of gap resolution in Bengali wh-dependencies. Both experiments employed three pretrained BERT models within a masked language modeling paradigm, focusing on argument gaps.

Experiment-1: Full-Sentence Masking for Gap Prediction: In the first experiment, complete sentences were presented to the models with a single potential gap site replaced by a [MASK] token. The models' top-5 lexical predictions at the masked position were extracted along with their probabilities. These predicted items were categorized based on case marking—specifically, accusative-marked versus others. For each sentence, the probabilities of tokens within each group were averaged to obtain one value per category —to evaluate the models' probabilistic bias toward argumental gap filling.

Experiment 2: Local Span Masking and Surprisal-Based Inference: The second experiment restricted the model's input to the linear span between the wh-phrase and the potential gap site, with the [MASK] token interpreted as a null element corresponding to an unpronounced syntactic gap. For each such input, we computed surprisal by summing the probabilities of all possible lexical continuations at the masked position. This approach yielded a more localized and structure-sensitive estimate of the model's expectation regarding gap realization.

Predictions: The core hypothesis is that encountering an accusative-marked wh-phrase (i.e., an argument) should prompt BERT to anticipate a gap, leading to higher probability and consequently lower surprisal at the masked site due to fulfilled expectations. This predictive effect is expected to vary with both the argument status of the wh-phrase and the clause order (matrix-first vs. embedded-first), reflecting interactions between lexical and syntactic cues. Experiment 1 used linear mixed-effects models (Bates et al., 2015) to test whether accusative-marked predictions at the masked site varied by clause order and argument type. Experiment 2 applied similar modeling to assess whether surprisal at the gap site was modulated by syntactic expectations.

Results

In **Experiment 1**, BERT models exhibited varying degrees of sensitivity to argument- driven gap expectations. **Model 1** showed a significant reduction in argument prediction probability in the presence of an accusative *wh*-phrase ($\beta = -0.101, p < .001$), along with a clause order effect ($\beta = 0.032, p = .014$) and a significant interaction ($\beta = -0.084, p = .005$), indicating structural modulation. **Model 2** replicated the main effect of argument type ($\beta = -0.025, p = .019$) and showed a strong clause order effect ($\beta = -0.083$, $p < .001$), though the interaction was not significant ($p = .23$). **Model 3** revealed no significant effects (all $p > .14$), suggesting reduced sensitivity to these manipulations.

In **Experiment 2**, **Model 1** showed a significant increase in gap surprisal due to clause order ($\beta = 0.107$, $p < .001$), while neither argument type ($\beta = -0.042$, $p = .17$) nor the interaction ($\beta = -0.022$, $p = .44$) reached significance. **Model 2** produced no significant effects of clause order ($p = .15$), argument type ($p = .59$), or interaction ($p = .18$), and exhibited a singular fit. **Model 3** yielded only a significant intercept ($\beta = 0.039$, $p < .001$), with all other effects non-significant (all $p > .14$). Overall, while some models reflect predictive syntactic encoding at gap sites, their structural sensitivity—particularly to argument type—is limited and inconsistent across architectures.

Discussion

The three BERT models exhibited divergent behaviors in processing filler–gap dependencies, likely due to differences in architecture and training data. While Models 1 and 2 demonstrated sensitivity to argument structure and clause order—capturing aspects of hierarchical syntax—Model 3 lacked such syntactic awareness. These results highlight that BERT, as a computational model, can represent predictive syntactic structure in some variants, but struggles to generalize to non-canonical constructions like embedded-second clause types. Such structures are characteristic of spoken discourse and may be underrepresented in the written corpora BERT is typically trained on. This suggests a limitation in the models' ability to capture out-of-distribution syntactic phenomena and points to the need for deeper inquiry into how training data and architecture influence structural generalization in language models.

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Processing of Emotional Expressions in Hindi L1 and English L2 Bilinguals

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Introduction

Multilingual speakers often experience a preference for using one of their language repertoires when it comes to expressing emotion. There has been research showing that a bilingual's first language (L1), the language developed from their birth, usually through interactions with caregivers, is closely tied to personal and emotional experiences (Harris, 2004; Dewaele, 2015; Chen et al., 2015; Naranowicz et al., 2022). For example, bilinguals were reported to switch to their L1 during heated arguments (Dewaele, 2015). Eilola et al. (2007) and Harris (2004) also demonstrated that L1 elicits stronger responses to reprimands and taboo words than their second language (L2), regardless of the proficiency.

However, recent studies have suggested that L2 can also carry emotional weight with regular use in emotional settings such as intimate relationships or expressive interactions (Ożańska-Ponikwia, 2012). Also, Caldwell-Harris et al.'s work (2010) on Mandarin-English bilinguals highlights the role of cultural norms in shaping emotional expression, indicating that L1 cultural norms may inhibit emotional expression.

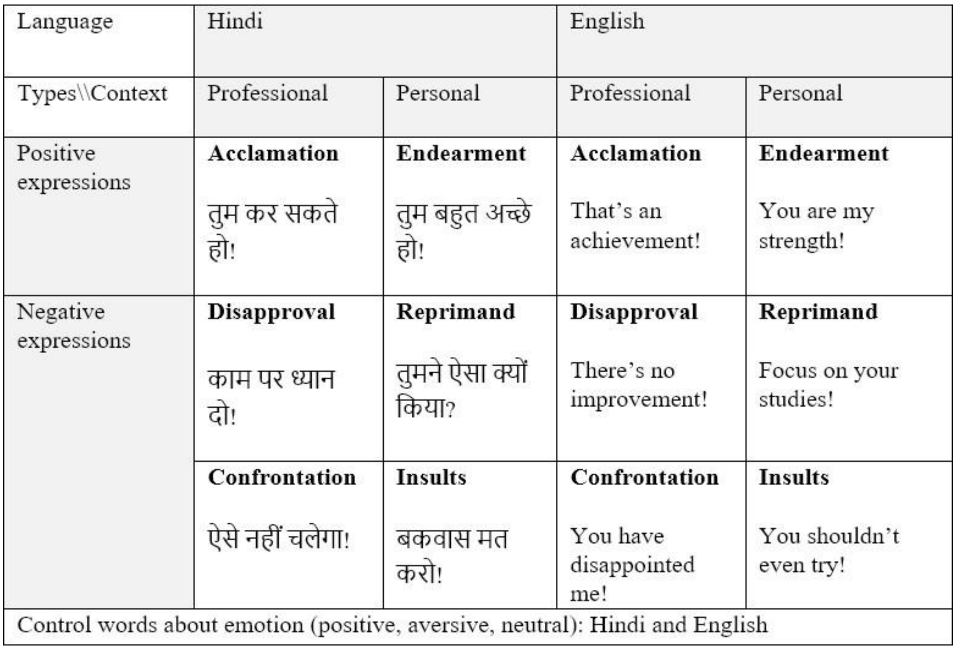
This study targets Hindi-English bilinguals in India, and aims to examine Hindi-English bilinguals' emotional reactivity patterns against emotionally charged inputs in (i) Hindi and English and (ii) personal and professional contexts, using Skin Conductance Responses (SCRs) via Electrodermal activity (EDA) electrodes.

Methods

Participants: 12 native Hindi speakers (M= 7, F= 5, Average age = 20.75, SD= 2.30) participated. All listed Hindi as their first-acquired language and English as their second. They were educated in English-medium schools in K-12 and reported high proficiency in English.

Experimental Design: Skin Conductance Responses (SCRs) were recorded as participants read 96 target expressions spanning three emotional categories (endearments, reprimands, insults), presented in both languages and contexts. An additional 54 control stimuli (neutral, positive, aversive words) served as baselines. The study followed a 2 (Language: Hindi, English) × 2 (Context: Personal, Professional) × 3 (Expression Type) factorial design. Most of the English stimuli were taken from Harris (2004) while the rest were derived from real- life interactions in both personal and professional contexts, making them representative of naturally occurring language use.

Table 1: Categories of Emotional Expressions in Personal and Professional Context



Language	Hindi		English	
Types\\Context	Professional	Personal	Professional	Personal
Positive expressions	**Acclamation** तुम कर सकते हो!	**Endearment** तुम बहुत अच्छे हो!	**Acclamation** That's an achievement!	**Endearment** You are my strength!
Negative expressions	**Disapproval** काम पर ध्यान दो!	**Reprimand** तुमने ऐसा क्यों किया?	**Disapproval** There's no improvement!	**Reprimand** Focus on your studies!
	Confrontation ऐसे नहीं चलेगा!	**Insults** बकवास मत करो!	**Confrontation** You have disappointed me!	**Insults** You shouldn't even try!
Control words about emotion (positive, aversive, neutral): Hindi and English				

Procedure: The experiment started with a fixation cross, displayed for 1 sec, followed by a stimulus, displayed for 3-5 secs (Main stimuli: 5 secs; Control stimuli: 3 secs), after which a blank screen appeared before the next fixation cross was displayed. The experiment was divided into 5 blocks of 30 stimuli each, to prevent habituation and carryover effects.

Results

A per-stimulus baseline subtraction was performed to isolate the phasic Skin Conductance Response (SCR) attributable to each stimulus. SCR values were normalized via z-scoring and were averaged across items within each language and context condition. After confirming the normality of the average scores ($p = 0.18005$), a two-way repeated measures ANOVA was conducted. The results yielded $F (3, 12) = 517$, $p < 0.001$, which suggested a significant interaction between language and context on emotional reactivity, meaning that the influence of language on emotional reactivity differs across contexts. Overall, participants exhibited strong emotional responses in Hindi during personal and professional contexts. In the case of English stimuli, participants exhibited weaker responses in the personal contexts, whereas they showed much stronger responses in the professional contexts.

Discussion

These findings contribute to ongoing debates in bilingualism research regarding the emotional grounding of L1 and L2. Traditional views have emphasized emotional distancing in L2 due to reduced early-life emotional exposure (Dewaele, 2015).

The heightened emotional reactivity to English in professional contexts highlights contextual embeddedness, where a language's emotional significance is shaped by the specific domains in which it is regularly used. This is consistent with Schrauf's (2000) proposal that the memory and emotional associations of a language are not fixed but emerge from its usage patterns. Moreover, the individual differences observed in SCR responses highlight that bilingual emotional experience is varied and not tied to language alone. Emotional resonance in either language can be shaped by personal history, language proficiency, and social norms (Kazanas & Altarriba, 2019).

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Body Parts and Early-Learned Verbs: Lexico-Semantic Networks In the Telugu and Hindi Contexts

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Introduction

In the last decade, theorists have attempted to move beyond modal and amodal accounts of conceptual knowledge, to incorporate a view that semantic knowledge is organized along different dimensions (multidimensionality) from amodal linguistic information to experienced-based dimensions (sensory-motor, emotional, social experience) depending on the task. Through observation, play and manipulation (early multimodality), children build essential early vocabulary, predictive of later vocabulary acquisition and language development, as well as reading comprehension and academic success. Traditionally early learned verbs have been seen as abstract and relational, building their meaning from the words that surround them, and body-verb interactions have received little attention. Multimodality has a number of implications in school context but only more recently has been examined in terms of how children learn early abstract verbs, including recruitment of the emotional system and interoception as well as gestures.

Using a semantic decision task, we report child judgements of preferred body part-verb interaction that potentially reflect the selective attentional statistics of the developing sensory-motor region while observing, doing, feeling, talking or thinking about and remembering events. We additionally examine gestures that some children spontaneously provide in this perceived social context as well as amodal linguistic fragments. We tested children exposed to Telugu and two dialects of Hindi for verb-body agreements of concrete and abstract verbs, providing new developmental evidence as a majority of studies have examined mostly English and adults.

Method

We investigate systematicity and coherence of verb meaning as organized by parts of the body for 100 Telugu and 84 Hindi early-learned verbs (Hindi CDI) (41 translational equivalents). Native speaker experimenters presented the verbs orally and individually to 56 Telugu-natives

(Hyderabad: 27 kindergartners, 29 first-graders) and 142 Hindi-natives (61 in Asawarpur, Haryana: 26 kindergarteners, 35 first-graders; 81 in Pune: 43 kindergarteners, 38 first-graders), respectively. The grade level was selected for the transitional period with increased capacity for systematicity, memory search and retrieval, and language expressing abstract knowledge. For a baseline, we used the prompt *What body part do you use when you verb?* Telugu: *Vantloni ye bagam tho nuvvu________*?/Hindi (Asawarpur): *Aap kis shareer ke ang ke saath* ______ *ho?* For dynamic interplay with instructions, a second prompt was used in Hindi (Pune): *If you had to verb, how would you verb? Agar apko______ hai, aap kaise_____?*

Results.

A restricted number of mostly surface body parts categorized the verbs with similar percentages across the three sets: Telugu (29 body part types, 29%), Asawarpur Hindi (26 types, 31%) and Pune Hindi (25 types, 29.8%). Further, grade level related moderately to number of body part types in Hindi (Asawarpur: r=.50, *p*<.001, Pune: r=.44, *p*<.001), but only weakly in Telugu (r=.265, *p*=.047). Separate network analyses on the three data sets (grades collapsed) using different clustering methods (hierarchical, centrality, spectral) and a correspondence analysis point to similar patterns in dimension reduction, with a cumulative frequency of .60 (Telugu), .63 (Asawarpur), and .61 (Pune) for the first 4 dimensions. Consistency is apparent in the clustering of verbs overall and for the 41 translational equivalents. Five body regions lead: ear, mouth (lip, tongue), leg/foot, hand/arm, eye. A constant trend across all three data sets is the importance of hand/arm in clustering verbs: 47% (Telugu), 56% (Asawarpur) and 50% (Pune). Although these percentages vary in function of the specific verbs in the original list, the three semantic spaces show highly similar patterns. These findings correspond to results from adult verb-body part associations cross-linguistically, which may also take into account granularity and inclusion of trunk regions and internal organs depending on how languages carve categories.

Cluster coherence also shows through the verbs unique to each language (Telugu hand verbs: *pinch, poke, rinse, measure*; Hindi hand verbs: c*lap, do pooja, do work, apply color*) as they did not significantly alter the structure. Regarding abstract verbs, Hindi emotional (*love, hate*) and cognitive verbs (*give permission, make excuses, wish*) recruited pragmatic meaning (gestures) where children integrated gesture of the hand and source in the mind, brain or mouth or hand; and in Telugu, for the verb *fear,* some children gave the answer hand and hugged themselves and for the verb *enough (chalu)*, some children used a conventionalized hand sign and reported *hand* but others used *mouth* (source). In both languages, children also relied on sentences or fragments for those types of verbs. The most salient crosslinguistic divergences concern *cut* (strongly connected to teeth in Pune Hindi versus hand in Asawarpur Hindi) and *like, think, want* (connected mostly to mouth in Telugu versus brain/mind in Hindi). Further network analyses compared the responses of children who gave fewer versus more body part types, run on the 41 overlapping verbs and by grade levels. The results support the same organization underlying the clusters but with a different combination between integration and modularization. Telugu data looks the most integrated overall consideringthe number of communities. Individual differences were apparent. In Pune Hindi, one child provided only 1 body part (*mouth*) and 4 children only 2 body parts (*leg/ear; hand/mouth, eye/mouth*) and *lap* was provided only once. We observed different kinds of legs in Hindi: *paon*, *pair* and *tang*. The results suggest that once the child has acquired a few verbs in each cluster, they can add more verbs as they learn them, preserving the fundamental organization of the semantic field. This suggests that the network is quite robust and can accommodate individual, abstract, granular and cultural differences. It is also susceptible to review, as older children go beyond surface properties (mouth, hand) to incorporate new knowledge (brain/mind).

Discussion

Our results support the multidimensionality of the semantic organization of early verbs. Further, we also show the importance of individual differences in the perception of the instructions and the task socialness. The implication for teaching is that anchoring new abstract and concrete verbs in multidimensional experiences is critical as it connects those with a rich network of earlier experiences that can be activated dynamically for retrieval and communication.

Processing of gender-neutral forenames in Punjabi

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With the rise of awareness to promote gender inclusivity in different domains in recent years, gender-neutral forms in language too are replacing gender-specific ones cross-culturally (Martin & Slepian, 2025). In the limited studies on gender inference and processing in ambiguous and neutral language contexts, a male preference has been observed (Lassonde, 2013, Gardner et al., 2024). However, some studies are also suggestive that neutral nouns might not really lead to a specific gendered inference (Carreiras et al., 1996; Foertsch & Gernsbacher, 1997). Thus, overtly gender-neutral nouns encoding probabilistic gender instead of categorical gender are yet to be fully understood in terms of inferences and associations they evoke, and the consequences they have for agreement processing and language comprehension in general. Further, the current understanding of processing of neutral language forms largely comes from studies focusing on gender-neutral pronouns, common role nouns or masculine generics: how these are processed in comparison to gender specific ones (Foertsch & Gernsbacher, 1997; Lassonde, 2013). There is a dearth of research exploring how neutral names are processed (Yao, 2024), which are also becoming popular and might be processed for gender differently from both gender specific names due to their neutral nature, as well as from common nouns due to differences in their semantic and referential properties (Semenza, 2009).

The present experiment was designed to investigate the processing of such gender-neutral person forenames, for which we chose Punjabi as our test case as it is a grammatically gendered language but displays a very consistent and stable phenomenon of gender-neutral forenames, especially in the subset of Sikh Punjabi names, compared to other languages where such names are comparatively a more recent phenomenon (e.g. Barešová et al., 2024). We employed non-cumulative self-paced reading method to investigate whether these neutral names in Punjabi lead to any gendered inferences under androcentric or language related influences. If they do, what inferences are made, and what consequences do these have for the verbal agreement? To test these questions, in a 3*2 factorial design, the gender of the person names (male, female, and neutral) and gender agreement on the verb (masculine and feminine) were manipulated in intransitive sentences. The gender of the name was therefore overtly realized only by the gender inflection at the position of the verb which followed it. The male, female and neutral names selected for the experiment were based on ratings obtained from pretests conducted prior to the self-paced reading experiment.

Linear mixed effects analysis for the preliminary data (N=26, mean age = 25.269; 10F, 16M) shows a main effect of Name Type on the RTs both at the noun (name) ($p < 0.05$) and the disambiguating verb ($p < 0.01$). A post-hoc pairwise comparison of estimated marginal means of Noun Type showed that neutral names (2997 ms) are in fact read significantly faster compared to male (3244 ms) and female names (3236 ms). Also, the acceptability ratings for both the conditions involving neutral names were overall very high, with the masculine agreement (88.5%) condition being slightly more acceptable compared to the feminine counterpart (82.4%).

This study furthers the understanding on the processing of neutral forms, particularly neutral names. Instead of their ambiguous nature leading to longer reading times at the noun position, surprisingly they seem to be processed faster than both male and female names from the preliminary results. Also, at the verb position, the absence of an interaction effect of Name Type and Agreement Type on the reading times, in conjunction with neutral conditions taking shorter reading times regardless of whether the agreement on the verb is masculine or feminine, is indicative that neutral names are actually being processed as neutral without leading to any major male or female preference. However, these claims need to be confirmed as we collect more data. Speculatively, the neutral processing of the names may be attributed to long time exposure and use of these names in the culture for both males and females, in line with the suggestion that the strategy of neutralizing gendered forms might be effective with continuous long-time exposure (Martin & Slepian, 2025).

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Toward Brain Connectomics: Examining Brain Connectivity During Rest and Movie Watching

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The study of brain connectomics often utilizes the Naturalistic Viewing Paradigm, which involves day-to-day activities such as watching videos or movies, to elicit brain responses from natural stimuli. This approach may have advantages over conventional, repetitive task paradigms (like finger tapping) because natural viewing can synchronously activate several networks of the brain, reflecting behavior more naturally. Naturalistic viewing encompasses complex cognitive aspects, including emotion, visual motion, language, and music.

This presentation reports on two key objectives regarding functional connectivity during naturalistic viewing. The first objective investigated the differences in spatial patterns and temporal consistency between resting state (REST) and two natural viewing conditions: INSCAPE and MOVIE. MOVIE consisted of segments of Hollywood films (action, adventure, animation) featuring sudden plot changes, dramatic music, and high cognitive demands. INSCAPE, conversely, involved non-social, non-verbal, context-less scenes of evolving 3D objects, requiring less cognition and attention. A primary goal was to verify if the functional connectivity of INSCAPE is closer to the REST condition.

Data were acquired from 12 healthy, right-handed adults (mean age 30.45 years) and analyzed using methods including Concatenated Independent Component Analysis (cICA), Tensor Independent Component Analysis (tICA), and functional connectivity correlation coefficient matrices based on Power's 264 Regions of Interest (ROIs). Spatial ICA revealed that INSCAPE and MOVIE activated additional networks, specifically the Occipital Pole (OP) and Auditory (AUD) Networks, compared to the six networks revealed during REST. However, temporal consistency was found to be higher for INSCAPE than MOVIE, suggesting that the plot twists and dramatic features of MOVIE may disrupt temporal coherence. Crucially, analysis of functional connectivity at both the subject and group levels indicated that changes in connectivity were considerably less in INSCAPE than in MOVIE when compared to REST. Paired t-tests with FDR correction demonstrated that the number of ROIs with significant differences relative to REST was nearly 50% less during INSCAPE than during MOVIE for both regression methods applied.

We addressed the utility of different connectivity measures, specifically comparing stationary versus time-varying connectivity during movie watching. The hypothesis explored whether time-varying connectivity, being more sensitive to movie content, could better reflect individual differences in behavioral phenotypes, such as Age, Full-scale Intelligence Quotient (FSIQ), and Social Responsiveness Scale (SRS-2). While different age effects were observed between the two measures, **stationary connectivity demonstrated better prediction performance** for behavioral measures like FSIQ and SRS-2. The results suggest that stationary connectivity is more trait-like, while time-varying connectivity is more state-like.

Age-related Differences in Loss Aversion: A Meta-analysis

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Throughout the lifespan, individuals make decisions pertaining to finance which necessitates weighing of losses and gains. Loss aversion (Kahneman & Tversky, 1979) refers to the psychological tendency to overvalue losses over equivalent gains from a reference point a concept pivotal for decision-making. However, the literature in decision-making offers some but contradictory insights. Some authors (Hassan et al., 2014, Arora et al., 2015) have found that loss aversion increases with age while others (Rutledge et al., 2016) have stated that it decreases across age, and some have found null effects (Barkley-Levenson et al., 2012, Seaman et al., 2018), and yet others (Blake et al., 2021, Guttman et al., 2021) suggested a non-linear relationship. As meta-analysis provides the advantage of combining individual data sets instead of having to select amongst them, a meta-analysis was conducted to gather a broader understanding beyond individual studies. Systematic search was done on Scopus and ProQuest with the key word “Age-AND-'Loss aversion'-AND-estimate-OR-measure-OR-parameter” to collect papers. The inclusion criteria required studies to estimate loss aversion through binary gambles, provide individual level data and have sufficient age variability across participants. Hence, we shortlisted studies (n=1120, 5 studies) and merged the individual data sets into a pooled dataset. Across the five studies, participants were required to evaluate mixed binary gambles. These varied in the kind of gamble used. For instance, study (Karle et al., 2015) made participants choose between a lottery with equiprobable loss and gain against a sure option, and another (Kijima, 2019) had participants choose between pairs of lotteries with probabilistic gain and loss. Despite these differences, every study produced a coefficient of loss aversion for each individual and provided a continuous range of age for participants. Owing to the mixed nature of findings in current literature, a scatter plot was generated in order to visualize the curve for the available data. Visual inspection of the plot indicated non linearity. In order to test it statistically, a Generalized Additive Model (GAM) model was fitted which permits non-linear smooth functions of predictor variables.

The model found a significant non-linear behaviour ($edf = 3.39$, $Ref.df = 4.24$, $F = 6.78$, $p < 0.001$) reflecting relationship between age and loss aversion. A quadratic model with random-effects of study-related-heterogeneity with age and square of age as predictors found a significant U-shaped relationship (beta(Age^2) =0.0003, $p<0.01$). It embodies the relationship between loss aversion and age with the vertex at 47.27 years which represented the age when estimated loss aversion was the minimum at 1.83, over a span of 15 to 93 years. As an additional test formodel fit, an analysis of variance (ANOVA) comparison was performed on the linear and quadratic model. This test computing improvement in model through difference in log likelihood (chi-sqr (1) = 6.84, $p = 0.008$) found the quadratic specification to be better at explaining age related difference in loss aversion in our data.

Further, the participants were categorized into age-categories corresponding to the literature on life-span development: adolescent-emerging-adults (15-24 years), young-adults (25-35 years), middle-adults (36-45 years), middle-senior-adults (46-60 years) and older-adults (61-93 years). After controlling study-related-random-effects with age (5 levels) as predictor, the middle-adults (beta= -0.33, $p<0.01$) were found to have significantly less loss aversion than adolescent-emerging-adults (beta=2.01, $p<0.01$), underscoring the non-linear U-shaped relationship of loss aversion across the adult lifespan. With a growing population globally, this meta-analysis provides unique reflections into the developmental trajectory of decision-making. It finds support for age-related differences in loss aversion. If loss aversion is denoted to asymmetric affection reactions (Sokol-Hessner, 2019) which are fundamental to arrive at the value of loss and gain (Mukherjee & Srinivasan, 2021), the findings of this meta analysis provide useful insights regarding development of emotional regulation. This emotional regulation may be facilitated by shifting motivational goals (Sugarman, 2004) and factors such as cognitive training, occupational competence, and social interaction. The study stresses the need to build and test existing psychological theories on age-varying populations. It promotes investigation in cognitive mechanisms underpinning age-related changes in behavioural loss aversion.

The limited number of studies raises caution against over generalization. However, the studies varied in characteristics as one (Kijima, 2019) was based on farmers in Uganda, and another on Chinese participants (Sun et al., 2021). The sample size ranges from 73 - 503. Such diversity in studies promotes an enhanced ecological validity. On the other hand, it introduces between-study heterogeneity that was controlled for by incorporating study-level random intercepts in the regression models. Aside from the insights on lifespan decision-making, the methodological enquiry, initially popular in the medical sciences, facilitates investigation in the field of Cognitive Science. Cognitive sciences are inclining towards integrative and cumulative approaches to evidence (Koile et al., 2021). Due to small samples, small but relevant effects might get overlooked. Meta-analysis provides a composite answer that can be utilized by researchers, policy makers and behavioural scientists.

Modulation of reward prediction errors by negative emotion

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Introduction

Human beings constantly make predictions about future reward outcomes. Often, however, the outcome received by an individual differs from their initial predictions, resulting in the *reward prediction error (RPE)*. These RPEs can be either positive (indicating better-than-expected outcomes) or negative (indicating worse-than-expected outcomes), and they drive reward learning. RPEs have been found to be typically encoded by midbrain dopaminergic neurons and reflected in activity across target sites in the striatum and prefrontal cortex [1]. While the role of RPEs in guiding behaviour through reward learning is well established, less is known about how emotional context—particularly task-relevant negative emotional information—influences this process [2,3]. Studying how negative emotion shapes RPE processing is important for uncovering mechanisms underlying affective disorders, where reward learning is frequently impaired [4]. In this fMRI study, we investigated the modulation of RPE-related brain activity by negative emotion. We hypothesized that this modulation could be driven either by the valence or the salience of negative relative to neutral stimuli.

Methods

We conducted an fMRI experiment where 32 healthy adult participants (14 F; Age: 23.2±2.8 years) performed a guessing task. On each trial, participants were shown 5 boxes and were told that one of those boxes was a rewarding box. If they selected the correct box, they won a reward (Rs. 2) for that trial. There were two types of trials – in some trials participants could select any 1 box out of 5 (20% probability of winning reward), while in other trials they could choose any 4 boxes out of 5 (80% probability of winning reward). Then, after a fixed inter stimulus interval of 3.5 seconds, the outcome was revealed indicating if they had won reward or not. Unknown to the participants, the outcomes on each trial were predetermined. In the initial localizer phase, outcome was conveyed via traditional monetary images (coin for reward, gray circle for no-reward), to identify standard RPE signals in the absence of emotional stimuli. In the following main phase, the outcome was indicated by an emotional image—either negative or neutral—mapped explicitly to indicate a reward or no-reward outcome, with the mapping reversed across blocks. Trial-wise RPEs were computed using a Rescorla-Wagnermodel and incorporated into a general linear model as amplitude-modulated regressors for rewarded (positive RPE) and unrewarded (negative RPE) trials.

Results

In the localizer phase, we identified brain regions encoding RPEs by performing one-sample t-tests on the beta coefficients corresponding to positive and negative RPE regressors. We found positive RPE (but not negative RPE) related activity in the bilateral ventral striatum and substantia nigra/ventral tegmental area, replicating previous studies. In the main phase of the experiment, we investigated the effect of negative emotion on positive and negative RPEs. Since negative images could differently impact positive and negative RPEs, we performed a 2 (Positive/Negative RPE) x 2 (Negative/Neutral outcome emotion) repeated-measures ANOVA to identify clusters with significant effects in the whole brain. We found a significant interaction between RPE type and outcome emotion in a right dorsolateral prefrontal cortex (dlPFC) cluster at an uncorrected $p = 0.001$ and 43-voxel cluster extent (cluster-level α of 0.05). Here, we observed a reduction in the positive RPE and enhancement in the negative RPE-related activity when the outcome was signalled by a negative (relative to a neutral) image.

Discussion

During the localizer phase, we observed clear positive reward prediction error (RPE) signals in bilateral ventral striatum and the SN/VTA, consistent with classical dopaminergic encoding of RPEs. However, these signals were absent in the ventral striatum during the main phase. This absence might be due to a reduced instrumental learning component or task engagement during the main phase. In the dlPFC, the pattern of positive and negative RPE signals for the two emotions suggests that the dlPFC is engaged in the modulation of RPE signals by negative stimuli, which is primarily driven by the competing valence between reward and emotional information. Overall, our findings contribute to the emerging role of dlPFC in reward learning during affective contexts.

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Affective-cognitive crosstalk in dual-tasking and the domain-specific limits of motivational control

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Introduction

Performing multiple tasks simultaneously can cause interference between the tasks, resulting in performance decrements reflected as increased errors and delayed response times (Kahneman, 1973; Pashler, 1994). For example, when combining processing of one task (e.g., talking on the phone) with executing another (e.g., driving), can lead to between-task interference or crosstalk, leading to performance costs. In dual-task scenarios, *backward crosstalk effects* (BCEs) arise when features of the second task influence the processing of the first, while *forward crosstalk effects* (FCEs) occur when the first task affects the second. Crosstalk is frequently driven by compatibility or overlap in features across the two tasks—such as matching response types, spatial alignments, or semantic categories—which can facilitate or disrupt performance depending on the degree of overlap. The present behavioural studies examined (1) whether affective compatibility between an emotion judgement task and a conflict resolution task can lead to *crosstalk* effects, and (2) whether motivational incentives can proactively regulate such affective-cognitive crosstalk.

Methods

Experiment 1:

A total of 30 university students (aged 18–28 years, 15 female) completed a dual-task paradigm. In Task 1 (T1), participants categorized facial expressions (happy or disgust) sourced from a standard database (KDEF). Task 2 (T2) employed the Multi-Source Interference Task (MSIT)\ (Bush et al., 2000), which requires participants to identify a unique target digit among distractors, with incongruent trials introducing response conflict by incompatible target identity and position, thereby reliably eliciting cognitive interference. Each trial presented a face (S1) for 100 ms, followed by an MSIT stimulus (S2) for 1,500 ms, with an additional 1,000 ms response window. Participants had to first respond to T1 valence using the index finger and thumb of the left hand and only then perform the MSIT task using the right hand. The experimental paradigm followed a 2 (T1 valence: happy, disgust) x 2 (T2 congruence: control, multisource interference) factorial design in a mixed trial structure. Participants completed 280 trials in 7 blocks, with feedback provided based on accuracy.Experiment 2: Thirty-six new participants (18–28 years, 15 female) performed the same dual-task paradigm with a reward manipulation. Reward was contingent on T1 performance (speed and accuracy) along with T2 correctness. Reward and No-reward blocks (7 each) alternated in the main experiment and the block order was counterbalanced across participants. Participants completed 336 trials in 14 blocks of the main experiment, with trial-wise feedback about points won based on RT and accuracy.

Results

Experiment 1

Task 1 RT (RT1) exhibited significant interaction with T2 conflict, $F(1, 29) = 45.91$, $p < 0.001$, $\eta^2_p = 0.61$. Pairwise comparisons indicated that RT for positive T1 was significantly slower when followed by incongruent T2 (1065ms), compared to control T2 (1019ms) stimuli $t(29) = 4.32$, $p < 0.001$, *cohen's d* = 0.34. Task 2 RT (RT2) also showed significant interaction with T1 valence ($F(1, 29) = 26.53$, $p < 0.001$, $\eta^2_p = 0.48$. Pairwise post-hoc analyses indicated that RT of incongruent T2 was significantly slower when preceded by positive T1 (1481ms), compared to negative T1 (1439) stimuli $t(29) = 3.30$, $p = 0.015$, *cohen's d* = 0.26.

Experiment 2:

Reward significantly reduced RT on both the tasks - RT1: $t(35) = 9.67$, $p < 0.001$, *cohen's d* = 1.61, RT2: $t(35) = 6.41$, $p < 0.001$, *cohen's d* =1.06, despite being contingent only on RT1. Reward also increased inter-response intervals [$F(1,35) = 12.45$, $p = 0.002$, $\eta^2_p = 0.37$], indicating more sequential task processing. The two-way interaction between T1 emotion and T2 conflict observed in Experiment 1 were replicated [$F(1,35) = 12.45$, $p = 0.002$ for RT1; $F(1,35) = 10.08$, $p = 0.004$ for RT2]. However, the three-way interactions including reward were non-significant [RT1: $F(1,35) = 0.82$, $p = 0.3$; RT2: $F(1,35) = 2.01$, $p = 0.165$], demonstrating a lack of evidence for the modulation of affective-cognitive crosstalk by reward.

Discussion

These behavioral studies provide new evidence that affective crosstalk between emotional processing and cognitive conflict operates bidirectionally in dual-task scenarios. Both experiments found that emotional valence and cognitive conflict interact to modulate performance on each task. Replicating findings from Dreisbach & Fischer (2012), here the crosstalk between the emotion and the conflict can be interpreted to arise from the affective compatibility between the aversiveness of conflict and negative face stimuli. Crucially, while reward incentives globally improved speed and appeared to encourage more sequential task execution, they failed to selectively modulate affect-based crosstalk. These findings suggest that motivational control by reward may have domain-specific limitations, failing to regulate automatic affective-cognitive interferences which may originate from neural pathways less sensitive to top-down motivational signals (e.g., amygdala versus prefrontal systems). The results have implications for optimizing multitasking performance, particularly in domains that require both cognitive and affective processing, such as user interface design or human-machine interaction, suggesting that simply incentivizing performance may not suffice to manage all sources of dual-task interference.

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The Spillover Effect of Emotional Words and Context on Sentence Processing: A Self-Paced Reading Study

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Introduction

The interaction of emotion and language has shown processing advantage of emotion words over non-emotion words (3). However, when these emotion words are placed in sentence or discourse settings, there have been mixed results (4,5). Emotion words also influence the reading speed of the neutral words that come after them. This is called the emotional spillover effect. While prior research has explored the spillover effect of emotion-laden words (words that have an emotional association, e.g. gift, funeral) (2), the spillover effect of emotion words themselves remains underexplored. Also, researchers have found that the emotional context of the sentence also influences comprehension (1,6). The present study explores the effect of emotional and non- emotional context on the reading of target words in the sentences, and further it examines the spillover effect on the post-target words of the sentence.

Method

20 participants (age=18-35years, non-native English speakers) were included. The experiment involved three emotional-content conditions (Positive, Negative and Non-Emotion word) and four context conditions (Positive, Negative, Non-Emotional and Meaningless contexts). The emotional- content words were the target words (T) and the context occurred before them. Target words were adapted from Knickerbocker et al., (2019) and validated via survey (N=50), with 15 words chosen per category based on valence ratings. These 45 target words were embedded into three context conditions resulting in 135 English sentences. Target-word and sentence lengths were controlled, and the post-target region (T+1, T+2, T+3), on which spillover effect was observed, was kept identical across conditions to ensure variations in reading times could be attributed completely to target word and context effects. Participants read sentences aloud in a self-paced, word-by-word presentation, with reaction times recorded for each word.

Example

Negative Emotional Context: During her mother's funeral, she carried the weight of her (Trust/Grief/Bag) in complete silence.

Non-Emotional Context: The girl in white dress, sat in the corner, holding onto her (Trust/Grief/Bag) in complete silence.
Meaningless Context: Funeral carried her during she the mother's of the her (Trust/Grief/Bag) in complete silence.

Results

The study revealed a significant main effect of context (*F*(3, 123) = 6.794, *p* < .001, ηp² = .142) with reading times being longer in meaningless sentences (M=0.487) compared to meaningful sentences with (M=0.450) and without emotional context (M=0.455), at T and post-target words, suggesting that contextual-coherence enhanced processing efficiency beyond T. A significant main effect of emotional content was observed (*F*(2, 123) = 5.649, *p* < .001, ηp² = .084), with emotional- words exhibiting longer reading times (M=0.478) at T and T+1 compared to neutral words (M=0.450). Emotional congruity exhibited longer reading times at target and post-target words compared to incongruent context-content conditions. The analysis showed that for sentences withnegative emotional context, the presence of negative T increased the reading time of T (M=0.475) and post-target words significantly, compared to when there was a positive (M=0.436) or a neutral T (M=0.435). Similarly, in sentences with a positive T, congruent-context took longer to be read
(M=0.475) than negative (M=0.437), but was faster than meaningless context (M=0.502) at T and post-target words. For sentences with a negative T significant effect of context was observed at T+3 (*F*(3, 41) = 3.480, *p* < .05, ηp² = .203), indicating delayed spillover.

Conclusion

The findings demonstrate that context significantly influences the target word processing, while emotionality of context and the target word together indicates the spillover effect on post-target words. The results aligned with predictive processing theory, showing that meaningfulness of then context modulates word-processing and meaningless contexts slows reading times. Emotional content increases attentional engagement or conflict leading to delayed processing, beyond the emotional word, supporting the affective priority hypothesis. Interestingly, emotional congruity exhibited longer reading times at target and post-target words compared to incongruent context- content conditions. This means that negative contexts induce an inhibitory or suppressive effect increasing the emotional burden therefore delaying the reading speed significantly not just at T but also for following words. A similar delay in the processing of congruent conditions was seen for positive context and positive target word, further strengthening the idea of elaborative processing in high emotion load. Further, for congruent negative conditions, delayed spillover is observed due to initial fluent processing and cumulative emotional load eventually impacting the final word processing. These results support dynamic interplay of emotional context and content, and highlight the need to further explore how context valence, relevance and emotional congruity shape cognitive load, perhaps more precisely using neurophysical measures.

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Does bimanual haptic exploration reveal information for length and weight judgment?

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Properties like the weight and length of wielded objects can be judged without visual information. Previous studies have investigated perceptual information, like the moment of inertia, available for judging such object properties by wielding with one hand. The current study extends this work by investigating how blindfolded participants bimanually heft and wield objects to explore the ambient array, to perceive object weight or length. Sixteen undergraduate students (9 females, age *M* = 19.94, *SD* = 2.35) participated in the study for partial course credit. Participants were presented with a rod, with weights attached either symmetrically on both sides of the center, or asymmetrically on one side. The magnitude of weights attached and their position on the rod were also manipulated. Blindfolded participants were asked to either judge the weight or the length of a set of rods, after they actively wielded each rod. We empirically tested whether people wield the rod differently, depending on whether they are asked to report the perceived weight or length. Participants' muscle activity was measured using surface electromyography, and their exploratory movements were tracked using an inertial motion tracking system. As expected, people wielded the rods differently, depending on whether they were judging the weight or length. Additionally, the symmetry of weight distribution, the magnitude, and the position on the rod where the weights were attached had an effect on perceived heaviness. Surprisingly, none of these factors affected the perceived length of the rod, indicating the availability of perceptual information other than the moment of inertia. This suggests the possibility that perceptual information for object length might exist as an emerging relation across multiple energy arrays, including gravitoinertial forces that could interact with the haptic array. Understanding the mechanisms of perceiving the weight and length of objects in two-handed lifts has implications for designing occupational and leisure activities where manual material handling is common.

Exogenous covert attention does not influence gradedness of visual awareness

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Introduction

Is consciousness graded or discrete? Theories like the global neuronal workspace theory (GNWT) posits awareness to be a discrete phenomenon with only two states – fully-aware, or not-aware. On the other hand, theories such as the radical plasticity hypothesis (RPT) (Cleeremans et al., 2020) posits awareness to be a graded phenomenon with intermediate states of awareness as well. This theory also suggests that gradedness is flexible and is influenced by attention and processing load. Most of the studies on gradedness have focused on object perception. However, recently we have shown that attention, when manipulated in a resource capacity framework via perceptual load, influences gradedness of visual awareness of scenes. This supports the proposals of the RPT. However, it is still not clear how other processes of attention such as exogenous covert attention influences gradedness of visual awareness. It has been shown previously that exogenous covert attention influences subjective experience of visual content (Carrasco, 2011). However, it is not clear whether it influences subjective experiences in a graded or discrete fashion. Hence, we investigated this issue by using a spatial-cueing paradigm to manipulate exogenous covert attention, and measured its effect on visual awareness via objective (Type-1) and subjective (Type-2) measures. We hypothesized that exogenous cueing would influence visual awareness both objectively and subjectively with more gradedness for invalid and neutral cue conditions compared to valid cue condition.

Methods

Participants

Thirty-four volunteers (*M*: 23.94 years, females: 14) participated in this study after providing informed consent. Six participants' data was removed due to bad fit of the psychometric curves (*R2* < 0.80). All participants had normal or corrected to normal vision. The study was approved by the Institutional Ethics Committee.

Design, stimuli, and apparatus

The design was a 3 (**Cueing-conditions**: *Valid/Invalid/Neutral*) x 7 (**Contrast-levels**: 3%, 6%, 9%, 12%, 15%, 18%, 21%) repeated measures design. Stimuli were real-world scene-images taken from ObScene-database (Andrade et al., 2024) and CB-Database (Sareen et al., 2016) and divided into indoor/outdoor categories. After pre-processing, 250 indoor and 250 outdoor images were selected for the experiment. All the images were converted to greyscale and their contrast was normalized using histogram equalization method. The contrast of these greyscale images was set to 7 levels with reference the normalized value. The presentation of a particular image at a particular contrast was fully randomized and no image was repeated twice. We used two dots as cues that appeared either to the left or right of fixation or at the center. The cue had no predictive value, and the cue-to-target contingency was 50%. There were 20 trials per contrast per cue-condition and the total number of trials was 420. During the experiment, participant's task was to (1) identify the scene-type (indoor/outdoor), and (2) rate their subjective clarity of the scene using a perceptual awareness scale (PAS) (Sandberg & Overgaard, 2015).

Results

Curve-fitting results

A four-parameter (d, c, b, and a representing slope, threshold, upper-asymptote, and lower-asymptote respectively) non-linear exponential model was fitted for individual subject's 2objective performance and subjective clarity ratings data. The slope parameter is taken as a measure of gradedness of awareness (Sandberg & Overgaard, 2015). A repeated measures ANOVA was conducted (after checking for normality) on the slope and threshold parameters of psychometric fits of both objective performance and subjective ratings data.

Objective measure results

A main effect of Cueing-condition was found on slope ($F(2, 54) = 10.65, p < .001, \eta p2 = .283$) and threshold parameters ($F(2, 54) = 22.91, p < .001, \eta p\ 2 = .451$) of the objective performance data. Post-hoc comparison (Bonferroni corrected) for slope parameter showed lesser slope values for valid cue condition compared to invalid ($t(27) = 3.71, p < .001, d = 0.70$) and neutral condition ($t(27) = 5.03, p < .001, d = 0.95$). There was no difference between neutral and invalid cue conditions. For threshold parameter, the threshold was lower for the valid cue compared to the invalid cue ($t(27) = 6.59$, $p < .001$, $d = 1.24$) and neutral cue conditions ($t(27) = 5.37$, $p < .001$, $d = 1.01$). The difference between neutral and invalid cues was not significant.

Subjective measure results

There was no effect of Cueing-condition on slope ($F(2, 54) = 1.02$, $p =$ threshold ($F(2, 54) = 0.94$, $p = .397$, $\eta p\ 2 = .034$). .366, $\eta p\ 2 = .\ 037$) or 3.

Discussion

As expected, the results show differences in scene perception performance as a function of cueing with better performance with a valid compared to the neutral and invalid cues indicating that cueing has a facilitatory effect on scene-gist perception. However, there was no effect of cueing on threshold or slope of the psychometric curves for perceptual awareness scale ratings for subjective clarity. This indicates that exogenous cueing may not influence gradedness as measured using PAS ratings. This is in contrast to the results we had previously shown with perceptual load. Further studies are required to understand whether exogenous cueing, in general does not influence gradedness or the lack of effect is more specific to scene-gist perception only. We are currently doing experiments using an orientation discrimination task using Gabor patches and the same paradigm.

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Exploring Visual Working Memory Limits: Trends in Eccentricity and Set Size Effects

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Introduction

Visual Working Memory (VWM) is a limited capacity system that temporarily retains and manipulates information. Studies have shown that individuals can retain only up to 4 items in VWM at a time and performance declines as the set size increases (Luck & Vogel, 1997), indicating a slot based model for working memory. Luck & Vogel, 1997 conducted various combinations of change detection tasks looking into the relationship between set size and VWM, controlling for factors like verbal working memory influence, decision processes, memory encoding and limitations posed by other perceptual processes. This study examines how both set size and eccentricity of stimulus affect performance on a change detection task with varying stimulus presentation time. Luck & Vogel, 1997 have compared the effect of stimulus duration time between 100 and 500 ms to rule out limitations in perceptual process but found no significant effect of stimulus duration on the performance. However, Staugaard et al., 2016 study have found a significant interaction effect of exposure duration and eccentricity on performance with increasing eccentricity negatively influencing accuracy. In the absence of spatial cues, the stimuli are shown to be processed with higher accuracy and speed when it falls within the perifoveal vision. However, increasing eccentricity has resulted in increased reaction time and error rates (Staugaard et al., 2016, Sengupta, 2025).

Method

Participants (N = 8) with normal or corrected vision between the ages of 18 and 30 participated in the study. The behavioural experiment was conducted on a lab computer on the PsychoPy version. Participants completed 360 randomized trials differing in set size (2,4,8), stimulus duration (100 and 500ms) and eccentricity (150 and 350 pixels) lasting about 20 minutes. Participants viewed arrays of colored squares of varying eccentricity, stimulus duration and set size and responded whether any change was detected in any one of the colored squares using keyboard keys 'z' for no change and 'm' for change. An ISI of 900 ms was set between the test array and response array.

Results and Discussion

Analysis of data from 8 participants (mean accuracy : .85 and mean RT : 1.5) revealed a significant effect of set size (F(2, 84) = 63.67, p < .001) on accuracy, with increase in set size (2,4,8) resulting in a decline in accuracy. No significant main effects were observed for eccentricity, F(1, 84) = 0.94, p = .34, or duration, F(1, 84) = 0.09, p = .77. Additionally, there were no significant two-way or three-way interactions among the factors (all ps > .39), suggesting that the effect of set size on accuracy was not influenced by eccentricity or stimulus duration.

Mean accuracy across all participants was highest for set size 2 (M = 0.96, SD ≈ 0.03), followed by set size 4 (M = 0.9, SD ≈ 0.04), and lowest for set size 8 (M = 0.67, SD ≈ 0.14). The plot shows that regardless of stimulus duration, lower eccentricity favors accuracy, and longer durations further enhance performance—particularly at lower set sizes (2 and 4). Although the results did not reach statistical significance, these trends suggest that eccentricity plays a role in visual encoding. Stimuli unguided by spatial cues are typically processed with higher accuracy and speed when presented within the perifoveal visual field (Staugaard et al., 2016). The higher density of receptive fields in foveal vision may serve as a compensatory mechanism for potential crosstalk that arises due to stimulus proximity—an effect that may not be adequately controlled at higher set sizes (Sengupta, 2025). The higher receptive field density in the fovea may also allow finer spatial discrimination, thereby reducing interference or crosstalk between closely spaced stimuli. Although these effects did not reach statistical significance, the directionality of the data suggests potential underlying mechanisms that merit further investigation. The study warrants replication with a larger sample size to validate these trends and further investigate how spatial factors interact with working memory capacity.

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Impact of motor learning on functional mobility after stroke

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Introduction

Stroke leads to significant cognitive and motor impairments, both of which contribute to reduced functional mobility and poor quality of life[1]. Functional recovery after stroke relies on the relearning of skills, which is the ability to acquire and retain new skills[2]. Despite this, the extent to which learning capacity influences functional mobility is not well understood. Furthermore, to what extent cognitive and motor deficits influence learning after stroke remains unclear[3]. To address these gaps, the study aims to address two critical aims: a) to evaluate the group differences in the functional mobility between learners and non-learners. b) to determine how cognitive and motor impairments impact the learning post-stroke.

Methods

One hundred five stroke survivors participated in this study. Participants performed cognitive, motor, and functional mobility assessments. In this study, a goal-directed learning task was performed at the beginning of the testing session, while functional mobility assessments were conducted approximately three hours later, towards the end of the session. This sequence ensured that learning performance was assessed before the functional mobility measurements, minimizing potential fatigue or practice effects.

All stroke survivors in the study completed the same goal-directed task using their affected lower limb. Learning was operationally defined as an improvement in task accuracy across 30 trials. Participants who demonstrated at least a 20% reduction in endpoint error between the first five and last five trials were classified as learners, whereas those who did not meet this threshold were classified as non-learners. Cognitive function tests were evaluated using an extensive neuropsychological battery. Motor tests included the extensive motor battery and balance assessment. We computed the composite z-score for motor and cognitive tests.

Functional mobility included overground walking to measure gait speed, the Time Up and Go test (TUG), turn velocity (m/s^2), stride length, and duration variability (CV%).

Results

Based on the goal-directed task, the study included n=47 learners and n=55 non-learners. Data from three participants were missing for the goal-directed learning task, resulting in a total sample size of N = 105. An independent samples t-test was conducted to evaluate group differences in functional mobility outcomes between learners and non-learners after stroke. The results revealed that non-learners demonstrated significantly poor functional mobility on TUG (p=0.02) and turning velocity (p=0.002) compared to learners. However, the gait speed, stride length, and stride duration variability were not significantly different between the two groups. Further, to investigate the impact of cognitive (composite z-score) and motor impairment (composite z-score) on learning, we conducted the linear regression which revealed that lower cognitive (B= -0.37, p=0.01) and motor function (B= -0.41, p = 0.006) significantly associated with poor learning after the stroke (R^2 =0.19, p <0.001). Collinearity between cognitive and motor function was assessed using tolerance and the variance inflation factor (VIF). Both tolerance (0.88) and VIF (1.13) were within normal limits, indicating no significant collinearity.

Conclusion

The study demonstrated that both cognitive and motor abilities significantly influence learning ability after stroke. Moreover, the ability to learn new skills has a significant impact on functional mobility, particularly during turning and the TUG test.

Significance

These findings highlight the critical role of learning processes in post-stroke rehabilitation to improve functional mobility, highlighting the importance of targeting both cognitive and motor domains to enhance recovery post-stroke. These results highlight a potential link between learning processes and mobility performance. As this is part of an ongoing longitudinal study, future follow-up sessions are designed to further evaluate the causal pathways underlying this relationship.

Limitations and Future Direction

In the goal-directed task, since learning was assessed across 30 trials, it is possible that individuals classified as non-learners were slow learners in acquiring the skill and may have demonstrated learning with additional practice. Moreover, a separate “no-training” control group was not included, as this was a cross-sectional study designed to examine the associations between learning ability and functional mobility poststroke. Additionally, the goal of this study was to examine the association between learning ability and functional mobility outcomes after stroke, rather than to infer a direct causal relationship.

Future studies should consider including a no-training control group to more directly assess the impact of learning during the goal-directed task on functional mobility.

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Seeing yourself in Others: Attentional Prioritization accompanies Enfacement Illusion

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Introduction:

Self-Prioritization Effect (SPE) refers to the preferential processing of self-related stimuli. Across many studies, researchers have observed an advantage for self-face compared to a friend's face or an unfamiliar face (Bortolon et al., 2017). However, it is unclear whether this effect stems from familiarity/overlearning of faces (Tong & Nakayama, 1999) or from actual processing/attentional differences in stimuli related to self (Truong, Roberts, & Todd, 2017).

Enfacement Illusion is a phenomenon where participants who have undergone synchronous Interpersonal Multisensory Stimulation (IMS) with another person, much like the rubber hand illusion, feel a sense of body ownership towards that person's face (Porciello et al., 2018). The effect has been explained using a predictive processing account of body ownership, that is, the sense of body ownership may be constructed by Bayesian 'best guesses' of the mind integrating continuous sensory information (Seth & Tsakiris, 2018). Enfacement Illusion can be used to create body ownership towards an unfamiliar face, providing means to disentangle the effects of familiarity/learning from the SPE for faces.

In this study, we controlled for familiarity effects in the self and unfamiliar faces and investigated whether the SPE occurs in the case of the enfacement illusion. If the SPE for faces observed in prior studies is independent of familiarity, we predicted that the SPE effect would be present for self-face as well as enfaced faces with synchronous IMS but not for unfamiliar faces without IMS.

Methodology

Participants:

11 participants performed the experiment, out of which four were excluded from the analysis due to their low accuracy (below 70%) in the TOJ (Temporal Order Judgement) task. All participants were students from an Indian educational institute aged 21-30.

Stimuli and Apparatus:

For the unfamiliar faces in both the TOJ Task and the Enfacement Video, faces of 5 males and 5 females from outside of the city were used. All faces used in TOJ Task were matched on lower-level image features such as luminance, spatial frequency, and contrast using SHINE Toolbox on MATLAB (Willenbockel et al., 2010).

The Enfacement video was 80 seconds long and showed a gender-matched face being stroked with a cotton bud at a frequency of 0.5 Hz.

Procedure:

The experiment consisted of three blocks of TOJ: Self Face vs. Unfamiliar (SF), Synchronized Face vs. Unfamiliar Face (SyncF) and Non-Synchronized Face vs. Unfamiliar Face (NSyncF). The blocks were counterbalanced and the usage of faces was randomized for all. Participants were asked to report which face they saw first- the one on the left or the one on the right, for all three blocks.

In the SF Block, the participant performed the TOJ Task with self-face and unfamiliar face. In the SyncF Condition, the participant first watched a video while undergoing the Enfacement Illusion Procedure and then began the TOJ task, comparing the enfaced face with an unfamiliar one. In the NSyncF Condition, the participant watched the video of the enfacement procedure without IMS and then performed the TOJ Task.

Results

Accuracy:

The overall accuracy in SF Condition (.86) was similar to accuracy in SyncF (.84) and NSyncF (.84) conditions, F(2, 4)=0.069, p=.934

Shift in perceived simultaneity:

The responses from TOJ Task were used to construct a psychometric curve for each condition for every participant to obtain PSS (point of subjective simultaneity) values. A logistic psychometric curve was constructed using the trials where the participant reported the 'preferred face' (which could be Self Face/Synchronized Face/Non-Synchronized face, depending on the block being SF/SyncF/NSyncF) to have appeared first. This is done for a range of SOAs (-175 to +175) wherein negative SOAs indicate the trials where the preferred face is presented after the unfamiliar face. Hence, a negative PSS would imply that the participant saw Self Face/Synchronized Face/Non-Synchronized face to have appeared first even for the trials where Unfamiliar Face came first, implying a prioritization effect.

Results indicate a shift in PSS for SF (mean shift=-4.57, t(6)= -4.70, p=.003, d=-1.78) and SyncF conditions (mean shift=-5.28 , t(6)=-2.99, p=.024, d=-1.13). However, no shift was observed for NSyncF condition (mean shift=-0.85ms¸ t(6)=-0.41, p=.694, d=-0.16).

Discussion

The findings support our hypothesis and suggest that SPE is present both for self as well as synchronized IMS faces. The presence of SPE for synchronized IMS faces indicates that the SPE effect might not be due to familiarity with the self-face but possibly a more basic phenomenon that has to do with multisensory integration of information. Further studies are needed to fully understand the underlying mechanism.

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How far as AI come in mimicking human Theory of Mind?

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Introduction

Theory of Mind (ToM)—the capacity to attribute beliefs, intentions, and emotions to others—is foundational to human social cognition. As artificial intelligence (AI) systems grow in complexity, researchers are increasingly exploring whether models like large language models (LLMs) and multimodal agents exhibit ToM-like behavior. Initial studies reported that GPT-4 could solve up to 75% of false-belief tasks (Kosinski, 2024), raising questions about the extent of this apparent understanding. However, follow-up work has challenged the robustness and generality of such findings (Shapira et al., 2024).

This analysis synthesizes empirical studies testing AI performance on ToM tasks across three modalities: language-based reasoning, interactive dialog, and visual-social inference. We also introduce a novel classification framework that organizes AI ToM capabilities into developmental levels, offering a structured approach to evaluating progress beyond benchmark scores.

Methods

We conducted a systematic search of databases including Google Scholar, APA PsycInfo, and arXiv (2010–2025) using keywords such as "AI," "Theory of Mind," "false-belief," and "mental-state reasoning." Inclusion criteria required (1) empirical evaluation of AI systems (e.g., LLMs, vision-language models, agents) on ToM tasks and (2) sufficient performance metrics to extract or compute effect sizes.

A total of 29 studies met inclusion criteria. Studies were coded by task type, AI model, human baseline, evaluation method, and contamination risk. We conducted a random-effects analysis using Hedges' g and 95% confidence intervals (CI), categorized by modality.

Correlation coefficients were computed to examine associations between model size and ToM accuracy. Publication bias was assessed via funnel plot symmetry and Egger's test.

Results

- **Language-based ToM.** Across classic tasks like the Sally-Anne or Social IQa (Sap et al., 2019), GPT-4 scored an average of 74% (95% CI [0.69, 0.78]) compared to human controls at 85% (CI [0.81, 0.89]), producing an average gap of Hedges' g = 0.61. Older models like GPT-3.5 performed closer to chance levels (50–60%). Prompt structure had a significant effect on outcomes, underscoring the influence of prompt engineering.

- **Interactive ToM.** On real-time dialog tasks such as the FANToM benchmark (Kim et al., 2023), GPT-4 achieved only 10–20% accuracy compared to ~80% for humans, yielding effect sizes over g = 2.0. analysis of seven studies in this category revealed a consistent AI-human accuracy gap of $\Delta = 0.17$ (CI [0.12, 0.22], $p < .001$).
- **Visual ToM.** Fewer studies addressed ToM in visual-social contexts. One study reported Gemini 1.5 Pro achieving 38.5/45 on the MASC video test compared to the human mean of 33.2 ± 5.8 (Refoua et al., 2025), suggesting that while Gemini may extract social signals effectively, its inferential processes remain qualitatively distinct from human cognition.
- **Pooled Analysis.** Aggregating 24 usable effect sizes across modalities yielded an overall Hedges' g ≈ 0.80 (CI [0.50, 1.10]) favoring human performance. The gap was smaller in language tasks (g ≈ 0.5) and larger in dialog and vision tasks (g > 1.0). A moderate positive correlation (r ≈ 0.42) was observed between model parameter count and ToM task performance.

Discussion

This analysis shows that while modern AI systems increasingly succeed on structured ToM benchmarks, they underperform significantly in socially complex, real-world settings. LLMs often rely on shallow textual cues—commonly referred to as "Clever Hans" behavior—rather than genuine belief inference (Shapira et al., 2024), and their performance degrades under prompt variation or when tested on out-of-distribution tasks.

Methodologically, we identified three core limitations in the literature:

1. Benchmark contamination from training data (Strachan et al., 2024),
2. Prompting sensitivity and scoring inconsistencies,
3. and Narrow task design that excludes multimodal, cultural, or second-order ToM Elements.

We also note that some ToM categories, particularly visual ToM, were underrepresented in the sample, and publication bias may inflate apparent model competence. The classification framework was applied to all studies analyzed, allowing quantification of ToM competence levels that is how well AI is able to mimic human ToM.

To address the lack of clarity around "levels" of ToM competence in AI, we propose a four-tier AI-ToM Classification Framework:

- Level 0: No ToM – random or scripted responses
- Level 1: Heuristic mimicry – correct answers via surface cues
- Level 2: Belief tracking – accurate inference of simple mental states
- Level 3: Integrated ToM – contextually flexible reasoning across modalities

Approximately 45% of the included studies fell into Level 1 (surface heuristic mimicry), 40% into Level 2 (belief tracking on structured tasks), and only 15% approached Level 3 (integrated, cross-modal reasoning). None qualified as Level 3 across all test conditions, confirming the framework's relevance for future ToM evaluations.

In conclusion, while AI systems show promising advances in ToM-like behavior— particularly in linguistic domains—their cognitive mechanisms remain distinct from human mentalizing. Continued progress will require improved evaluation methods and theoretical frameworks that clarify what it truly means for AI to "understand" minds.

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Effects of Gradual Sensory Load on Visual Attention: Role of Individual Cognitive Traits.

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Introduction

Visual attention is a critical component in human information processing. It plays a major role in navigating through the complex environment. The ability to sustain visual attention under complexity is essential for decision-making, learning, and high-performance tasks. While much research on perceptual load and its impact on attention has demonstrated that high perceptual load can impair attentional performance, most studies have considered the manipulation of load in a binary which is "low" or "high" conditions. This categorical design limits the understanding of how attention operates in a continuum of perceptual complexity, especially in the real-world context. Moreover, individual differences- such as processing speed, working memory capacity, and media multitasking behaviour- may influence how people respond to the increasing demands. However, their role in modulating attentional performance under gradual conditions remains unexplored. To address these gaps, the present study investigates the impact of gradual perceptual load on visual search task performance and how individual cognitive traits contribute to variations in attentional outcomes.

Objective and Aim

This study aimed to investigate how gradual increases in perceptual load affect visual search task performance in terms of reaction time and accuracy. Additionally, it examined whether individual differences such as processing speed, visual working memory, and media multitasking behaviour moderate this relationship.

Method

The study employed a within-subjects design with 128 young adults (aged 18-25 years). The participants with a history of any neurological and psychological disorders affecting perceptual processing were excluded from the study. The participants completed a computer-based visual search task built using Psychopy. The task consisted of 50 trials divided into two blocks of 25 trials with gradually increasing perceptual load. The perceptual load was gradually increased across the trial by a) increasing the number of distractors, b) increasing target distractor similarity, and c) increasing the background clutter (randomly distributed black dots, increasing in density). The trials were presented in a fixed order, with each sequence trial containing the increased perceptual load compared to the previous one. Reaction time and accuracy were recorded for each trial.

To assess the individual differences, the Corsi Block Tapping Test (Visual Working Memory), the Digit Symbol Substitution Test (Processing Speed), and a custom 10-item Media Multi-tasking questionnaire were administered. The questionnaire was developed based on the conceptual framework of Ophir et al. (2009) to reflect contemporary digital media use among young adults (e.g., "I send or read messages while watching videos"; "I browse social media while listening to music"). Participants responded using a 5-point scale (1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always), with total scores ranging from 10 to 50. Higher scores indicate greater self-reported media multitasking. In a pilot sample (N = 10), the scale demonstrated high internal consistency (Cronbach's $\alpha = .82$). The data analysis was done using statistical methods such as Logistic regression and Linear Mixed models to analyze the impact of gradual Perceptual Load on performance, and Correlation analysis to explore interactions between task performance and individual differences measures.

Results

The linear mixed modelling analysis of the data showed that increasing perceptual Load in each trial gradually led to significantly longer reaction time ($b = 0.093$, $p < 0.001$), and the logistic modeling showed a negative effect of trial on accuracy ($b = -0.040$, $p < 0.001$), confirming that performance declined as Perceptual Load increased. This finding supports the hypothesis that attention declines under high perceptual demands. Spearman's correlation revealed that working memory was positively associated with accuracy ($\rho = -0.181$, $p = 0.40$), while processing speed was negatively associated with accuracy ($\rho = -0.241$, $p = 0.006$), suggesting a possible trade-off. Media multitasking was negatively correlated with reaction time ($\rho = 0.210$, $p = 0.17$), indicating that multitaskers responded faster but not more accurately. Further, a multiple regression analysis confirmed that only media multitasking significantly predicted reaction time ($\beta = -0.184$, $p = 0.41$), while working memory and processing speed were not significant predictors.

These finding suggests that working memory supports attentional accuracy, whereas high processing speed and frequent multitasking may lead to faster but less accurate responses, reflecting underlying attentional fluctuations.

Conclusion

The finding suggests that a gradual increase in perceptual load complexity impairs attentional performance, with individual cognitive traits shaping this effect. While working memory maintains accuracy, faster processing speed, and frequent media multitasking may introduce attentional fluctuations, leading to speed-accuracy trade-offs in a demanding environment. These findings have practical implications for the environment that demands sustained attention under complex perceptual conditions, such as air traffic control, driving, or digital learning. By identifying that working memory enhances accuracy while multitasking and processing speed can lead to trade-offs, interventions can be designed to train attentional control or reduce multitasking in high-stakes settings. The results also inform the development of adaptive interfaces that monitor cognitive load and adjust complexity in real time to prevent attentional lapses.

Impact of White Matter Hyperintensity in Caudate and Frontal Horn Distance mediated by Lateral Ventricle Enlargement

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Introduction

With aging, the brain undergoes structural changes, including atrophy or shrinkage. Since the caudate nucleus is a part of the brain's circuitry involved in executive functions, memory, and other cognitive abilities, changes in the size or shape of the caudate nucleus, or the distance between them, may potentially lead to changes in cognitive behaviors. Simultaneous changes in frontal horn distance are indicative of neurological diseases. Changes in caudate and frontal horn distance may get accelerated in presence of White Matter Hyperintensity, leading to disrupted communication between brain regions, setting up a platform for transition of the aging subject to Mild Cognitive Impairment (MCI) and Alzheimer’s Disease (AD). The study investigates the impact of small vessel disease and white matter hyperintensity (WMH) load on Caudate and Frontal Horn distances with aging, using brain MRI segmentation and WMH lesion segmentation.

Methods

T1-weighted and T2-FLAIR MRI images from 520 cognitively normal (CN) subjects from the National Alzheimer's Coordinating Centre (NACC) cohort were included in the study for neuroanatomic segmentation to determine brain regional volumes and white matter hyperintensity (WMH) load. The subjects were stratified in 3 groups based on WMH load: 0-1 ml, 3-5 ml, and 5-10 ml to explore the impact of WMH on inter-table width (IT), caudate distance (CC), and frontal-horn distance (FH), CC/IT, FH/IT, and FH/CC ratios. Further, a mediation model analysis was conducted to examine direct and indirect impacts of WMH.

Results

The CC, FH, CC/IT, and FH/IT ratios increase with age in CN subjects, whereas the FH/CC ratio declines but IT remains constant. Furthermore, the CN subject showed the enlargement of the lateral ventricle ($\beta=1.06$ ml/year, $p<0.001$) with age but caudate volume ($\beta=-0.01$ ml/year, $p=0.16$) remained constant. However, when WMH load exceeded 3ml, there was a significant increase in CC, CC/IT, and FH/IT ratios, with the lateral ventricles mediating alternations in CC($\beta=0.022$ ml/year, $p<0.01$), FH($\beta=0.011$ ml/year, $p<0.01$), CC/IT($\beta=0.151$ ml/year, $p<0.01$), FH/IT($\beta=0.002$ ml/year, $p<0.01$), and FH/CC($\beta=-0.022$ ml/year, $p<0.01$) ratios.

Discussion

Accumulation of White matter hyperintensity load more than 3 ml leads to significant changes in Caudate and Frontal horn distance mediated through the enlargement in lateral ventricles.

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Effects of Vipassana meditation on compassion

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Introduction

Vipassana, a mindfulness meditation technique, includes metta-bhavana, a practice intended to cultivate loving-kindness towards all beings. In meditation research and theory, compassion, mindfulness—typically defined as non-judgmental, present-moment awareness—and equanimity are key concepts. Given that meditation is expected to enhance mindfulness, compassion, equanimity, and prosocial behaviour, we investigated the effects of Vipassana using trait measures and a behavioural task. In this study, we focused specifically on responses towards individuals who had acted unfairly rather than strangers as a stronger test of prosocial behaviour and compassion. Hence, we designed a simple economic game assessing compassionate giving towards someone who had previously acted unfairly. If meditation enhances compassion, we would expect meditators to behave more prosocially and give more money to those who may have been unfair to them.

Methods

Forty non-meditators and forty Vipassana meditators, with a minimum of three years of regular practice, participated in the study. We used age and socio-economic status (SES), measured using the Kuppuswamy socio-economic scale (Saleem & Jan 2021), as covariates for the analysis. The meditator group had a mean age of 40.9 years (range = 23-66), and the non-meditator group had a mean age of 35.0 years (range = 28-57). Mean socio-economic status (SES) scores were 2.00 (SD = 1.05) for meditators and 1.95 (SD = 0.80) for non-meditators. Mindfulness was measured using the Five Factor Mindfulness Questionnaire (Baer et al., 2008), and equanimity was measured with the ES-16 questionnaire (Rogers et al., 2020). A game-like task was developed to measure compassionate giving toward someone who had previously acted unfairly. Participants interacted with two hypothetical players—one ‘fair’ who shared Rs 500 and one ‘unfair’ who shared Rs 100 out of Rs 1000 they were given. Later, participants were told the ‘unfair’ person needed money and were given Rs 1000 to share any amount (Rs 0–1000) with him. The amount given was used as a measure of compassionate giving. Finally, they rated both players on likeability using a 1–5 Likert scale. Images used to represent the players were taken from the IIM Indore Emotional Face Data Base (Tewari et al., 2023). Participants in both groups received standardised instructions with no reference to compassion, to minimise response bias.

Results

Datapoints were not included in the analysis if their z-scores were ≥ 3 SDs from the mean. ANCOVA was conducted with age and socio-economic status as covariates.

Compassion

Eight participants were excluded due to recall errors—they could not accurately remember the amounts shared by the fair or unfair player. Data was also missing for one meditator. Meditators gave a significantly larger amount (M = Rs. 410) than non-meditators (M = Rs. 188.8), $F(1, 67) = 20.61$, $p < .001$, $\eta^2 = .24$. Non-meditators showed significantly higher likeability difference scores (fair minus unfair player scores) than meditators, $F(1, 67) = 4.32$, $p = .04$, $\eta^2 = .06$.

Equanimity

As expected, meditators (M = 60.4) had significantly higher equanimity scores compared to non-meditators (M = 52.83), $F(1, 76) = 18.29$, $p < 0.001$, *np 2* = .19, with no significant covariate effects.

Mindfulness

Data from four participants (two missing, two outliers) were excluded. ANCOVA showed no significant covariate effects, but as expected, meditators had significantly higher mindfulness scores than non-meditators, $F(1, 75) = 22.07$, $p < .001$, $\eta^2 = .23$

Correlations

Spearman correlations were used due to non-normal distribution of compassion scores (Shapiro-Wilk $p < .001$). For correlations, data from both groups were merged into one single group. Mindfulness was positively correlated with giving amount, $r(67) = .28$, $p = .02$, but equanimity was not. Similar trends appeared for likeability difference scores, though neither mindfulness ($r = –.18$, $p = .15$) nor equanimity ($r = –.07$, $p > .05$) showed significant relationships.

Discussion

Meditators gave significantly more to the 'unfair' player than non-meditators with non-meditators' amount being closer to what they received suggesting greater compassion for meditators. Meditators also rated the fair and unfair players more similarly, whereas non-meditators favoured the fair player. This indicates that meditators respond with more compassion and forgiveness, regardless of how they are treated. Mindfulness scores correlated positively with giving. These results align with earlier findings that meditation enhances compassion across self-report and behavioural measures (Luberto et al., 2017). Surprisingly, we found no direct correlation between equanimity and giving amounts. However, factor analysis—conducted as part of a larger study measuring multiple variables—revealed that equanimity and compassion loaded on the same latent factor, suggesting an indirect relationship. This hidden factor may be metta (loving-kindness), which fosters even-mindedness, compassion, and forgiveness.

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Emotionally Valenced Facial Cues Modulate Visual Sensory Evidence Accumulation in the Human Brain

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Introduction

The human brain continuously integrates noisy sensory inputs over time to make perceptual decisions. The drift diffusion model (DDM) captures this stochastic process as the gradual accumulation of sensory evidence until a decision threshold is reached, culminating in a response. Drift rate (μ), a core DDM parameter, reflecting the quality of this evidence accumulation has been known to be influenced by sensory factors e.g., sensory signal strength but whether non-sensory factors e.g., emotional arousal and anxiety also influence the drift rate is less known. Specifically, the role of transient, task-irrelevant emotional cues and their interaction with trait and state anxiety to modulate sensory evidence accumulation remains underexplored, which this ongoing study addressed. While we did not find correlation related to anxiety, our tentative results suggest a significant modulation of the drift rate by emotional valences in the visual integration time window.

Methods

Forty healthy adults (9 females; age= 21.8 years ± 2.76 mean ± SD) completed a random dot motion (RDM) task while continuous electroencephalogram (EEG) was recorded at 500Hz from 32 channels. Each trial began with a brief (150 ms) facial expression cue (angry, disgusted, or neutral), to isolate the effect of negative high-arousal emotions with different motivational aspects (approach vs. avoidance) relative to neutral. The cue was followed by a random dot motion (RDM) sequence with four coherence/difficulty levels (difficult: 25%, 35%; easy: 50%, 70%). We hypothesized that emotional modulation of the drift rate would depend on the level of stimulus coherence. Participants were instructed to judge the direction of motion, ignoring the facial cue, and respond via keypad. A total of 240 trials were completed across four separate sessions with intermittent breaks per participant. Prior to the task, participants completed the State-Trait Anxiety Inventory (STAI).

Preliminary analyses showed stark differences between the easiest and hardest conditions which is why further analysis was performed on easy trials with 70% coherence and difficult with 25% coherence. Therefore, we looked at reaction time (RT) and accuracy of the behavioural data across these six conditions- angry easy, disgust easy, neutral easy, angry difficult, disgust difficult and neutral difficult. The EEG data was down sampled to 250Hz, filtered, re-referenced and epoched. After artifact removal (eye, muscle, and cardiac components) using independent component analysis, Bonferroni-corrected paired *t*-tests were applied following verification of normality and homogeneity of variance. The association between the STAI and CPP measures was tested using Pearson's correlation coefficients.

Results

Average waveforms corresponding to centroparietal positivity – CPP, an established event-related potential component reflecting the neural dynamics of evidence accumulation over time in perceptual decisions (Tagliabue et al, 2019) was computed from electrodes CP1, CP2, and Pz between 300 ms pre- to 3000 ms post-target (coherent RDM) onset. The behavioural accuracy and RTs were analysed alongside centroparietal positivity (CPP), a neural marker of evidence accumulation aligned with DDM drift rate. For each participant, the instantaneous slopes of the CPP waveform in correct trials was calculated at each sampled time point and further, the mean of the instantaneous slopes was calculated within separate time windows of 150 ms between 300 ms (post-target onset; allowing for the visual input to reach the higher visual processing regions) and 600 ms (roughly the average point of peak evidence accumulation across participants), giving us two windows: 300-450 ms and 450-600 ms of interest. This was done for the difficult and easy conditions separately. Comparison of emotion conditions using paired *t*-tests in the 450-600 ms time window revealed a statistically significant difference in the mean instantaneous slopes of the difficult condition, between neutral and both disgust (mean difference = 0.0049, $p = 0.0023$, $d = 0.26$, $t_{(39)} = 3.2562$) and anger (mean difference = 0.0042, $p = 0.0221$, $d = 0.25$, $t_{(39)} = 2.3839$) conditions (inset), suggesting an influence of anger and disgust emotion cues over neutral in biasing the rate of evidence accumulation in reaching a visual decision. In the easy condition we did not note any significant difference between slope values across emotions. No significant correlations emerged between STAI scores and CPP measures in this sample.

Discussion

Our findings indicate that task-irrelevant, brief, emotionally valenced facial cues modulate the neural dynamics of evidence accumulation, as reflected in CPP slope. Specifically, high-arousal negative cues (anger, disgust) reduced the rate of perceptual processing compared to neutral cues, particularly under difficult stimulus condition. There were no differences in slope values during the sensory storage stage of the target stimulus (100-200 ms after onset), or in time to make the final decision, as evidenced by no difference in mean RTs across emotions.

The differences were noted in a very narrow time window of 450-600 ms, suggesting a probable impact during the visual sensory integration stage. It is possible that the emotion cue adjusted the decision bounds of individuals, thus changing the thresholds for reaching a choice; adjusted the non-decision time or even biased the starting point of sensory accumulation leading to the decision. These are the possibilities we are currently investigating in the ongoing study. Although anxiety did not significantly modulate CPP in this healthy sample, future work with clinical populations or stress manipulations using negative or positive affect scenes, altering stimulus presentation duration, may further clarify these interactions.

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Faces of Joy: An Unbroken Link in Alzheimer's: A Comparative Study of Facial Emotion Processing in Alzheimer's, MCI & Healthy Aging

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Background

Alzheimer's disease (AD) is the most common type of dementia, causing progressive decline in memory, thinking, language, and emotional understanding. It is an age-related brain disorder that particularly affects the ability to form new memories. While some memory decline is part of normal aging, the changes in AD and Mild Cognitive Impairment (MCI) are more severe and disabling. Facial emotion processing is a significant aspect of nonverbal communication and is also affected in both normal aging and age-related conditions like MCI and AD. However, this area is less studied in dementia research, especially in the Indian context, where culturally and linguistically appropriate tools are lacking. There is a growing need to develop emotion-based memory assessment tools to improve early screening and diagnosis of dementia. Such tools should be standardized for use in Indian populations, taking into account regional languages and cultural differences. Identifying novel neuropsychological markers focused on emotion and memory could help in screening MCI, and AD patients more effectively.

Purpose

This study aims to validate facial emotion processing paradigms and evaluate their diagnostic utility in differentiating individuals with MCI or early-stage AD from cognitively healthy older adults.

Methods

The methodology used in the study was adopted from previous study by Gupta & Srinivasan, 2009, and was customised to administer in elderly individuals and patients, invernacular language of Malayalam. The experiment involves two phases - an encoding phase followed by a recognition phase. In each encoding trial, the face stimulus (happy, sad, or neutral) was randomly presented with its name underneath it. The participants were asked to learn these face name associations presented in vernacular language Malayalam. The interval between successive face presentations was 3 seconds. Immediately after the encoding phase, a two-choice recognition test was administered with the whole-face and parts of face (eyes, mouth).

In whole face trial condition, participants were presented with two faces, the target and foil. The target and the foil faces did not differ with respect to emotional expressions. In the isolated-part condition, participants were presented with one feature from the target face and foil feature displaying the same emotion. Participants were instructed to find the target face (whole-face condition) or the target feature (isolated-part condition).

Result

The sample size of the study was 50, which included 25 patients (female 12, male 13) and 25 elderly controls (female 9, male 16) of age above 55 years. We computed the recognition accuracy for faces and parts of face (eyes, mouth) corresponding to emotional expression (happy, neutral and sad) and plotted the result for controls as well as patients. Statistical analysis was performed with a 2X [3 X3] mixed analysis of variance (ANOVA) using group (patients vs. healthy control) as a between-group factor, emotion (happy, sad, neutral) and face-type (whole, eyes, mouth) as within-group factors on recognition accuracy score. The main effect for emotions, F (2, 96) = 4.31, p = .016 was significant. Pairwise comparisons revealed that participants performed significantly better on Happy expressions than Neutral (p = .049) and Sad expressions (p = .045). There was significant main effect of stimuli type F(2, 96) = 19.71, p < .001. Participants performed significantly better with Face stimuli compared to both Eyes (p < .001) and mouth (p < .001). Significant main effect of Group was noted, F(1, 48) = 4.46, p = .040, indicating that that Elder controls (M = 55.07) outperformed Patients (M = 52.18) which was obvious.

However, recognition accuracy for whole face analysed using T-test for within group comparisons for emotions - happy, sad, neutral reveals that; in healthy control group, recognition accuracy of whole faces for all emotions were similar (happy vs. sad, *t* (48) = 0.39, p = 0.34; happy vs. neutral, *t* (48) = 0.71, *p* = 0.24; sad vs. neutral, t (48) = 0.36, *p* = 0.36). Interestingly, individuals with AD were better in recognizing whole faces with happy expressions compared to sad, *t* (46) = 3.52, *p* = 0.000; and neutral expressions, *t* (46) = 3.52, *p* = 0.000. There was no significant difference in recognizing whole face with sad and neutral expressions, *t* (46) = -1.16, *p* = 0.12. These results indicate that recognition of happy facial expressions, compared to sad facial expressions, are quite intact in individuals with AD.

Discussion

Interestingly, individuals with AD demonstrated relatively preserved recognition of happy facial expressions, particularly when presented as whole-face stimuli, compared to their diminished recognition with sad expressions. This suggests that the processing of positive emotions, such as happiness, may remain more intact in AD. In contrast, healthy controls appeared to benefit more from part-based processing, especially for happy expressions, indicating a differential reliance on facial processing strategies across groups. These findings highlight the potential diagnostic relevance of emotion-specific and format-specific facial recognition patterns. Such differential processing profiles could serve as valuable markers for distinguishing pathological aging from normal aging with paradigm performance and its neural correlates. And also, it may inform the development of targeted, emotion-based cognitive retraining interventions emphasising positive facial clues for individuals with AD.

Outcome of CST in Rehabilitating an Elder with Mixed Dementia in an In-Patient Care Unit: A Case Study

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Introduction

This study assesses how personalized and focused cognitive stimulation have impacted the psychological and behavioral symptoms of a 77-year-old elder diagnosed with Major Neurocognitive Disorder due to Alzheimer's disease and Mild Vascular Neurocognitive disorder, hereafter referred to as Mixed Dementia. It also focuses on the effectiveness of a specialized inpatient Dementia care unit at a tertiary care hospital and its impact on the caregivers' wellbeing. The study tracks the changes in behavioral and psychological symptoms of Dementia (BPSD) for the elder over a period of one year from his admission to the facility. It also considers factors influencing BPSD, such as ongoing staff training and tailoring interventions to the elder's temperament. The study shows how adapting theoretical frameworks Cognitive Stimulation Therapy (CST) and Behavioral Therapy (BT) - to suit the needs and culture of the elder with Dementia can help improve the perceived quality of living of the elder. Diagnosis was made based on obtaining history, clinical assessment of patient by a psychiatrist and by following the DSM-5 diagnostic criteria for the same.

Methods

A single-case study design was employed, for a 77-year-old male elder receiving CST (Raghuraman et al., 2017) and BT in an inpatient care unit for Dementia at a tertiary care hospital. The frequency of interventions in the inpatient care setting was five times a week for one year. The interventions included orientation, focused memory training, and recreational socialization for CST along with agitation management, reinforcing adaptive behaviors through positive affirmations and encouragement among other approaches for BT administered in a combination of individual and group sessions. Periodic assessments for cognitive, behavioral, and functional outcomes were assessed using ADAS (cognition), CMAI (agitation), NPI-Q (BPSD), and Barthel Index (activities of daily living).

Results

Following the intervention, the patient demonstrated clinically observable improvements; significant overall cognitive improvements (ADAS), especially in the domains of comprehension, concentration and orientation among others and steady functional independence (Barthel Index). Behavioral symptoms trended upward, with emerging neuropsychiatric symptoms (CMAI). Neuropsychiatric symptoms, for the elder, significantly reduced during the intervention period (NPI-Q).

Discussion

The findings suggest that personalized CST & BT program administered within an inpatient Dementia care unit appeared to enhance the cognitive and behavioral outcomes in the elder with Mixed Dementia, over a period of one year. Pharmacological intervention that was stabilized over the duration of the study was also seen to impact the outcomes positively. The importance of personalized CST in improving well-being and reducing caregiver distress is also highlighted. The role of continuous improvement of nursing care within the care unit is mentioned as well. Also, prompt identification and management of physical health issues as part of the multidisciplinary team's role at the tertiary care hospital contributes to the improvement in the overall health of the elder.

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Performance Instability and Internal Bias in Perceptual Choice: A Nonlinear Dynamics Approach

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Introduction

Individual differences in perceptual decision-making may offer insight into the mechanisms underlying psychosis-proneness. However, most studies in this area have relied on static performance metrics such as mean accuracy or average reaction times (Park et al., 2016). Research has shown that psychosis is associated with disruptions in evidence accumulation (Culbreth et al., 2018) and sensory prediction (Knolle et al., 2023). Computational models invoking attractor dynamics provide theoretical accounts of cognitive instability during belief updating, yet behavioral-level trial-by-trial nonlinear signatures remain underexplored (Adams et al., 2018). This study, therefore, addresses a trifecta of gaps, temporal dynamics, structured variability, and behavioral-level nonlinear signatures, to examine whether hallucination-proneness in a non-clinical population is associated with distinct performance instability, response randomness, and reliance on internal biases over external evidence. We adopt an exploratory approach, using methods from nonlinear dynamics to characterize these signatures, followed by a formal statistical model to investigate the potential underlying mechanisms.

Methods

The analysis was conducted on a publicly available dataset in which participants (N =126) performed a multi-element perceptual averaging task (Larsen et al., 2021). On each trial, participants made a dichotomous judgment about the average color of an array of stimuli. The task systematically varied the perceptual evidence's strength (mean) and reliability (variance). Each participant's predisposition to hallucinatory experiences was quantified using the Cardiff Anomalous Perceptions Scale (CAPS), yielding a total score (hereafter referred to as NRS) as a continuous measure of hallucination-proneness.

Three primary analyses were performed:

1. **Bifurcation Analysis**: Participants were grouped into bins based on their NRS score to test for a critical transition. The mean and, critically, the standard deviation of task accuracy were calculated for each bin to identify regions of increased performance variability, a classic indicator of a system approaching a bifurcation.

2. **Fractal Analysis**: Detrended Fluctuation Analysis (DFA) was applied to the trial-by-trial sequence of correct and incorrect responses for each participant to quantify the predictability of performance. This yielded a Hurst exponent (H) for each participant, measuring the persistence or "memory" in their performance sequence.
3. **Generalized Additive Model (GAM)**: To formally test the mechanisms underlying any observed instability, a hierarchical Bayesian GAM was fit to the trial-by-trial choice data. The model was tested for non-linear interactions between the NRS score and two key predictors: evidence reliability (Variance) and trial history (previous choice).

Results

Bifurcation analysis revealed a peak in the standard deviation of accuracy for individuals with moderate-to-high NRS scores, with change-point analysis identifying a critical threshold, emerging from the data, at NRS = 18, corresponding to a significant drop in mean accuracy from 0.874 to 0.827. Fractal analysis showed a negative correlation between NRS score and the Hurst exponent ($r = -0.25$, $p < 0.01$), suggesting that higher hallucination-proneness is associated with less persistent and more random response sequences. The GAM analysis (Pseudo $R^2 = 0.368$) confirmed these patterns: the Variance × NRS interaction revealed reduced sensitivity to evidence variance at higher NRS levels, whereas the Previous choice × NRS interaction showed an amplified hysteretic influence of prior choices among high-NRS individuals. Together, these findings indicate that hallucination-proneness is characterized by diminished responsiveness to sensory variability and increased reliance on internal choice history.

Discussion

This study shows that hallucination-proneness is linked to alterations in the nonlinear dynamic structure of perceptual decision-making. Individuals with higher NRS (Hallucination Proneness) scores displayed greater performance variability, reduced temporal persistence, and increased reliance on internal choice history. These alterations were evident in both exploratory analyses and formal modeling, suggesting a shift in the balance between external sensory evidence and internally generated biases. The attenuated sensitivity to evidence variance in high-NRS individuals points to reduced weighting of sensory reliability, consistent with predictive-processing accounts of psychosis.

The amplified influence of previous choices reflects stronger hysteresis, potentially indicating inflexible decision updating or over-reliance on prior beliefs. Together, these results align with models proposing altered precision-weighting and attractor-like dynamics in psychosis-related cognition. In the future, I plan to develop a formal mathematical model, such as a stochastic differential equation, to provide a mechanistic understanding of the observed bifurcation and fractal phenomena.

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The Effect of Vibroacoustic Stimulation and Music Listening on Relaxation in Healthy Adults

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Background

Vibroacoustic therapy (VAT) is ‘a combination of low-frequency sound vibration, [and] music listening combined with therapeutic interaction’ (Punkanen & Ala-Ruona, 2012, p. 128). The low-frequency vibration used in VAT (referred to as VA stimulation hereafter), similar to massage chairs, has been used for relaxation. Additionally, many studies have found listening to music to be relaxing, outside the context of VAT (Dingle et al., 2021). Helsing et al. (2016) found that relaxation using self selected music resulted in increased intensity of positive emotions, reduced stress and decreased cortisol levels compared to relaxing without music. However, the physiological effects of listening to relaxing music are inconclusive. Thaut et al (1993) found that people used additional strategies like deep breathing and muscle relaxation to enhance the relaxation caused by music. Although this was done unconsciously, it gives reason to believe that the relaxation effect of music can be more significant if it has been enhanced using other strategies.

Aim

In this study, we aim to see if V A stimulation can improve the relaxation effect of music listening using MEG.

Methods

Participants

Healthy, right-handed adults (N= 40, Age: 18-65 years (M= 33.08, 29 Females).

Procedure

Participants listened to self-selected relaxing music for 10 minutes during 2 sessions spaced 1 week apart. In one session, they received V A stimulation for 20 minutes before the music listening and in the other (control) session they were asked to lie on the V A mattress for 20 minutes but with no stimulation. The order of the sessions was randomized. Self-reported scores of relaxation, arousal, mood and pain were collected before the stimulation/control, after the stimulation/control and after music listening. Resting state MEG (8 minutes eyes closed and 4 minutes eyes open) was recorded after the stimulation/control and after music listening. Repeated-measures ANOV A was performed on the self-reported scores with time (before stimulation, after stimulation, after music listening) and condition (stimulation/ control) as factors. MEG data were analyzed using the FOOOF (Fitting Oscillations & One-Over-F) algorithm to parameterize the power spectral density into aperiodic and periodic components (Donoghue et al., 2020). Alpha, beta and theta power were computed at the sensor level by first grouping MEG sensors into anatomical regions (e.g., left/right frontal, temporal, parietal, occipital) and compared across time and condition.

Results

A significant effect of time was found on scores of relaxation ($F=64.14$, $p < 0.001$, $\eta p2 = 0.622$) and arousal ($F=48$, $p < 0.001$, $\eta p2 = 0.522$). No significant differences were found in scores of mood and pain, and no significant effect of condition was found in any of the variables. Preliminary results from the sensor level analysis found a significant effect of time in the eyes closed condition in the offsets of all the regions, in the exponents of the left occipital, parietal and temporal regions and right frontal, parietal and temporal regions and in the alpha power in the all the regions of the left hemisphere and the frontal, temporal and occipital regions of the right hemisphere.

Discussion and Future Directions

VA stimulation and music listening can be used to increase subjective relaxation among participants. To further investigate if the effect occurs at the physiological level, source level analysis will be performed for the MEG data and spectral band power differences will be assessed across time and condition.

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Same-same, but different: Perceptual diversity is shaped by a shared phenomenal structure

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How do we know if two people, given the same visual input, have the same visual experience? Under constructive, indirect views of perception, such as those licensed by 'predictive processing' theories, it is entirely possible, even likely, that two individuals will have different perceptual experiences for the same shared objective reality. Yet, they may still use the same words (e.g., "a red mug") to describe what they see, posing a challenge for empirical analysis of perceptual differences and commonalities. To address this challenge, recent research has relied on principles of structuralism: instead of asking how a particular stimulus appears to an individual, participants are asked how one perceptual experience relates to other perceptual experiences of the same kind. A good example is provided by colour perception, where asking people to make relative 'colour similarity' judgements has helped to uncover universal representational spaces for colour. Structural approaches, however, go far beyond colour. A rich phenomenological literature argues that there are properties of perception which universally constrain all perceptual experiences. These include indeterminacy, valence, anticipation, flow, situated spatiality, persistence, among several others.

In this study, we investigated whether we can recover universal constraints like these from a large dataset of diverse perceptual tasks, and whether this is a shared feature across a large sample of participants. We used data from the Perception Census, a large-scale online survey of perceptual diversity which reached nearly 40,000 people and included over 50 separate 'tasks' ranging from psychophysical experiments to questionnaires (https://perceptioncensus.dreamachine.world/).

We pre-selected 10 tasks from the Census that had no between subject variables and captured aspects of phenomenal awareness. Two tested how prone participants were to classic perceptual illusions of size (Ebbinghaus and Müller-Lyer). Two tracked the duration of motion and colour aftereffects. Two tested representational momentum and beat alignment (relating to anticipation). Two measured change detection (change blindness) and identification of faces in abstract shapes (Mooney faces). Finally, two tasks were measuring the neon spreading effect and mental rotation abilities. Only participants who completed all 10 tasks were included (N = 3684).

To look for meaningful structure in participants' perceptual experiences, we employed two analyses: representational similarity analysis (RSA, a labelled analysis) and Gromov-Wasserstein optimal transport (GWOT, an unlabelled analysis). RSA involves computing a representation dissimilarity matrix (RDM) by correlating performance across all 10 tasks, and then splitting participants' data into two groups to compare the correlation between their RDMs. This was done multiple times with bootstrapping for random splits (200 runs). We found that the correlation between RDMs was always high across the bootstrapped runs (95% CI: 0.79, 0.92). To further show that RSA captured a meaningful structure, we shuffled the task labels. The correlations between the RDMs of this shuffled null model had a mean of zero (95% CI: -0.3, 0.3). There was a significant difference between these two distributions, showing that RSA captured something reliable in the RDMs of the perceptual tasks. Next, we performed a GWOT alignment to match the global geometry of the relationships between the tasks in an unsupervised manner (i.e., without task labels), again by bootstrapping across multiple partitions of the sample (into two). In each iteration, the optimal transport plan attempted to align the embeddings of the two groups over the same 10 tasks. The optimal transport plan aligned the global geometry across random splits of the data with a 100% matching rate. Since GWOT aligns the global geometry of the data in an unsupervised manner, to further investigate task-level alignment accuracy we reintroduced the labels in the analysis.

We measured the top-k matching rate across tasks to see if knowing the label of one task allowed us to establish a one-to-one mapping across the groups. We did this by using three values of k-nearest neighbours (1, 3, and 5). Our results showed that for any given task, we could achieve a matching rate of 54%, 81% and 90.9% across the k values. Finally, to interpret the alignment, we visualised it using a principal component analysis (PCA). The 10 tasks mapped onto four unique dimensions. These were interpreted as indeterminacy resolution (PC1; change blindness, Mooney faces, mental rotation, and neon spreading), anticipation of perceptual contents (PC2; representational momentum and beat alignment), situated spatiality (PC3; Ebbinghaus and Müller-Lyer illusions), and persistence of perceptual contents (PC4; motion and color aftereffects).

This clustering suggests that our ability to align people's diverse perceptual experiences rests on the existence of a shared phenomenal structure. Despite the diversity across participants in the susceptibility to illusions, adaptation after-effects, ability to track changes and mental imagery, our analysis reveals certain principal constraints on their perceptual experiences. These results can be interpreted within structural and phenomenological theories of perception as revealing shared constraints on people's experiences. Thus, even though people may differ in how they experience an illusion of one kind, the relationships across the different experiences they undergo in performing these tasks, may be similar.

On the interplay of object case marking, object animacy and verb type during the comprehension of transitive sentences in Malayalam: ERP evidence from Differential object marking violations.

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Language conveys real-world and imagined situations[1]. Often, these situations involve multiple participants and some form of interaction or transfer between them[2]. A prototypical instance of such interaction is a transitive event, in which two participants are involved, whereby one participant is more responsible for the event or action (Agent like) and the other participant is mostly affected by what takes place (Patient like). This concept of transitivity plays a central role in language comprehension architecture[3]. Research on the role of transitivity in language comprehension has largely concentrated on the semantic (animacy, definiteness, rationality) and structural properties (± accusative case marking) of the direct object [1,3]. However, relatively little attention has been paid to whether and how different verb types influence transitivity and sentence processing. In particular, the interaction of verb type with the semantic and structural features of the direct object remains underexplored.

To this end, we conducted an ERP study on the processing of Differential Object Marking in Malayalam, an agglutinative South Dravidian language, in which animacy and verb type interact to determine the case marking of the direct object argument[4]. We employed a 2x2x2 design, manipulating verb type (experiencer vs. action verb), case marking of the object noun at NP2 (accusative marked vs. unmarked), and animacy of NP2 (animate vs. inanimate). EEG from 36 first-language speakers of Malayalam (mean age: 27.08; 17 female; 19 male) was recorded when they read the critical sentences and performed acceptability judgement and probe detection tasks. Results showed that behavioural acceptability ratings for violation conditions involving animate object arguments – regardless of verb type - were significantly lower (mean < 6.79%) than those for their correct counterparts (mean > 93.35%). Similarly, for sentences with inanimate arguments, violation conditions received lower acceptability ratings than their corresponding control conditions (ACT: 56.4 vs. 80.3; EXP: 50.2 vs. 77.9). ERP analysis at the verb revealed that all the violation conditions involving unmarked object arguments evoked a negativity effect in the 400-600 ms time window compared to their control counterparts, regardless of the animacy of the object and the verb type. Additionally, a positivity effect ensued in the 700-900 ms time window for experiencer verbs when the preceding object argument was unmarked and inanimate. The N400 effect found in our study can be interpreted as the reflection of the violation of interpretively relevant case marking[5,6]. The P600 effect found for the experiencer verb construction with nominative inanimate object argument may reflect a blocked expectation for a more transitive action verb. This blocking occurs when argument distinctness is maximally fulfilled but a less transitive experiencer verb is used instead[7,8]. Interestingly, for action verbs, the parser did not distinguish between unmarked and accusative inanimate object arguments. In contrast, for experiencer verbs, the neurophysiological data showed a clear distinction between unmarked and accusative objects regardless of animacy. This indicates that experiencer verbs impose stricter case-marking requirements, regardless of the animacy of the object argument. Taken together, our results indicate that the parser processes differential object marking differently depending on whether the verb is an experiencer or an action verb.

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Multimodal Neural Signal Analysis for Brain-Computer Interface Development Using EEG and fNIRS

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Introduction

Brain-Computer Interfaces (BCIs) require robust signals for decoding cognitive states. While Electroencephalography (EEG) provides high temporal resolution, it lacks spatial precision; conversely, functional Near-Infrared Spectroscopy (fNIRS) offers better spatial stability but poor temporal characteristics. Combining these modalities is a strong strategy to enhance decoding accuracy. This study utilizes the open-access simultaneous EEG-fNIRS dataset by Shin et al. (2018) to provide two distinct advancements: (1) a systematic evaluation of the performance gain of a hybrid BCI model, and (2) a novel, comprehensive investigation into **task-specific neurovascular coupling patterns** across three diverse cognitive tasks.

Methods

Data from 26 participants performing n-back, Discrimination/Selection Response (DSR), and Word Generation (WG) tasks were analyzed. Preprocessing and feature extraction followed the standardized pipelines described by Shin et al. (2018), consistent with open-access dataset protocols. Our unique contribution in the analysis lies in the fusion and coupling analysis. Classification compared unimodal (EEG-only, fNIRS-only) versus hybrid (concatenated features) models using sLDA with 10x5-fold cross-validation. Crucially, we quantified neurovascular coupling via time-lagged correlations between specific neural activity (EEG theta power) and hemodynamic responses (fNIRS HbO/HbR) across prefrontal and motor regions to assess global, bilateral, and task-specific patterns.

Results

The hybrid EEG-fNIRS model significantly enhanced decoding performance, particularly for the internally-driven **Word Generation (WG) task**. The hybrid system achieved an average classification accuracy of **92%**, markedly surpassing the unimodal models (78.12% for EEG-only and 66.26% for fNIRS-only). **Our core novel finding is the neurovascular coupling analysis**, which revealed that EEG theta power consistently correlated with ΔHbO responses with a physiological delay of **4-6 seconds**. Importantly, these coupling patterns were both **task-**

specific and hemisphere-specific, a result **not previously reported** using this dataset. The language-based WG task exhibited a left-dominant HbO coupling, which aligns with expected language processing lateralization. Conversely, working memory and inhibition tasks (n-back, DSR) showed **right-lateralized coupling**. For example, the n-back task displayed moderate EEG-HbO coupling that was particularly active in the right hemisphere.

Discussion

These results confirm the complementary strengths of EEG and fNIRS, demonstrating that their fusion significantly enhances BCI performance. The novel neurovascular coupling analysis is the central contribution of this work, offering mechanistic validation by showing that task-specific neural activity predicts later hemodynamic responses. The observed hemispheric lateralization patterns support the use of **physiologically-informed channel selection** to further optimize future hybrid BCI pipelines, moving beyond standard channel inclusion. This suggests task-related activation, particularly in the right hemisphere.

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Localizing Memory Errors Around a Salient Stimulus

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Introduction

When information is presented in a rapid sequence, memory for individual items is not uniform. Classic studies demonstrate robust primacy and recency effects, where the first and last items are recalled best (Waugh & Norman, 1965). However, within the stream, directing attention to a specific target can impair the processing of subsequent items, a phenomenon known as the attentional blink (Raymond et al., 1992).

This experiment investigates a more specific effect: whether making one item salient actively suppresses the memory of its immediate temporal neighbors. It is hypothesized that enhancing a target creates an inhibitory surround, weakening the representations of the items at the +1 and -1 positions. This prediction aligns with computational frameworks, such as on-center off-surround neural networks, which model this precise pattern of recall suppression for items adjacent to a cued target (Vindhya et al., 2024). This study tests this by measuring temporal order accuracy for neighbors versus distant items.

Methodology

Seventeen participants, aged 18 – 21, were a part of the experiment, completing 300 trials within an average of 20-25 minutes. Each trial showcased 9-12 items (either letters or coloured squares) in a sequence at a rate of 100 ms per item. Every sequence consisted of an underlined item that served as a reference. Following the sequence, participants were presented with two probes and given a two – alternative forced – choice question to answer: “Which came earlier?” or “Which came later?”

- Neighbour vs. Distant (80% trial): one probe immediately before (–1) or after (+1) the underlined item, and the other far away in the sequence.
- Distant vs. Distant (20% trial): both probes far from the underlined item.

Data were analysed for accuracy and reaction time (RT), averaged by the serial position of the underlined item to examine primacy and recency patterns.

Results

Analysis of temporal order judgments revealed a distinct pattern in the distribution of errors based on their proximity to the underlined target item. The primary investigation focused on whether errors were more likely to be items immediately adjacent to the salient underlined item (a positional error of |±1|) versus items further away (a positional error of |±2|).

Statistical comparisons of |±1| and |±2| errors demonstrated a medium-to-large effect size, indicating there was an error of neighbour confusion that occurred consistently across participants. As illustrated in, errors of magnitude 1 were consistently more frequent than errors of magnitude 2, regardless of the target's serial position within the stream. This indicates that when participants made a mistake, they were significantly more erroneous for an item that appeared immediately before or after the salient (underlined) object, rather than an item further away in the sequence. The proportion of |±1| errors remained relatively stable across all tested target positions (4 through 8), suggesting a robust local binding effect for items surrounding a salient stimulus.

Discussion

The high frequency of |±1| errors suggests that items adjacent to the salient item (underlined one in RSVP stream) were strongly, albeit imprecisely, encoded. The suppression of memory for items near a salient target can arise from either attentional capture, where the salient item draws cognitive attention to itself, or active inhibition, where the system is non-consciously suppressing surrounding representations in a form of an effective processing strategy that is intended to optimize the encoding of the salient target. Although perceptual crowding may partially contribute to confusion with adjacent items, the sequential RSVP design significantly reduces this overlap. Making the target salient appears to suppress the precision of its neighbours' temporal encoding, in turn making adjacent items highly confusable with the target, leading to frequent positional judgment errors. The findings indicate an impairment of temporal order rather than forgetting - neighbouring items were encoded but in a different order. The occurrence of neighbour suppression may be influenced by individual variances in attentional capacities and working memory, highlighting that cognitive flexibility may act as a protective factory against the interference of salient items.

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The Impact of Post-Stroke Cognitive Impairment on Intraindividual Variability in Processing Speed

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Introduction:

Intraindividual variability (IIV) refers to the natural fluctuations in a person's performance over time and is an inherent part of human behavior. IIV in processing speed refers to unintentional, trial-to-trial fluctuations in a person's reaction time and is strongly linked to neural dysfunction[1]. Elevated IIV in processing speed has been observed in older adults with cognitive impairment and Alzheimer's disease, and is associated with reduced executive control, white matter disruption and risk of cognitive decline[2,3]. Despite extensive evidence highlighting the connection between IIV in processing speed with neuronal damage, systematic investigations on the impact of stroke on IIV in processing speed are notably absent[4]. Moreover, given its relevance to cognitive impairment in older adults, investigating IIV in processing speed may be more critical in stroke survivors with cognitive impairment who comprise more than half of the stroke population[5]. Here we aim to understand how clinical measures can predict this variability. We hypothesize that stroke survivors with cognitive impairment would exhibit greater IIV in processing speed than those without cognitive impairment and healthy controls. We also hypothesize that clinical outcomes will positively predict this variability.

Methods:

The study included 127 participants: 40 stroke survivors with cognitive impairment (71.3 ± 9.4 years; 19F), 52 stroke survivors without cognitive impairment (62.95 ± 14.09 years; 24F), and 35 healthy controls (68.47 ± 14.33 years; 22F). Stroke participants were classified as cognitively normal or cognitively impaired based on consensus by two trained examiners using the National Institute of Neurological Disorders and Stroke-Canadian Stroke Network Vascular Cognitive Impairment Harmonization Standards (NINDS-CSN). A 30-minute protocol assessed at least four cognitive domains (i.e. executive function, language, visuospatial abilities, and memory) via the Montreal Cognitive Assessment (MoCA) and the age- and education-adjusted Dementia Rating Scale (DRS-2 AEMSS). A MoCA score < 26 indicated mild cognitive impairment, whereas a DRS-2 AEMSS < 9 reflects cognitive impairment. Participants completed 32 simple reaction time trials. To compute IIV in processing speed, we applied the established approach by Hultsch et al. (2000)[1]. This approach provides a purified measure of IIV by controlling for the systematic effects of practice and mean level performance. Additionally, participants completed global clinical assessments including education, Dementia Rating Scale-2 (DRS-2), ankle strength, and the modified Rankin Score (mRS). To answer our second question, we ran a multiple regression using these assessment scores as predictors.

Results:

IIV in processing speed was greater in stroke survivors with cognitive impairment compared with stroke survivors without cognitive impairment and healthy controls. In stroke group,clinical measures marginally predicted IIV in processing speed ($R^2 = 0.148$; $p = 0.064$) In stroke survivors with cognitive impairment, clinical outcomes significantly predicted IIV in processing speed ($R^2 = 0.316$; $p = 0.009$). Interestingly, mRS was the only significant clinical predictor of IIV in processing speed among stroke survivors with cognitive impairment ($p = 0.009$).

Conclusion

Our findings show that variability in processing speed is greater in stroke survivors with cognitive impairment than in those without impairment and healthy individuals. This variability can be seen as linked to overall disability, as measured by the mRS scores. These results emphasize the clinical relevance of processing speed variability in understanding and addressing disability after stroke.

Significance

IIV in processing speed offers a distinct marker of post-stroke cognitive instability that aligns with real-world functional disability as measured by mRS. This relationship underscores its potential utility for enhancing clinical assessment and monitoring of recovery in stroke survivors with cognitive impairment.

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Temporal Distortions Associated with Object Affordance in Peri-Hand Space

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Introduction

Micro-affordance refers to the potentiation of specific action plans best suited to interact with an actual or virtual object (reaching, grasping, manipulating, etc.) based on the visual attributes of the object, irrespective of whether the observer intends to act upon it or not (Ellis & Tucker, 2000). That is, micro-affordance seems specific to objects that can be grasped with the hands (*manipulable*) and is stronger when the object is presented in the graspable region of the hands- often termed as the Peri-Hand Space (PHS; Costantini et al., 2010). However, the PHS is characterized by early anticipatory mechanisms- giving sufficient temporal allowance to plan and perform immediate actions on objects. The current study assumes an increased role of temporal factors underlying a micro-affordance-related visual processing bias for manipulable objects in the PHS. Specifically, it is hypothesized that the anticipatory mechanisms associated with the PHS are stronger for manipulable objects. On the other hand, no such prioritization is expected for non-manipulable objects or if objects are placed beyond the PHS. Additionally, the availability of *extra* time- due to the early anticipatory mechanisms associated with the PHS- should result in temporal expansion for manipulable objects in the PHS, as predicted by the Attentional Gate Model (AGM) of time perception (Zakay & Block, 1995).

Methods

Participants completed a Temporal Bisection task (Experiment 1; n=26) and a Verbal Estimation task (Experiment 2; n=28) in two different conditions. The first condition required participants to place both their hands on the sides of a computer monitor, making the stimulus presented at the centre of the monitor appear within the Peri-hand space (PHS). Whereas the second condition required the hands to be placed on the lap, making the stimulus far away. The experimental stimuli, selected from the standardized database (Salmon et al., 2010), were images of manipulable and non-manipulable objects. Based on the familiarity rating analysis for all objects in Indian context, 70 experimental images were chosen from each category. The stimuli were presented at approx. 60 cm away from participants in both the conditions and the responses were collected through mice attached on both sides of the computer monitor (Near-hand condition) or to a cardboard placed on the lap (Far-hand condition). Participants were initially familiarized with the anchor durations of 50 ms ('short') and 350 ms ('long') in Exp. 1 and 50 ms ('short') and 450 ms ('long') in Exp. 2. Later in the test phase, Exp. 1 required participants to judge whether the comparison durations of 50, 100, 150, 200, 250, 300 & 350ms were closer towards the previously trained 'short' or 'long' durations. Whereas, in Exp. 2, participants verbally responded to the temporal estimates (in milliseconds) of the duration of the image presented for the intermediary durations of 100, 150, 200, 250, 300, 350, and 400ms. Participant's responses were compared between 'Near-hand' and 'Far-hand' conditions in both experiments.

Results

Experiment 1- A repeated measures ANOVA on the mean proportion of long responses, with Conditions (Near-Hand & Far-Hand), Manipulability (Manipulable & Non-Manipulable) and Durations (50ms, 100ms, 150ms, 200ms, 250ms, 300ms & 350ms) as within-subject factors revealed significant main effect of Duration F(6,150)=552.38, p<.001, η_p^2=.95. No significant main effect was obtained for either Condition or Manipulability. Importantly, a significant interaction was obtained between Conditions and Manipulability, F(1,25)=10.71, p<.01, η_p^2=.30. To examine these results in detail, the Bisection point (BP) was derived from a psychometric function (logistic function) fitted on the mean proportion of long responses given for the actual durations in 'Near-Hand' and 'Far-hand' conditions, for Manipulable and Non-Manipulable stimuli. A paired-sample *t*-test run on the bisection point revealed significantly lower BP for the Near-Hand condition (190ms) relative to the Far-Hand condition (207ms), for the Manipulable stimuli, t(25)=-2.36, p=.02, implying a leftward shift in the bisection function for the manipulable stimuli in the peri-hand space. No such differences in the BP were obtained between the hand conditions for the non-manipulable stimuli, p=.80

Experiment 2- A repeated measures ANOVA was performed on the mean verbal estimates, with the same within-subject factors as in experiment 1. Significant main effect was obtained for both Manipulability [F(1,27)=6.17, p=.02, η_p^2=.19] and Durations [F(6,162)=175.23, p<.001, η_p^2=.86], but not for Conditions (p=.66). Importantly, as in experiment 1, a significant interaction was obtained between Conditions and Manipulability, F(1,27)=10.90, p=.003, η_p^2=.28, implying that the hand-specific differences in verbal estimates is contingent on the manipulability of the stimuli used. Post hoc analysis showed the hand proximity to affect the mean verbal estimate only for the manipulable stimuli [F(6,162)=2.35, p=.03, η_p^2=.08], and not for non-manipulable stimuli [p=.70]. The 3-way interaction was also found to be significant [$F(6,162)=2.93$, $p=.01$, $\eta_p^2=.09$]

Discussion

The finding of a leftward shift in the bisection function (Exp.1) and interaction effects (Exp 1 & 2) implies distortion in time perception, specifically temporal expansion for manipulable stimuli when presented in the peri-hand space, and not in the space beyond. The 3-way interaction effect suggest that the temporal expansion is not uniform across all durations. These findings can be explained in terms of early anticipatory mechanisms to react/act towards an object when in the Peri-hand Space, making 'more' time available to the motor system. Within the framework of the AGM, the availability of more time can be explained in terms of the Attentional Gate opening wider, to allow the Switch to close early, resulting in greater number of pulses flowing from the Pacemaker to the Cognitive Counter. The present study thus shows that action-anticipatory effects are specific to manipulable objects, but not non-manipulable objects, and restricted to the PHS and not beyond.

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Pre and post temporal context effects on temporal integration windows

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Introduction

Perception is continuously shaped by the integration/segregation of information within temporal windows operating at the sub-second timescale. While some properties of temporal windows like the temporal extent (Drissi-Daoudi et al., 2019), influence of attention (Sharp et al., 2018), and load (Vogelsang et al., 2023) have been investigated, the effect of ongoing temporal context—particularly when it could facilitate anticipation or postdiction--has not been systematically studied.

Methods

To investigate this, we developed a novel paradigm of temporal integration where two halves of a Kanizsa square are integrated or segregated (seen or not seen as a full square) as a function of their ISI (30,100, 300, 800ms). The two halves (T1 and T2) were preceded and succeeded by context consisting of rotating-discs of the same Kanizsa square in a temporally correlated or random fashion. Participants were asked whether they saw a full square or not by pressing Y for Yes and N for No on the keyboard. We had previously found that sensitivity to perceiving an integrated square was higher when the context was temporally correlated as compared to when it was random only up until the intermediate ISI of 300ms. As a follow-up, we conducted two experiments in the current study. Here, we sought to investigate whether sensitivity differences were contributed by the temporal context either preceding or succeeding the two frames that were integrated. To test this, Experiment 1 manipulated the pre-context—making it either temporally correlated or random— while keeping the post-context random across conditions. In Experiment 2, we applied the same manipulation to the post-context, while holding the pre-context random. Eighteen participants took part in each of the experiments. In half of the trials, both T1 and T2 were present and could be integrated as a square. In the remaining trials, either T1 or T2 was replaced with a version in which both diagonal disks were rotated by 180°, preventing the formation of a square upon integration. These trials were taken as square-present and square-absent trials, respectively, in order to calculate Signal Detection Theory (SDT) analysis parameters.

Results

We performed signal detection theory (SDT) analysis on proportion yes responses to obtain sensitivity (d') and criterion (β) values. We conducted a repeated measures ANOVA on d' scores with ISI (30, 100, 300, and 800 ms) and Condition (Correlated, Random) as within-subject factors for both the pre- and post-context manipulation experiments.

Experiment 1 (Pre-context Manipulation):

We found significant main effects of ISI, $F(3, 51) = 4.39$, $p = 0.008$, $\eta p2 = 0.21$, and Condition, $F(1, 17) = 10.31$, $p = 0.005$, $\eta p2 = 0.38$, on the d' scores. As expected, the sensitivity in seeing an integrated square decreased with increasing ISI. Overall, participants performed better when the pre-context was temporally correlated compared to when it was random. However, the interaction between ISI and Condition was not significant ($p > 0.1$).

As for the criterion, there were also significant main effects of ISI, $F(3, 51) = 19.38$, $p < 0.001$, $\eta p2 = 0.53$, and Condition, $F(1, 17) = 6.07$, $p = 0.025$, $\eta p2 = 0.26$. Participants adopted a stricter criterion when the pre-context was random compared to when it was correlated. Again, the ISI × Condition interaction was not significant ($p > 0.1$).

Experiment 2 (Post-context Manipulation): In contrast to Experiment 1, there was no significant effect of Condition, $F(1, 17) = 1.07$, $p = 0.32$, $\eta p2 = 0.06$, on d' values indicating that whether the post-context was temporally correlated or random did not significantly influence performance. However, a significant main effect of ISI was observed, $F(3, 51) = 8.82$, $p < 0.001$, $\eta p2 = 0.34$, and no significant interaction effect was found ($p > 0.1$).

As for the criterion, Condition had a significant effect, with higher criterion values observed in the correlated condition compared to the random one, $F(1, 17) = 4.87$, $p = 0.041$, $\eta p2 = 0.22$—opposite to what was observed in Experiment 1. A significant main effect of ISI was also present, $F(3, 51) = 10.96$, $p < 0.001$, $\eta p2 = 0.39$, with no significant interaction between ISI and Condition ($p > 0.1$).

Discussion

Our results show that the regularities in the pre-context enhanced the sensitivity to perceiving an integrated square. However, modulating the post-context regularities did not yield the same effect. In our recently published study, we had found higher sensitivity when both the pre and post context was temporally correlated as compared to when both were random. With the current results from the two experiments, we showed that the temporal context preceding and succeeding the frames of interest influence integration asymmetrically. These results suggest that the effects observed in our earlier study were predominantly driven by anticipatory mechanisms. We think that the higher sensitivity in the temporally correlated condition in the previous study may have resulted from the participants' ability to more precisely estimate the target onset timing.

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Keynote 3 **Chair: Nandini Chatterjee Singh**

Developing the attentive brain: Early foundations of executive attention development

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Early cognitive models have emphasized sustained, selective, and executive control as key components of attention. These broad domains can be further subdivided into specific operations, depending on whether the function is primarily driven by external stimulation (bottom-up attention) or by internal processes such as voluntary intentions and expectations (top-down attention). Within this framework, executive attention refers to a central cognitive mechanism in humans that regulates and organizes the flow of perceptions and actions, shaping both voluntary behavior and mental life. We argue that the early development of endogenous attention forms the foundation for executive control and self-regulation.

In this talk, I will present recent research on the development of executive attention from infancy through mid-childhood. Findings from a longitudinal study reveal significant advances in endogenous attention control during the transition from infancy to toddlerhood. Voluntary control of attention begins to emerge in the first half of the first year of life, when infants start directing their gaze intentionally and gradually become better at sustaining attention based on their interests. By the end of the first year, infants also begin to exert control over motor behavior. Alongside these behavioral changes, we have observed notable developments in oscillatory brain activity. Specifically, theta and alpha frequency bands show significant maturation in the early years and are closely linked to the development of executive attention. Our results suggest that efficient functional connectivity in the alpha band may serve as a neural marker of early attention development.

These findings contribute to theoretical models by refining existing frameworks and generating new hypotheses, while also offering insights relevant to developmental disorders. By clarifying the early developmental trajectory and neural mechanisms of executive attention, a cognitive neuroscience approach can inform the design of targeted interventions—bridging the gap between theory and practice in developmental psychology and cognitive neuroscience.

Feedback and Reward Facilitate Shifts Between Cognitive Control Modes in Children

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Introduction

Flexible cognitive control – the ability to shift between proactive control (anticipation and prevention of interference) and reactive control (detection and resolution of interference) according to changing demands is critical for adaptive functioning in childhood. Although motivational factors like feedback or reward influence different aspects of cognitive control[5,4], their impact on the flexible deployment of these control modes remains underexplored. Intrinsic motivators like performance feedback may promote sustained engagement by fostering self-monitoring, while extrinsic motivators like performance-contingent rewards may enhance efforts through incentive-driven attention focus. Prior work suggests that children given feedback[4] or reward[5] respond more accurately and adopt a cautious or conservative response strategy (slower RTs) than without such motivation, promoting proactive control. Yet, it remains unclear how these factors differ in their effects and how each uniquely contributes to flexible shifts between cognitive control modes. The present study examined how feedback and reward facilitate flexible shifts between proactive and reactive control (Proactive Possible condition) in children using a cued task-switching paradigm.

Methods

Participants: Children aged 6-8 years (N = 25) and 9- 11 years (N = 25) were recruited from schools in Prayagraj. Demographic data (age, grade, socio-economic status, languages known/spoken) and Colored Progressive Matrices (CPM) scores were collected, with CPM used as a covariate for fluid intelligence.

Experiment: A cued color–shape task-switching paradigm was administered on a touch-screen laptop. Cues—colored patches (color) or grey patches (shape) on a black circle—preceded targets. Cue-target intervals were manipulated in two conditions: ***Proactive Possible*** (PPC, cue was presented prior to the target and remained visible with the target, making flexible use of proactive and reactive control possible), and ***Proactive Encouraged*** (PEC, cue disappeared before the target, encouraging proactive control only). Three counterbalanced blocks—Baseline (no feedback/reward), Feedback (happy/sad snowman for correct/incorrect), and Reward (candy image every 10th trial if accuracy > 60%)—were run in separate sessions. Each block had 81 trials (50% switch, 50% non-switch) and lasted ~15–20 min.

Results

A linear mixed-effects model was fit to log-transformed response times, and a generalized linear mixed-effects model was fit to logit-transformed accuracy with block (Baseline, Feedback, Reward), condition (PPC, PEC), trial-type (switch, repeat), and age group (6-8 and 9-11 years) as fixed effects and random intercepts for participants. Both Feedback ($\beta = -0.071$, $p < 0.001$) and Reward ($\beta = -0.097$, $p < 0.001$) produced faster RTs than Baseline. PEC was faster than PPC ($\beta = -0.046$, $p = 0.038$), repeat trials were faster than switch trials ($\beta = -0.079$, $p < 0.001$), and 9-11-year-olds were faster than 6-8-year-olds ($\beta = -0.16$, $p = 0.0024$). Block effects also modulated switch costs: both Feedback ($\beta = 0.082$, $p = 0.015$) and Reward ($\beta = 0.126$, $p < 0.001$) significantly reduced switch costs, with Reward being more effective. The interaction effects of Block, Condition, and Trial type indicated that Reward produced a substantially larger reduction in switch cost in PPC than in PEC ($\beta = -0.124$, $p < 0.001$), while Feedback only showed a marginal tendency to reduce switch cost more in PPC than in PEC ($\beta = -0.061$, $p = 0.081$).

Age further shaped Block effects. Pairwise comparisons using Bonferroni correction indicated that in PPC, 6-8-year-olds benefitted from both Feedback ($\beta = 0.029$, SE = 0.0129, $p = 0.067$) and Reward ($\beta = 0.034$, SE = 0.0128, $p = 0.023$), while 9-11-year-olds exhibited a strong improvement only from Reward ($\beta = 0.048$, SE = 0.0126, $p < 0.001$). In PEC, 6-8-year-olds showed an advantage only with Reward ($\beta = 0.056$, SE = 0.012, $p < 0.001$), and 9-11-year-olds gained little to no benefit from Reward, and were negatively affected by Feedback($\beta = -0.109$, SE = 0.011, $p < 0.001$).

Accuracy analysis showed parallel block effects: Feedback ($\beta = 2.472$, $p < 0.001$) and Reward ($\beta = 3.032$, $p < 0.001$) improved accuracy; PEC has higher accuracy than PPC ($\beta = 0.477$, $p < 0.001$); and repeat trials are more accurate than switch trials ($\beta = 1.348$, $p < 0.001$). However, neither age group differed significantly in accuracy. In PPC, Feedback helps accuracy strongly; in PEC, Feedback benefit shrinks dramatically ($\beta = -1.1005$, $p < 0.001$). Reward's accuracy benefit also shrinks significantly in PEC ($\beta = -1.1733$, $p < 0.001$).

Discussion

Results show that both feedback and reward improved flexibility across both age groups, highlighting that intrinsic or extrinsic motivation facilitates engagement in flexible cognitive control. In the PPC condition, children demonstrated flexibility in shifting between proactive and reactive control modes, highlighting its importance as a key condition for assessing flexible shifts in cognitive control across age groups[6]. The influence of both feedback and reward was particularly evident in this condition, compared to the condition that promotes proactive control (PEC). Feedback minimises attentional lapses and promotes sustained attentional focus and a more conservative response style, while reward increases general attentional mobilisation, encourages readiness and cautious responding. In the PPC condition, feedback likely helped children detect when the response rules do not apply, promoting flexible shifts to alternative strategies or rules[3], whereas when anticipated reward keeps on increasing (more candies), it encouraged to explore new strategies or switch strategies when it is possible to gain more rewards[1,2]. We find that both feedback and reward enhance flexible shifts in cognitive control in children (both age groups), allowing them to adopt a conservative strategy to enhance their performance, which has implications for academic achievement and learning life skills across the developmental period.

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Investigating the relationship between Meta-control and Creative Thinking in Children

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Introduction

Metacontrol- the ability to regulate cognitive control along a persistence- flexibility continuum, reliably contributes to the idea generation process.[1] It has been theorized to underpin creative thinking, yet its development and impact on creativity in children remain underexplored. This study investigates how metacontrol flexibility and persistence relate to creative performance in children aged 6–9 years, compared to adults. We specifically examine spontaneous engagement of metacognitive processes when participants receive no feedback or explicit strategy instructions. We hypothesize that (1) adults will demonstrate higher metacontrol adaptability and more accurate metacognitive monitoring than children, and (2) across both age groups, greater adaptability will predict superior performance on divergent (idea generation) and convergent (analytic reasoning) tasks.[2]

Methods

Participants were 26 children (M = 7.6 years; SD = 0.9) and 26 adults (M = 22.8 years; SD = 1.9). Metacontrol was quantified using a colour-coded Numerical Discrimination Task: on each trial, two coloured "games" mapped covertly onto "easy" (1:2 dot ratio) or "hard" (9:10 ratio) discriminations.[3] No performance feedback or strategy guidance was provided. Adaptability scores were computed as the difference in performance ratios (accuracy ÷ reaction time) between easy and hard trials.[4] Following the task, participants made unguided global judgments of overall accuracy, accuracy by colour, and perceived difficulty, yielding measures of task- and performance-monitoring. Divergent thinking was assessed via the Alternative Uses Task (AUT), scored for fluency and originality by two independent raters ($ICC > 0.90$). Convergent thinking was measured with the Raven's Coloured (children) or Standard (adults) Progressive Matrices and the Vocabulary and Similarities subtests of the WISC-IV/WAIS-III. Group comparisons employed mixed ANOVAs and t-tests, and simple linear regressions tested adaptability as a predictor of AUT originality, Raven's scores, and vocabulary/similarities performance.

Results

Metacontrol & Monitoring: Mixed ANOVA revealed significant main effects of Task Difficulty (easy > hard; $p < .001$) and Group (adults > children; $p < .001$), with a Task × Group interaction indicating greater adaptability in adults. Adults' adaptability ($M = 1.53$, $SD = 0.77$) exceeded children's ($M = 0.68$, $SD = 0.30$), $t(50) = 5.24$, $p < .001$, $d = 1.45$. Adults also opted for easy trials on 68% of decisions versus 53% for children, and 60% met criteria for strategic "optimizers" compared to 4% of children. On metacognitive monitoring, adults outperformed children on task-monitoring accuracy ($M = 1.52/2$ vs. $0.92/2$; $p = .017$) and displayed calibrated performance judgments, whereas children overestimated their accuracy.

Creativity: In divergent thinking, adults scored higher in originality ($M = 2.86$, $SD = 1.03$) than children ($M = 1.97$, $SD = 0.81$), $t\ (50) = 3.31$, $p = .002$, $d = 0.92$; fluency did not differ ($p > .05$). Convergent thinking measures (Raven's CPM/SPM, Vocabulary, Similarities) all favoured adults (all $p < .001$, large effect sizes). On convergent tasks, adults outperformed children on Raven's matrices (.84 vs. .64; $t = 5.53$, $p < .001$, $d = 1.53$), Similarities (.84 vs. .46; $t = 10.87$, $p < .001$, $d = 3.02$), and Vocabulary (.65 vs. .39; $t = 7.94$, $p < .001$, $d = 2.20$).

Predictive Relations: Regression analyses showed that adaptability significantly predicted each outcome: Raven's $F\ (1,50) = 23.14$, $p < .001$, $\eta^2 = .095$; Vocabulary $F\ (1,50) = 36.13$, $p < .001$, $\eta^2 = .236$; Similarities $F\ (1,50) = 66.69$, $p < .001$, $\eta^2 = .311$; Originality $F(1,50) = 6.33$, $p = .015$, $\eta^2 = .113$, across participants. Higher adaptability accounted for 9–31% of variance in creative performance.

Discussion

The findings demonstrate that metacontrol in terms of adaptability and metacognitive monitoring predicts divergent and convergent thinking in children and adults, providing direct evidence in support of the Metacontrol State Model.[5] Children exhibited immature monitoring and control: most failed to adopt consistent strategies or to track their own performance and task difficulty, and even those who did monitor did not adjust their behavior to optimize outcomes. We also found that by operationalizing metacontrol and linking it to both divergent and convergent thinking measures, we find that greater capacity to flexibly shift between persistence and flexibility underpins more original idea generation and more efficient analytic reasoning.[6]

Dynamic regulation of cognitive control biases toward persistence or flexibility drives creative performance—and extend this framework to a developmental context, revealing that children's emerging metacontrol capacities, while sufficient for basic task differentiation, constrain their ability to adaptively engage in creative tasks.

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Stop or not: Do we have conscious access to the decision to stop?

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Introduction

Response inhibition allows us to rapidly inhibit or cancel incipient responses, for example, stop ourselves from stepping onto the street if a vehicle suddenly approaches. It is critical for adaptive behaviour and is deficient in several clinical populations such as Obsessive-Compulsive Disorder. These populations are also known to have poorer sense of agency over their motor actions[1]. While motor agency has been well-explored, our sense of agency during inhibition of actions remains underexplored. And yet this has important implications for the motor control research. In this context, using a modified Anticipatory Response Inhibition task where participants had to intermittently stop their incipient response when a stop signal was presented, we tested sense of agency during response inhibition. Specifically, in two groups (N=21 per group), we investigated whether individuals could report, with temporal specificity, their decision to stop an action, and whether this awareness is dissociable from the perception of the stop signal.

Methods

In study 1, participants (N=21) performed the 720 trials of a modified Anticipatory Response Inhibition task[3] (where we employed an auditory stop signal instead of a visual one). Each trial began with a fixation period of 500ms with the presentation of two unfilled left and right bars each with 10 major and minor notches. Additionally, a horizontal line was present at either 75% or 90% of the bars' height, indicating the target location for that trial. After that, one of the bars started filling up at a rate of 1 major notch in 100ms and participants had to perform a keypress when the bar reached the target. The total response window is 1.25s meaning that participants could respond up to 250ms after the bar was completely filled. On a random 25% of trials (180 Go trials), participants were asked to report the timing of when they make the decision to make the keypress 'When did you decide to press?' and they used the mouse cursor to mark the point on the bar. On a random 25% of trials (180 stop trials), a tone, i.e., the stop signal was presented, and in these trials, participants tried to stop their response. After every stop trial, irrespective of stopping success, participants were asked 'When did you decide to stop?' and they used the mouse cursor to mark the point on the bar. The stop signal delay was initially set to 400ms and 550ms for the lower and upper targets, respectively (i.e., 350ms before reaching the lower or upper target positions) and it increased or decreased by 33ms after a successful or failed stop trial, respectively. In study 2, another group of participants (N=21) performed the same task, but in the stop trials they were asked to report the time when they heard the stop signal. Since the time when one stops a response cannot be observed, we estimated the Stop Signal Reaction Time (SSRT) using standard procedures (see below)[2]. We then compared the reported times of studies 1 and 2 to the estimated SSRT. We hypothesized that: A) In study 1, if participants do not have awareness of the time *when* they decided to stop then the reported timing would not have any systematic relationship with SSRT. B) In study 2, participants would be able to report the time when they heard the tone where a positive correlation between tone time and SSRT would indicate longer auditory processing time in individuals with longer SSRT.

Calculation of SSRT using integration method: SSRT was estimated using the integration method as recommended by Verbruggen et al. (2019). Briefly, the reaction times of all go trials (including premature and choice errors) were collected and go omission trials were replaced by the maximum RT and arranged in ascending order. After that, the probability of responding on stop trials was calculated and multiplied with the total number of go trials to determine the nth RT. Then the mean SSD across all stop trials was subtracted from the nth RT to calculate the estimated SSRT.

Results

In study 1, participants' reported *decision time* correlated well with their SSRT for both lower target (r=0.7, t(19)=4.4, p<0.001) and upper target (r=0.7, t(19)=4.0, p<0.001). The decision time preceded SSRT by 85±9ms and 99±10ms for the lower and upper target, respectively. Interestingly, the decision time was not significantly different between successful (lower: 350±11ms, upper: 342±13ms) and failed (lower: 356±13ms, upper: 347±13ms) stop trials for either lower (t(20)=0.7, p=0.49) or upper target (t(20)=0.6, p=0.566). In study 2, the reported *tone timing* correlated well with SSRT for both lower target (r=0.8, t(19)=6.3, p<0.001) and upper target (r=0.8, t(19)=5.4, p<0.001). The tone time preceded SSRT by 151±15ms and 174 ± 17ms for the lower and upper target, respectively. The perceived tone time was significantly different between successful (lower: 330±24ms, upper: 309±27) and failed (lower: 306±25ms, upper: 296±27ms) stop trials for the lower target (t(20)=4.3, p<0.001) but not the upper target (*t*(20)=1.6, *p*=0.132). Interestingly, although SSRT was not significantly different between study 1 (lower: 439±13ms, upper: 445±13ms) and study 2 (lower: 468±15ms, upper: 476±16ms), for either lower target (*t*(39)=1.5, *p*=0.135) and upper target (*t*(39)=1.5, *p*=0.145), the *tone time*(lower: 151±15ms, upper: 174±17ms) was significantly lower than *decision time* (lower: 85±9ms, upper: 99±10ms) relative to the SSRT for both lower (*t*(33)=3.8, *p*<0.001) and upper target (*t*(33)=3.7, *p*<0.001). This may suggest that the two reported timings indicate separate mental events.

Discussion: Our results suggest that participants can report the time when they decide to stop. Further, the reported decision time is invariant to the behavioural outcome of the trial and is unrelated to the tone time which suggests genuine prospective awareness to inhibition rather than post-hoc inference. This suggests that we may have conscious access to the intention to stop but that this appears late preceding behavioural stopping by ~92ms. While it is possible that the self-reported time is untrustworthy, there are several arguments against this. First, in the successful stop trials, there is no observable behaviour. Hence, participants cannot rely on observable behaviour to retrospectively report the decision time. Second, the target positions changed between trials (left/right and lower/upper), stop trials were randomly interspersed, and the time of presentation of the stop signal changed between trials, so participants could not simply decide to report one specific, arbitrary time in every trial. Third, the decision time varied systematically with SSRT which suggests that participants were not simply reporting an arbitrary timing.

Our study has several limitations. First, we required a timing decision response in every stop trial. This design choice was made to prevent participants from simply skipping trials instead of trying to introspect. Second, the same group of participants did not perform both studies. This was done to prevent biased timing reports but please note that there was no difference in SSRT between the studies.

This study represents an initial exploration into the nature of conscious intention in response inhibition. Our findings suggest that participants possess prospective awareness of stop decisions. These results inform theoretical accounts of agency by elucidating the volitional aspects of inhibition.

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Automatic pause and deliberate stop mechanisms in the basal ganglia

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Introduction

Unexpected salient events can automatically capture attention, causing a brief pause in ongoing actions. When such events signal stopping, a deliberate response inhibition process follows, and performance monitoring evaluates the outcome for future control adjustments. The stop-signal task (SST) measures response inhibition, the capacity to halt a preplanned movement. In the SST, subjects respond to a go cue but cancel the movement if a salient stop cue appears after a variable delay. However, salient events that do not instruct stopping can still capture attention and briefly suppress movement. The neural dissociation of attentional capture and inhibition remains unclear. Embedding a salient 'continue' or 'ignore' cue in the SST allows researchers to separate attentional capture from inhibition- and error-related activity.

The pause-then-cancel (PTC) model proposes a two-stage mechanism: an initial automatic global pause via the hyperdirect pathway, followed by deliberate selective cancellation through the indirect pathway. This initial pause can also be triggered by non-stop cues, reflecting attentional capture distinct from inhibition. While human studies and the PTC model implicate fronto-basal ganglia networks in both stages, whether these processes are dissociated at the single-neuron level remains unknown. Here, we demonstrate, for the first time, a dissociation of automatic pausing from deliberate response inhibition and error monitoring at the single-neuron level in the basal ganglia.

Methods

We trained two monkeys (F and J) to perform a saccadic stop-signal task with salient continue (ignore) trials, enabling direct dissociation of attentional capture–driven pausing from response inhibition and error monitoring. During task performance, we recorded activity from 4,914 striatal neurons (2,426 caudate; 2,488 putamen). Each trial began with fixation, followed by extinction of the fixation point and appearance of an eccentric target (∼12°) to the left or right, serving as the go signal. In ~56% of trials (go), monkeys made a saccade within a deadline; in ~22% (stop), a central square instructed them to withhold the saccade; and in ~22% (continue), a rotated square instructed them to ignore the signal and complete the saccade. The delay between the go and stop/continue signals had four fixed values in each session. We used a latency-matching procedure, comparing correct stop trials with slow go trials, error stop trials with fast go trials, and applying the same approach to continue trials. This ensured that neural differences reflected cognitive processes—such as inhibition, attentional capture, or error monitoring—rather than movement speed.

Results

Monkeys F and J completed 83 and 57 sessions, consistently making saccades within the deadline in go and continue trials, and inhibiting ~50% of stop trials. Error stop RTs were shorter than go RTs, while continue RTs were longer, reflecting a behavioral pause triggered by attentional capture. The RT distributions, aligned to stop/continue signals, initially increased for both error stop and correct continue trials, but only continue RTs showed a significant recovery, producing a clear temporary pause following the continue signal. We identified two functional neuron classes: (1) go neurons and (2) stop neurons. Go neurons were defined by two criteria: (1) a significant firing-rate increase around contralateral saccade onset (–100 ms to +100 ms from saccade onset vs. baseline –300 ms to go cue) on go trials, and (2) a significant decrease in correct stop trials compared to latency-matched slow go trials in the contralateral direction (0–400 ms from stop-signal onset). Using these criteria, we identified 528 go neurons in the caudate. Go neurons in putamen were inconsistent across monkeys, so not analysed further. Stop neurons were defined as those showing a significantly greater firing rate in correct stop trials (both directions combined) during the 400 ms after stop- signal onset compared to the 400 ms before the stop signal. This yielded 507 stop neurons in the caudate and 467 in the putamen. The difference in neural activity emerged just before the stop-signal reaction time (SSRT)—the estimated time required to stop a response—in caudate go neurons and striatal stop neurons, suggesting their direct role in response inhibition. Caudate go neurons were briefly suppressed following the continue signal, indicating a transient pause driven by attentional capture. In contrast, this suppression was sustained in correct stop trials, reflecting complete response inhibition. Stop neurons in both caudate and putamen showed elevated activity in continue trials compared to slow go trials, consistent with attentional capture. Thus, both go and stop neurons encoded the behavioral pauses caused by attentional capture and response inhibition. During the late phase, comparison of error stop and fast continue trials with fast go trials revealed that striatal stop neurons showed elevated activity in both continue and error trials, reflecting processing of the salient signal (attentional capture). Notably, these neurons also distinguished between fast continue and error trials, indicating explicit error monitoring. In contrast, go neurons did not consistently encode error monitoring. Thus, striatal stop neurons encoded error monitoring distinctly from attentional capture.

Discussion

We found that continue trials produced an automatic behavioral pause, accompanied by brief suppression of caudate go neurons and excitation of striatal stop neurons. These results support the PTC model, showing that salient signals can transiently disrupt motor plans via the striatal pathway, independent of outright inhibition. While previous models proposed that rapid activation of subthalamic nucleus (STN) neurons in the hyperdirect pathway underlies this pause, our findings indicate striatal suppression may be a complementary mechanism. The pre-SSRT divergence of go neuron activity between slow go and correct stop trials further highlights their role in inhibition, consistent with engagement of the deliberate cancel phase after the pause.

Our results provide the first single-neuron evidence linking putamen activity to both inhibition and attentional capture. We propose a circuit in which pause and cancel processes can be implemented within the striatum, likely driven by pre-supplementary motor area input, complementing pathways involving STN to substantia nigra pars reticulata (SNpr) for pause, and STN–arkypallidal–striatal route for cancel. We also identify novel error-related signals in striatal neurons, previously thought exclusive to cortex (supplementary eye field, anterior cingulate cortex). These results show that the basal ganglia implement distinct control signals, supporting a revised circuit model of inhibition and error monitoring.

A Pause is sufficient for stopping: evidence from computational modelling of stop/continue signal task

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Introduction

The ability to rapidly inhibit movements that are no longer appropriate, called **response inhibition**, is crucial for goal-directed behaviour. It is often assessed with the stop-signal task, in which participants execute a response to frequent ‘go’ signals (**go trials**) but must withhold it when an infrequent, salient ‘stop’ signal occurs (**stop trials**). However, salient cues that do not instruct stopping—such as “continue” signals—can still evoke attentional capture, leading to a pause in behaviour, complicating the interpretation of behavioural and neural responses as inhibition-related. A stop signal task variant incorporating a salient ‘continue’ cue that captures attention without requiring stopping (**continue trials**) is used to separate attentional capture from inhibition. Using these tasks, studies have elucidated that the neural mechanisms of response inhibition involve the basal ganglia[1]. Other studies in elucidating the computational mechanisms of response inhibition have proposed several models, some of which are discussed below.

The most common model is the independent race model[2] which posits that the stop trial outcome is determined by a race-to-threshold between a **Go** and a **Stop process**. If Go reaches the threshold first then a response is made (failed stop), and if Stop reaches the threshold first then the response is inhibited (successful stop). Alternatively, the **Pause-then-Cancel** model[1], posits that stopping consists of a two-step mechanism involving different basal ganglia pathways: a rapid ‘Pause’ process that temporarily interrupts the Go process, followed by a slower ‘Cancel’ process that ceases the response. Another model, the **trigger failures** model[3], posits that stopping failures occur because the ‘brake' mechanism mediating the cancellation of the response is not ‘triggered’. Since many models fit behaviour reasonably well, comparing them with neural data may be the only way to resolve model mimicry. Considering this, here we try to develop a model that fits behavioural data from monkeys, reconciles existing models, and attempts to relate findings to neural data recorded from the basal ganglia.

Methods

Two monkeys (F and Y) performed the stop/continue-signal task. Data from 60 sessions were analysed. Each trial began with a circle at the centre of the screen, jumping left or right to prompt a gaze shift. In 22% of trials (stop), a square appeared at the center after a variable stop-signal delay (SSD), signalling cancellation of the saccade. In 22% (continue), a rotated square appeared at the center after a variable continue-signal delay (CSD), signalling to ignore it and complete the saccade.

Our model had three non-leaky stochastic accumulation-to-threshold processes with an afferent delay of 50 ms, described by $a(t)=a(t-1)+\mu+\varepsilon$, where $a(t)$ and $a(t-1)$ is accumulation at time t and t-1, respectively, μ and σ are mean and SD of drift rate, and ε is Gaussian noise $(0,\sigma)$. The processes were: (1) Go process starting after the go signal, initiating the saccade at threshold. (2) Pause process starting after continue/stop signal, temporarily interrupting response—implemented by threshold modulation (transient threshold increase) or as a halting mechanism (transiently holds Go accumulation). Trigger failures were modelled as trials where the Pause was inactive, which was compared to the % estimated from the BEESTS model[3]. (3) Cancel process starting after the stop signal to cancel the saccade.

Parameter optimization was done using MATLAB *fmincon* function in a stepwise manner. First, from Go RTs we estimated μ_{Go} and σ_{Go}; fixing these, from Continue RTs we estimated Pause parameters (μ_{Pause}, σ_{Pause}, proportion and duration of active trials); then, fixing Go and Pause, from the inhibition function (probability of failed stop vs. SSD) we estimated μ_{Cancel} and σ_{Cancel}.

Results

The Go RTs were well fit (Monkey-F: RT_{Left} R^2 =0.99, RT_{Right} R^2=0.97; Monkey-Y: RT_{Left} R^2 =0.85, RT_{Right} R^2=0.85). The Pause with a halting mechanism (Monkey-F: RT_{Left} R^2 =0.95, RT_{Right} R^2 =0.93; Monkey-Y: RT_{Left} R^2 =0.77, RT_{Right} R^2 =0.80) and threshold modulation (Monkey-F: RT_{Left} R^2 =0.93, RT_{Right} R^2 =0.92; Monkey-Y: RT_{Left} R^2 =0.82, RT_{Right} R^2 =0.79) produced comparable fits. The proportion of Pause-inactive trials (Monkey-F: 2–3%, Monkey-Y: 30–50%) did not match BEESTS trigger failure estimates (Monkey-F: 15.5%, Monkey-Y: 7.91%). The Cancel process could fit the inhibition functions well with both Pause as a halting mechanism (Monkey-F: RT_{Left} R^2 =0.96, RT_{Right} R^2 =0.91; Monkey-Y: RT_{Left} R^2 =0.8, RT_{Right} R^2 =0.72), and threshold modulation (Monkey-F: RT_{Left} R^2 =0.96, RT_{Right} R^2 =0.93; Monkey-Y: RT_{Left} R^2 =0.85, RT_{Right} R^2 =0.89). However, Pause and Cancel reached the threshold at similar times (Pause RT=80-85ms, Cancel

RT=80-85ms), inconsistent with the Pause-then-Cancel model which posits that the Cancel process is slower than the Pause. To reconcile this, we conceptualized that the Pause led to the complete cessation of the response. In the continue trials, this cancellation is followed by an initiation of a second Go process. This model provided reasonable fits to the Continue RTs (Monkey-F: RT_{Left} R^2=0.95, RT_{Right} R^2=0.92). Interestingly, in the stop trials, the same Pause parameters also yielded good fits to the inhibition function (Monkey-F: RT_{Left} R^2 =0.96, RT_{Right} R^2 =0.90).

Discussion

This study attempts to reconcile various existing models of response inhibition using behavioural data from two monkeys performing the stop/continue signal task. In contrast to the two-step Pause-then-Cancel model, we observed that a single-step Pause process is sufficient to fit the behaviour in both the continue and stop trials. In the future we will attempt to relate the neural findings to the model estimates.

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Emotional Facial Cues Modulate Visual Distractor Suppression

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Introduction

In everyday stimulus-rich environments, selective attention plays a critical role in facilitating goal-directed behaviour by enhancing relevant sensory input and suppressing irrelevant stimuli. This mechanism, known as visual distractor suppression, is fundamental to efficient cognitive processing. However, this process is often disrupted by interference, particularly from emotionally salient stimuli, such as human facial expressions. Among these, fearful faces have been shown to exert a strong attentional pull due to their social and evolutionary significance as signals of potential threat (Vuilleumier & Pourtois, 2007).

To examine the interaction between emotional salience and distractor suppression, the present study employed a modified visual filtering task in which participants were asked to focus on task-relevant target stimuli while ignoring centrally presented emotional face cues (Fearful, Neutral, or Scrambled). The key measure of interest was filtering efficiency, quantified using Cowan's K, a formula that estimates the number of items that can be held in visual working memory (Cowan, 2001). Cowan's K provides a sensitive index of how effectively individuals can resist encoding task-irrelevant information. In situations where distractor suppression is compromised, e.g., by emotional interference, working memory resources are misallocated, leading to increased Unnecessary Storage (US), defined as the additional number of items stored due to the presence of distractors.

By comparing US scores across emotional cue conditions, the current study aimed to reveal how emotional facial signals, particularly Fear, affect the capacity to suppress visual distractors. Understanding this interaction is crucial for attentional control models and for disorders characterized by attentional biases toward emotional stimuli, e.g., anxiety. We present the behavioural results of the ongoing study, which also involves neuroimaging to examine the structural brain correlates of the observed behavioural difference.

Methods

A total of 68 healthy adults (20 females; age = 21.72 ± 2.48 mean ± SD) completed an emotion-cued visual filtering task in which the participants were instructed to identify the orientation of the arrows (UP/DOWN) in a probe array while ignoring a task-irrelevant facial emotion cue (Fearful, Neutral, or Scrambled) presented at the center and responded using a response pad. A total of 288 trials were completed across six sessions. The filtering efficiency was quantified using Cowan's K formula. Furthermore, we calculated the Unnecessary storage (US), which is computed as the difference between the K scores of distractor-absent and distractor-present conditions. A higher US score indicates greater distraction and reduced filtering efficiency.

Results

The Cowan's K scores of the Scrambled condition were subtracted from Fear and Neutral conditions to isolate the effect of pure emotions on distractor suppression. Paired-sample t-tests comparing the emotional conditions, Fear and Neutral, revealed a statistically significant increase (t(67) = 2.80, 95% Confidence interval of the difference [0.18,1.08], p = 0.006, d = 0.44) in the US for Fear as compared to the US of Neutral. It suggests that task-irrelevant Fear emotion pre-cues reduce the ability to ignore distractors, which in turn lessens the participant's ability to focus their working memory capacity on task-relevant targets compared to Neutral emotion pre-cues.

Discussion

The present findings reveal that task-irrelevant fearful facial cues significantly impair distractor suppression compared to neutral facial cues, as evidenced by higher Unnecessary Storage (US) values. This suggests that emotionally salient stimuli, particularly Fear, compromise the efficiency with which individuals can filter out irrelevant visual information. These results are consistent with the view that fear-related stimuli have privileged access to attentional systems due to their high biological and social relevance (Öhman, 2005).

Importantly, the use of Cowan's K as a metric of visual working memory capacity allows for a nuanced understanding of this interference. While K typically reflects the number of target items stored, the derived US measure isolates the specific impact of distractors on memory performance. The increase in the US with fearful cues suggests a failure to suppress irrelevant input and an intrusion of emotional content into working memory, effectively crowding out space that should be reserved for task-relevant information (Vogel, McCollough, & Machizawa, 2005).

These findings have important implications for cognitive neuroscience, particularly in understanding how emotional modulation of attention intersects with working memory systems. Ongoing neuroimaging analysis in our study will help clarify the neural mechanisms that underlie the observed behavioral effects.

The study contributes to the broader understanding of attentional control under emotional load, a topic of growing relevance in both basic and clinical research. Dysregulated distractor suppression in the presence of emotional stimuli has been implicated in anxiety disorders, PTSD, and ADHD (Eysenck et al., 2007). Thus, our findings advance theoretical models of attentional filtering and hold potential for identifying cognitive markers of vulnerability in clinical populations.

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Investigating the Direct Effects of Directed Forgetting on Emotional Associations

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Cognitive efficiency requires maintaining a balance between remembering and forgetting. Remembering is crucial for learning or acquiring knowledge, but excessive recall of unwanted memories has been linked to mental disorders including post-traumatic stress disorder (PTSD), anxiety, and depression. The intrusions of distressing memories further disrupt emotion regulation, emphasizing the importance of selective forgetting mechanism. Directed forgetting, one such cognitive strategy involves voluntary suppression of information in response to presentation of forget or remember instructions. Although much research in Directed Forgetting has been directed primarily at its effects on declarative memory and isolated information (words, images). The current study aims to determine if Directed Forgetting modulates encoding for emotional associations and further to investigate the underlying electrophysiological mechanisms.

Thirty-nine participants, ranging between 18-30 years, underwent the experiment including forty-four line-drawing images; the images were either associated with an aversive sound of a screaming lady (CS+) or with no sound (CS-). In acquisition phase, images were encoded under remember or forget instructions, a beep sound (1 second) served as a forget cue. Experimenter examined the participant's memory through the recall, recognition, and liking ratings. Behavioural findings showed that participant were able to recall more of "remember" than of "forget" items ($F(1,38) = 146.26$, $p <. 001$, $\eta^2 = .794$), and higher recall rates of CS+ items relative to CS- items ($t(1,38) = 10.78$, $p <. 001$). The interaction effect of stimulus x instructions was also significant ($F(1,38) = 6.25$ $p <. 05$, $\eta^2 = .141$). In the case of associative recall both stimulus ($F(1,38) = 146.26$, $p <. 001$, $\eta^2 = .794$) and instructions ($F(1,38) = 23.53$, $p <. 001$, $\eta^2 = .382$) had a significant impact. The results highlighted non-significant impact for recognition rates and liking ratings. Notably, participants showed near perfect recognition. Electrophysiological data showed an enhancement of delta and beta power to CS+ stimuli at

0–2 secs and 6–8 secs post stimuli presentation, respectively. Furthermore, alpha and beta power band peaks were observed during the forget cue presentation (i.e., at 0-2 s). These peaks have been associated with the neural signature of memory inhibition (encoding suppression). Overall, results demonstrate that Directed Forgetting significantly impacts the emotional as well as emotional associative memory, being accompanied by both behavioural and neurophysiological indices of cognitive inhibition. Unravelling memory forgetting mechanisms could provide advancement in the identification of the neurological correlates for forgetting and as such the opportunity to develop clinical interventions for traumatic memories which may support or reduce distressing cognitive events. Additionally, performing cognitive exercises or training based on directed forgetting could be formulated to strengthen an individual's memory control abilities.

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Traditional vs. AI Cognitive Offloading: A Pilot Study of the Effects on Text Comprehension and Retention

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This pilot study investigates the effects of cognitive offloading mechanisms on text comprehension and retention, comparing traditional notetaking, generative AI assistance, and unsupported reading. Cognitive offloading, where mental processes are externalized via tools, may reduce cognitive load but its impact on learning outcomes is unclear, particularly with emerging AI technologies. A 3×2 mixed-factorial experiment involved 28 urban school students aged 14–17, reading a 500- word SAT-equivalent passage. Participants were assigned to three conditions: notetaking; AI- assisted reading (using constrained ChatGPT interactions); or unsupported reading. Comprehension was assessed via immediate and delayed retrieval tests (IRT and DRT, four hours apart) targeting recognition, reconstruction, and reasoning. Results showed notetaking outperformed other conditions in immediate and delayed retrieval, especially in reconstruction tasks, supporting active encoding theories. AI-assisted participants underperformed, even compared to unsupported readers, likely due to extraneous cognitive load from managing AI interactions and reduced text engagement. A "reversal effect" was observed, where AI users showed improved delayed recognition and reconstruction but not reasoning, suggesting distinct memory consolidation pathways. Unsupported readers exhibited high immediate recognition but significant forgetting. Notetaking quality varied, indicating a need for training, while AI use lacked strategic focus, suggesting learning competency is critical. The findings align with cognitive load theory and self-generative elaborative encoding theories, highlighting notetaking's superiority in supporting comprehension, and AI's potential to induce cognitive laziness or outsourcing. The reversal effects in the AI-supported group suggest the need for further exploration—with larger sample sizes—to determine the effect sizes and consistency of this unexpected finding. Reasoning performance was generally poor, possibly indicating a focus on factual memorization, indicating the need to consider individual differences in need for cognition. Limitations include small sample size, short delay periods, and insufficient training. This pilot study supports a larger investigation into trained versus untrained offloading, qualitative analysis of offloading artifacts, and individual differences in tool effectiveness. Educational applications suggest prioritizing active learning strategies like notetaking, with strategic AI training needed to enhance outcomes. Expert feedback is sought

to improve ecological validity, methodological rigor, and the theoretical grounding for the planned larger study.

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Role of familiarity on event transitions and temporal structure of memory

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Introduction

Event segmentation is a cognitive process through which individuals parse ongoing experiences into smaller, meaningful units. Transitions between these units/events also known as event boundaries (e.g., a doorway between two rooms) serve to demarcate one event from the next[1]. These boundaries attract greater cognitive resources, acting as anchor points in experiences, as information presented at boundaries is typically better remembered than elsewhere within events, scaffolding memory. Behaviorally, event boundaries are often identified by asking participants to indicate, via keypresses, when they perceive a meaningful transition while watching a continuous stream such as a movie[2]. Perceptual features such as task changes, categorical shifts[3], background color changes, or film cuts are known to drive segmentation. However, relatively little is known about how knowledge structures, such as familiarity, influence the segmentation process. In the literature, familiarity is operationalized as relatedness of activities to the participant and not to the content itself. Moreover, use of artificial mediums as stimuli hamper how results can be generalized in the domain of episodic memory. We hypothesize that since naturalistic events offer a meaningful context for organizing temporal memory, temporal order accuracy will be greater for item pairs that span event boundaries compared to those occurring within a single event in line with a previous study[4]. This effect should be particularly pronounced under conditions of unfamiliarity, as boundaries are likely to be more salient, leading to higher temporal order accuracy across boundaries in the unfamiliar group relative to the familiar one (**H1**). We predict that subjective time estimates will be influenced by both event segmentation and familiarity. When the objective time interval is held constant, participants should estimate a longer time elapsed for items that span a boundary compared to those that do not. The time distortion effect should be stronger for the unfamiliar group as compared to the familiar counterparts (**H2**).

Method

To investigate the effects of familiarity with event boundaries on the temporal organization of memory, we developed an experimental paradigm using naturalistic, egocentric video stimuli (https://visualize.ego4d-data.org/). Before the experiment, participants were exposed to two 8-

minute-long first-person videos depicting everyday activities, such as performing household chores, with familiarity manipulated by assigning each of 10 participants to one of *three conditions*: viewing the videos either once, twice, or not at all. In the lab, participants (N=30) watched the same videos, segmented into 2-minute clips, with task-irrelevant words superimposed every 6 seconds, remaining on screen for 2 seconds. Participants were instructed to encode both the visual content and the words, and were subsequently tested after each segment. Pairs of words were presented, and participants were asked to judge the temporal order in which they had appeared, followed by an estimate of the subjective temporal distance between them. Critically, the objective temporal distance between the words was experimentally controlled to be either short (~12s) or long (~68s). A source memory task was also included to assess attention to the video content. A separate group of 10 individuals each provided annotation data for the two videos to identify the norm boundaries.

Results

To establish the ground truth for event boundaries, we analyzed group-level coarse boundaries identified by participants for the two videos using the segmentation agreement method. Key-presses were aggregated and smoothed to account for temporal proximity across responses, and local maxima in the density curve were identified as moments of peak agreement. The top N peaks, where N was the average number of boundaries marked by participants, were selected as the consensus boundaries. This procedure yielded 16 coarse boundaries for Video 1 and 12 for Video 2.

To address H1 and H2, we conducted mixed-design ANOVAs with boundary conditions (within-subjects: 0 vs. 1 or 1 vs. 2 boundaries) and familiarity (between-subjects: most familiar, somewhat familiar, unfamiliar) as factors, separately for the short and long interval conditions. The outcome variables were *temporal order accuracy*, measured as the proportion of correctly identified word pairs (P(correct)), and *time elapsed judgments*, measured as the mean ratio of participants' estimates to the actual elapsed time, where ratios > 1 indicate temporal expansion and ratios < 1 indicate temporal compression in memory.

These analyses tested for main effects and interactions between boundary and familiarity. Additionally, to compare overall temporal order performance and time elapsed judgments across boundaries while collapsing familiarity groups, we performed paired t-tests for each question in both interval conditions. Post exclusion criteria, the following analysis was conducted on N = 28 participants (9 most familiar, 9 somewhat familiar, 10 unfamiliar).

For temporal order memory, collapsing across familiarity groups, order accuracy did not differ between 0- and 1-boundary word pairs in the short-interval condition (~12 s; t(27) = –0.44, p = 0.66), but was numerically higher for 2- vs. 1-boundary word pairs in the long-interval condition (~68 s; t(29) = –1.94, p = 0.0626). For time elapsed judgments, participants tended to overestimate short intervals and underestimate long intervals, consistent with prior observations in prospective timing studies. Short-interval judgments were numerically higher for 1- vs. 0-boundary pairs (t(27) = –1.71, p = 0.0979), whereas no increase was observed in the long-interval (2 vs. 1 boundary pairs) condition (t(27) = 0.56, p = 0.5797). While these effects did not reach statistical significance, the trends align with our predictions that intervening event boundaries improve order memory and increase perceived temporal distance. For short-interval temporal order accuracy (~12 s), a 2 (Boundary: 0 vs. 1) × 3 (Familiarity) mixed ANOV A revealed no main effects of familiarity, F(2, 25) = 0.61, p = .55, η^2 = .047, or boundary, F(1, 25) = 0.88, p = .36, η^2 = .034, but a significant interaction, F(2, 25) = 4.62, p = .020, η^2 = .270, with boundaries improving accuracy particularly for unfamiliar participants. In the long-interval condition (~68 s), no main effect of familiarity emerged, F(2, 25) = 0.007, p = .993, η^2 = .001, and neither did an interaction, but the boundary effect approached significance, F(1, 25) = 4.08, p = .054, η^2 = .14. For time elapsed judgments, short-interval trials showed no main effect of familiarity, F(2, 25) = 1.06, p = .361, η^2 = .078, but a trend toward expansion of duration estimates across boundaries was observed, F(1, 25) = 2.99,p = .096, η^2 = .107. The interaction effects were not significant, indicating that the influence of boundaries on time elapsed judgments was not modulated by familiarity. Long-interval trials showed no main effects or interactions in the long interval trials (all p > .13).

Overall, our results provide some support for **H1**. Boundaries enhance temporal order memory for items separated by both short and long intervals. However, the enhancement at short intervals is primarily driven by participants in the unfamiliar group, as we predicted. On the other hand, in the long interval condition, boundaries enhance order memory irrespective of the level of familiarity. As for **H2**, our results suggest that boundaries tend to expand perceived elapsed time estimates but only for short intervals, and this effect does not seem to be dependent on familiarity, offering only partial support for **H2**.

Our results align with prior work showing that in naturalistic settings, strong item-context binding enhances order memory for items that span event boundaries[4]. This pattern contrasts with findings from studies using more artificial paradigms, which often report impaired order memory across boundaries and have informed much of the current understanding of temporal structure in event cognition[6]. Our work also partially aligns with the literature that suggests that boundaries expand the subjective estimation of time[5]. However, the effects were modest and not affected by familiarity. In refining the experimental design, we decided to focus on just two levels of familiarity: familiar and unfamiliar. This decision was informed by limitations in the pilot study, where participants were allowed to view the movies in the exposure phase from the comfort of their homes/hostel rooms. However, this may have led to a weak familiarity manipulation if their self-reports of completion of the movie-watching task are inaccurate. To address these concerns, participants in the main study will complete an in-lab exposure phase to ensure they view the movies. Specifically, we will implement a 2 × 2 mixed design (one within-subjects factor: boundary presence; one between-subjects factor: familiarity group) for each of our hypotheses, with a projected sample size of N = 128. This design allows us to directly test the interaction between event boundaries and familiarity while maintaining sufficient statistical power.

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A Semantically-Grounded Attention-to-Thoughts (A2T) Model with Variable Scope of Attention

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Model with Variable Scope of Attention

1 Introduction

Human thought unfolds as a sequence with successive thoughts sufficiently distinct, but also semantically linked to previous thought, influenced by overall affective tone, contextual demands, contents in working memory, and attentional scope. The A2T model[1] offers a dynamical-systems account of how several lower-level components feed in to give rise to different higher-level thought trajectories and in turn are influenced by them. The model links contextual demands, internal attention, working memory, and affect in feedback loops, but abstracts thought representation to a binary valence (negative/neutral). It also lacks any notion of range of thought transitions, or scope of attention (or next thought selection).

We extend the model using GloVe-derived semantic representations[2] and continuous valence from the NRC-VAD Lexicon v2[3] to have a richer representation of a thought unit, and an attentional breadth parameter that modulates semantic search radius to capture the notion of narrow/broad or focused/diffuse attention in internal selection. This allows us to explore in-silico how attentional scope shapes thought dynamics.

2 Methods

2.1 Original A2T model

At each time step t, the model updates the selection bias $\tau_{i,t}$ for thought i according to:

$$\tau_{i,t} = \frac{\text{Representations in WM}_{i,\,t-1} + \left(\text{Affect}_{t-1} \times \text{Reactivity to Affect}_{i}\right)}{2 + \text{Context}^2_{i,\,t}} \qquad (1)$$

This is a heuristic formula. Here, Representations in $\text{WM}_{i,t-1}$ is the sum of valence-coded working memory (WM) contents at t−1 (neutral = 0, negative = 1), and Reactivity to Affect_i

scales the influence of prior affect. Contextual demands is a positive scalar that captures the influence of task-related demands with the idea that increased contextual demands suppress the selection of negative thoughts. Selection likelihood for negatively-valenced thoughts is then drawn from an ex-Gaussian distribution:

Selection likelihood$_t$ ~ExGaussian μ, σ, τi,t (2)

This likelihood is used in a biased coin-toss to determine which representation enters WM. Alongside this, at each time step, momentary affect is updated as:

Affect$_{i,t}$ = Reactivity to representations in WM$_i$ ×WM representation$_{i,\, t-1}$ (3)

Throughout the simulation, the WM buffer stores five representations. At each step, the oldest item is dropped when capacity is reached.

2.2 Modified A2T model

The modified framework preserves the dynamical nature of the original equations while expanding the representational space to continuous valence scores and embedding-based semantic relations (e.g., GloVe).

WM stores the last n= 5 tokens, each with valence vi ∈R and category {negative, neutral, positive}. Beyond the original A2T parameters, we include focus strength and a baseline decay width (BASE WIDTH) controlling how sharply selection probability decays with semantic distance: high values broaden attention to distant concepts, low values enforce narrow focus. Initial tokens have near-neutral valence (v_i ∈[−0.2,0.2]). Subsequent selections are weighted by

$$w_i = \exp\left(-\frac{\mathrm{rank}_i}{\mathrm{BASE\_WIDTH} + \mathrm{focus\_strength}}\right),$$

normalized to form a semantic distribution psemantic. A negative-only distribution pneg is also computed, with mixing governed by the negative task-relevance parameter μ. For t ≥5, the τt parameter in the ExGaussian bias sampling incorporates continuous valence and reactivity scaling via

$$\tau_t = \frac{\mathrm{WM\_avg}_{t-1} + \mathrm{Affect}_{t-1} \cdot (1 + R_{\mathrm{affect}})}{2 + \mathrm{Context}_t^2}$$

followed by

$$p_{raw} \sim \text{ExGaussian}(\mu,\sigma,\tau t), \text{ valence biast} = \max(0,\tanh(p_{raw}))$$

The final selection distribution is

$$p_{final} = (1-\text{valence bias}_{t})\cdot p_{semantic} + \text{valence bias}_{t}\cdot p_{neg},$$

from which the next token is drawn, inserted into WM, and the oldest dropped. Affect is updated as

$$\text{Affect}_{t} = (1 + R_{WM})\cdot WM_{avg,t.}$$

3 Results

3.1 Replication of original trends

Following the original A2T article, we ran 300-step simulations updating Internal Attention, WM content, and Affect each step. Results show trends under varying contextual demand, valence composition, and reactivity. Our simulations replicated these patterns using identical parameters and conditions. Findings are consistent with the original findings: in the high-context condition, selection bias and negative affect remain low with only brief, random intrusions of negative content, while in the low-context condition, working memory and affect are more influenced by noise, resulting in greater variability and more frequent negative selections.

3.2 Observation of new trends

We examined valence trajectories under two attentional conditions: broad (focus strength = 100) and narrow (focus strength = 1). Averaging the mean-simulation-affect over 100 independent runs revealed that broad attention tended to maintain a near neutral emotional state, while narrow attention shifted toward more negative affect. Across simulations, the average number of negative-thought runs was generally higher in the broad condition; however, the average total length of negative runs showed a clearer effect, being consistently higher for narrow than for broad focus.

4 Discussion

The modified A2T model preserves the original mechanisms while adding semantic grounding and adjustable attentional scope. The simulation results show that narrow scope confines thought sequences to semantically and affectively restricted regions, often prolonging negative valence runs - mirroring rumination patterns. The broader scope promotes semantic exploration and shifts toward neutral or positive content, consistent with findings that positive affect broadens attention and improves flexibility. In the context of mind-wandering, this distinction maps onto evidence linking broad scope to creative problem solving and narrow scope to self-focused, negative content.

A key limitation is the static focus strength used in each simulation, which fixes the balance between related and unrelated word selection. Future versions could dynamically link focus strength to affect, extending when recent WM valence is high and reducing when low, reflecting empirical affect-attention links[4]. Other constraints include reliance on a fixed lexicon with pre-computed embeddings, absence of sensory or external inputs, fixed and unchanging contextual demands, and a still simplistic representation of a thought unit.

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Implicitness of the Contextual Cueing Effect Differentially Affected by Feature-type

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Introduction

Contextual cueing effect has been demonstrated in terms of enhanced search efficiency for a target when presented among distractors; however, under conditions of regularity in the interspatial arrangement of the target and distractors. Since the invariant spatial relationship of the search items (termed as 'context') remains unbeknownst to the participants, contextual cueing effect is considered to be implicit, rapid, automatic, and effortless (Theeuwes, 2018), implying the effect to be perceptual (pre-attentive) in nature. The present study looks at the robustness of the contextual cueing effect when pitted against violations at the featural level.

Method

The present study consisted of 65 participants (32 and 33 adults in experiments 1 and 2, respectively), who completed a standard letter identification task with a set size of 10. The search items consisted of the following letters: 'H', 'M', 'N', 'P', 'Z', 'L', 'K', 'S', 'X', with 'E' or 'F' as the target. The search items appeared on six imaginary concentric circles, each divided equally to have 8 locations.

Experiment 1

Half of the items appeared in red and the other half in green colour (RGB [255,0,0] and [0,255,0], respectively). The experimental protocol consisted of a Training phase and a Testing phase. In the Training phase, participants were presented with ten fixed search configurations, unbeknownst to the participants, and in random order. Each configuration was presented thirty times; thus, the training phase consisted of a total of 300 trials. The Testing phase tested the strength of the learnt fixed configuration in 150 trials equally divided into the following experimental conditions; 1) 'No color'- no item appearing in any color but in white, 2) 'Color Violated'- half of the items appearing in red and green color randomly, 3) 'Perceptually grouped'- search items in upper half and lower half presented in red and green, respectively, 4) 'Old'- the same old colored configuration as in the training phase, 5) 'New'- search array with a new spatial and color configuration. The time taken to respond to the target was recorded in both the Training and the Testing phases.

Experiment 2

Experiment 2 was similar to experiment 1 in its procedure and trial structure, except that the context was defined in terms of a size feature. The training phase, therefore, had half of the search items appearing in the font size 20 (0.4 cm × 0.3 cm; 0.38° × 0.28° visual angle) and the other half in font size 50 (1.0 cm × 0.7 cm; 0.95° × 0.66° visual angle), in 10 fixed spatial configurations. The Testing phase had the following conditions: 1) 'Same size'- all items in the same size (font size: 35; 0.6 cm × 0.5 cm; 0.57° × 0.47° visual angle), 2) 'Size violated'- half of the items appearing in size 20 and other half in size 50, randomly, 3) 'Perceptually grouped'- search items in upper half and lower half presented in size 20 and size 50, respectively, 4) 'Old'- the same old configuration as in the training phase, 5) 'New'- search array appearing in totally random locations.

Results

Experiment 1

Learning Phase:

A one-way Repeated Measures (RM) ANOVA performed on the mean reaction time (RT) across the training session (grouped into 6 bins, consisting 50 trials) revealed significant main effect of the bins, F(3.97,122.98)=28.68, P<.001, ηp2=.48, suggesting implicit learning of the fixed configurations.

Testing Phase:

A one-way RM ANOVA performed on the mean reaction time (RT) obtained for the types of configurations [Old, No color, Color Violated, Perceptually grouped, New] revealed a significant main effect, F(4,124)=39.96, P=.001, ηp2=.56. Despite retaining the learnt spatial configuration, a significant RT cost for 'No color', 'Color Violated', and 'Perceptually-grouped' conditions relative to the 'Old' condition [t(31)=-5.41,p<.001; t(31)=-5.81,p<.001, & t(31)=-2.73,p<.001, respectively], imply disruptive effects of colour feature on the extraction of regularities of search items.

Experiment 2

Learning Phase:

A one-way Repeated Measures (RM) ANOVA performed on the mean reaction time (RT) from each bin across the training session revealed a significant main effect of the bins,

F(2.89,92.46)=44.79, P<.001, ηp2=.58, implying implicit learning of the fixed configurations.
Testing Phase:

A one-way RM ANOVA performed on the mean reaction time (RT) obtained for the types of configurations [Old, Same size, Size-violated, Perceptually-grouped, & New] revealed a significant main effect, F(2.92, 93.47)=33.83, P<.001, ηp2= .51.

As in experiment 1, despite retaining the learnt spatial configuration, a significant RT cost for 'Size violated' and 'Perceptually grouped' conditions relative to the 'Old' condition [t(32)=-3.75,p<.01, & t(32)=-4.11,p<.001, respectively], imply disruptive effects of size feature on extracting regularities in the inter-spacing of search items. Additionally, a one-way ANOVA on six bins of the Training phase, with experiment as a between-subject factor, revealed a significant effect of all the Bins: Bin 1[F(1,63)=43.54,p<.001]; Bin 2 [F(1,63)=43.54,p<.001]; Bin 3 [F(1,63)=43.54,p<.001]; Bin 4 [F(1,63)=43.54,p<.001]; Bin 5 [F(1,63)=43.54,p<.001]; Bin 6 [F(1,63)=43.54,p<.001], implying feature-specific differences in the implicit learning in all the bins despite the regularity in the spatial arrangement of items. The overall mean RT across the bins for the color-embedded context was found to be lesser than the size-embedded context (1027ms vs. 1321ms).

Discussion

Extraction of regularities does not seem to be a generic phenomenon as suggested previously (Saffran et al., 1996). Feature-level violations (color and size in this instance) seem to override the advantages offered by the implicitly learnt regularity. The relatively faster learning of color-embedded context relative to the size-embedded context implicates higher contributions from the ventral pathway than the dorsal pathway. Contextual cueing effects, though implicit and perceptual in nature, seem to be differentially sensitive to feature types.

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Error Desensitization as the cause for Attenuation in visuomotor adaptation upon relearning

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Introduction

The continuous recalibration of internal representations of action-effect relationships to account for changes in the body and environment is essential for the precise control of our actions[1]. Laboratory studies involving perturbations to reaching movements suggest that such recalibration is driven at least by two learning mechanisms: deliberative, volitional strategies, and implicit adaptation, reflecting automatic updates to prior internal representations[2]. A hallmark of adaptation is "savings", or faster relearning upon re-exposure to a previously experienced perturbation[3]. However, recent work isolating just the implicit component has intriguingly demonstrated that not only is savings absent, but adaptation is actually *attenuated* during relearning[4]. Avraham et al. (2025) attributed this attenuation to memory interference resulting from the same or similar actions becoming associated with discrepant forms of visual feedback[5]. If this hypothesis is true, then: 1) attenuation should be evident regardless of how this discrepancy is created, and 2) eliminating discrepant action- effect contingencies should eliminate attenuation during relearning. We tested these ideas in a series of visuomotor adaptation experiments.

Method

80 healthy, right-handed individuals were recruited across four experiments (20 in each) in this study. In all experiments, participants performed point-to-point reaching movements with the help of a stylus from a single start position to a target appearing at 45°,135°, 225° or 315° angles. Feedback about hand motion was provided by means of a cursor displayed on a computer screen. Participants were instructed to quickly move their hand to the target and slice through it. Cursor feedback could be matched to hand motion, rotated, or eliminated altogether. Cursor rotations were used to induce learning; on these trials, the cursor was rotated by a fixed or "clamped" 30° angle relative to the target direction, regardless of the direction of the underlying hand motion. Subjects were instructed to ignore the cursor and move their hand towards the target, slicing through it. This procedure is known to induce implicit learning in

isolation[6]. The direction of the error clamp (clockwise or counterclockwise) was counterbalanced across participants.

In experiment 1, subjects first performed 10 cycles of “baseline” movements (5 no-feedback, 5 feedback) and then adapted to the clamped rotation over 60 cycles. This was followed by a “washout” block of 60 cycles during which only endpoint feedback about the movement was provided, and that too after a delay of 2 seconds from the end of the trial. This washout block was followed by a second learning block of 60 cycles, followed by a 10-cycle no-feedback washout block to measure aftereffects. Experiment 2 was similar, except that the first post-learning washout phase comprised of a long 140-cycle block of no-feedback trials. This was followed by re-learning and no-feedback washout blocks like experiment 1. In experiments 3 and 4, subjects performed a long, 140-cycle baseline block before their first learning block, the difference being the availability of cursor feedback on baseline trials (no feedback in experiment 3, veridical feedback in experiment 4). Learning trials remained identical to other experiments, and the 10-cycle no-feedback washout block followed the learning block. In these two experiments, there was no re-learning block. These settings allowed us to vary action-effect contingencies and probe their influence on learning and/or relearning.

Results

Adaptation was measured by the change in reach angle, calculated as the angle between the hand’s movement direction at peak velocity and the direction to the target from the start. Our interest was twofold: first, to probe for attenuation of adaptation (reduction in learning) during re-learning in experiments 1 and 2, and second, to assess whether initial learning itself would be lower in experiments 3 and 4. In Experiment 1, we observed significant attenuation during re-learning. This was evident as smaller changes in hand angle at asymptote as well as smaller aftereffects compared to initial learning. Notably, significant attenuation was also evident during re-learning in experiment 2, again evident as a reduced change in hand angle during late learning and smaller after-effects compared to levels seen initially. Furthermore, we found that learning was not attenuated in experiments 3 and 4, with the change in hand angle reaching levels similar to those seen during naive learning in both experiments 1 and 2.

Discussion

In experiment 1, endpoint cursor feedback (presented after a delay) during washout induced errors opposite in sign to those experienced during learning. The observed attenuation could therefore be attributed to interference between the learning and washout error memories, consistent with Avraham et al. (2025). However, experiment 2 eliminated all feedback during washout, thereby removing discrepant action-effect contingencies and thus the possibility of interference. Nevertheless, robust attenuation occurred during re-learning, contradicting the notion that interference is essential for attenuation. This finding, alongside that of experiment 1, suggests attenuation may be better explained by a different mechanism: desensitization to previously experienced errors. The results of experiments 3 and 4 provide further support to this hypothesis: since no errors preceded initial learning, there was no prior experience of errors that would cause desensitization, and consequently, no attenuation. Collectively, our results contradict the idea that implicit learning attenuation stems from interference and instead indicate that attenuation arises from desensitization to the original error. Mechanistically, such desensitization could result from saturation in recently activated synapses.

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Patients with epilepsy have increased spontaneous mind wandering and poorer response inhibition during mind-wandering

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Introduction

Response inhibition is the crucial ability to quickly stop a response that is no longer appropriate, for example, stop oneself from reaching to a cup if an insect is spotted. Deficiencies of this ability is seen in various clinical populations such as those with epilepsy, Tourette's, etc. To develop better managements for these populations, we must better understand their ability to perform response inhibitions as every action needs quick situational reactiveness in the external world. In the lab, response inhibition is often measured using the **stop signal task**. In this task, participants make a response in every trial but try to stop their response when an infrequent stop signal is presented. This allows researchers to estimate the time taken to stop a response, called **stop signal reaction time (SSRT)**[1]. While most stop signal task studies assume that participants perform the task with focused attention, this is far from reality. Oftentimes during task performance, our focus shifts from the external task to internal task-unrelated thoughts (called **mind-wandering**). A recent study demonstrated that during periods of mind-wandering, i.e. state-level mind-wandering, response inhibition becomes slower1. Interestingly, other studies have demonstrated that several clinical populations, who also have poorer response inhibition, have increased mind wandering. Specifically, it has been observed that clinical populations have increased unintentional or **spontaneous mind-wandering**, where mind-wandering occurs without intentional control[2] (as opposed to intentional or **deliberate mind-wandering**). Taken together, this suggests a link between increased mind-wandering and poorer response inhibition which has not been explored in **patients with epilepsy** (**PWE**). Additionally, no study has tried to characterize the **trait-level** incidence of mind-wandering in PWE. In this context, the current study attempts to: 1) Test the impact of state-level mind-wandering on response inhibition in PWE, 2) Characterize the trait-level mind-wandering in PWE using existing questionnaires.

Method

The study was approved by the Institute Ethics Committee of AIIMS Delhi where the data collection was performed. 103 participants (Healthy Controls (HC)=37, females=11, right-handed=37, age=20.0±0.8yr; PWE=66, females=25, right-handed=59, age=20.0±0.6yr) performed 400 trials of the stop signal task (100 stop trials) with intermittent mind wandering probes that appeared every 40-55s (20 probes in total). (This probe rate is consistent with the standard frequency of approximately one probe per minute used in mind wandering research5 and falls within the validated range of 30 seconds to 3 minutes that balances adequate sampling with minimal response bias6). (Stop-signal delays were tracked separately for left and right directions and adjusted by ±50 ms following failed and successful stops respectively to maintain ~50% stopping accuracy.) The probe required the self-report of whether in the previous trial, participants' focus was on the task (on-task), was wandering (mind-wandering), or blank (mind-blanking – since few mind-blanking episodes were reported, they have not been considered here). If participants reported mind-wandering, then they were additionally asked whether their mind-wandering was deliberate or spontaneous (since reported state-level deliberate and spontaneous mind-wandering were too few for meaningful analysis, they have not been considered here). At the end of the study, they also filled in their responses to three questionnaires to assess trait-level mind-wandering: 5-item Mind Wandering Questionnaire4-item Mind-wandering-Deliberate, and 4-item Mind- wandering-Spontaneous questionnaires. Response inhibition analysis was performed on 62 participants who satisfied standard behavioural performance criteria such as at least 80% correct responses in go trials, etc. (HC=28, age=20.0±1.0yr; PWE=37, age=20.0±0.6yr). (Similar behavioral criteria were employed by Jana and Aron (2022). However, considering that our participants included patients and those with limited familiarity with computer-based tasks, the criteria were relaxed slightly, remaining consistent with the minimum requirements outlined by Verbruggen et al. (2019). To compare between mind-wandering and on-task performance, we epoched the data of 6 trials prior to the probe based on the probe response and then concatenate all epochs of the same type (mind-wandering or on-task) for analysis.

Results

State-level analysis

Overall, in participants with good behavioural performance, SSRT was significantly greater in PWE (417.8±8.4) compared to HC (395.4±6.2ms; $t(63)=2.0$, $p=0.046$, $d=0.5$). However, there was no significant difference in the state-level incidence of any mental state between HC (On-task=81.4±3.3%; mind- wandering=13.8±2.9%; intentional mind wandering = 5.4±2.6%; unintentional mind- Wandering =8.4±1.5%) and PWE (On-task=83.1±2.7%; mind-wandering=14.1±2.5%; intentional mind-wandering=5.1±1.8%; unintentional mind-wandering=9.0±1.8%). We then compared the performance between on-task and mind-wandering episodes (participants with >=4 episodes of mind wandering were included; HC=7; PWE=9) using a 2-way ANOVA with dependent variable SSRT and factors mental-state (on-task, mind-wandering) and group (HC, PWE). It revealed a significant main effect of mental-state ($F(1,76)=27.6$, $p<0.001$, $\eta 2=0.26$) but no significant effect of group ($F(1,76)=3.2$, $p=0.077$, $\eta 2=0.03$) and no significant interaction effect ($F(1,76)=0.1$, $p=0.723$, $\eta 2<0.001$). Post-*hoc* tests revealed that SSRT was greater during mind-wandering compared to on-task in both HC (on-task=400.9±12.2ms, mind-wandering=487.0±16.7ms, t(33)=3.3, ptukey=0.009) and PWE (on-task=426.1±10.8ms, mind-wandering=524.8±24.2ms t(43)=4.2, ptukey<0.001). Taken together and consistent with previous literature, this shows that response inhibition becomes poorer during mind- wandering. (Since SSRT during mind-wandering (MW) could not be calculated for all participants due to a paucity of data, a paired comparison was not feasible. Therefore, a standard two-way ANOVA was employed for the analysis.)

Trait-level analysis

Across all participants, the trait-level mind-wandering as assessed by the Mind Wandering Questionnaire was positively correlated with the percentage of mind-wandering reports during the task, i.e., state-level mind wandering ($\rho=0.26$, $p=0.008$). This suggests that the self-reports are consistent. (However, this could also indicate a potential carryover of the state-levelreporting on the MWQ reports.) As assessed by the Mind Wandering Questionnaire, there was no significant difference in the trait-level mind-wandering between PWE and HC ($t(99)=0.5$, $p=0.638$, $d=0.1$). As assessed by the Mind-wandering-Deliberate questionnaire, there was no significant difference in the trait-level deliberate mind-wandering between PWE and HC ($t(101)=0.8$, $p=0.414$, $d=0.2$). However, as assessed by the Mind-wandering-Spontaneous questionnaire, there was significantly increased spontaneous mind-wandering in PWE compared to HC ($t(101)=2.5$, $p=0.014$, $d=0.5$).

Discussion

This study is the first to test trait-level and state-level mind wandering in PWE and test its impact on task performance. We observed that consistent with previous literature, SSRT was poorer in PWE compared to HC, and that mind-wandering made response inhibition slower in both HC and PWE. Further, consistent with previous studies in other clinical populations, we observed that specifically trait-level spontaneous mind-wandering increases in PWE compared to HC. This suggests that targeting a reduction in mind-wandering could be a valuable treatment strategy to improve cognitive functions in PWE.

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Error Size Determines the Engagement of Distinct Learning Strategies in Task-Error-Driven Motor Learning

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Introduction

How humans adapt their movements to changing environments is a central question in motor learning research. Recent work in this area has focused on mechanisms that drive learning in response to task performance errors. Such errors are defined as a failure to achieve the task goal, for example, a failure to strike a reach target. This work suggests that reinforcement learning processes, namely model-free (computationally inexpensive, cached learning) and model-based (computationally costly, planning-driven learning) reinforcement mechanisms, contribute to such learning. Based on past work (Sadaphal et al., 2022), we hypothesized that the engagement of these distinct mechanisms is dependent on the size of the task performance error. We expected that learning from smaller errors would rely on a model-free process, while larger errors would recruit model-based learning. We predicted that the recruitment of these systems would be expressed via distinct behavioural signatures.

Methods

We employed a centre-out reaching task, wherein subjects reached from a single start position to 4 targets located at 45°, 135°, 225°, or 315°. They first performed a block of 56 baseline trials, followed by four blocks of 28 "target jump" trials each; target jumps were used to induce task performance errors. Interspersed between each of the first three target-jump blocks were 8 "no-jump" trials (four with visual feedback of the hand, four without). The fourth target-jump block was followed by a final washout phase comprising 16 no-feedback and 32 veridical feedback trials. A total of 60 healthy, right-handed subjects were recruited and randomly assigned to one of six experimental groups (N = 10 per group), corresponding to the target jump magnitudes (7.5°, 10°, 15°, 30°, 60°, or 90°). Statistical analyses were conducted on reaction times, movement kinematics, and after-effects in no-jump and washout trials. Movement onset was defined as the time when hand velocity first exceeded 5% of the maximum velocity for that trial. Reaction Time (RT) was calculated as the time interval between the appearance of the target and movement onset. Hand Deviation (used to quantify learning and after-effects) was calculated as the angle between the line joining the start circle to the original target and the line joining the start circle to the hand position at peak velocity.

Results

Our results revealed a dissociation in the adaptation strategies used based on the jump magnitude**.** For smaller target jumps, with jump size less than 15°**,** corrections exhibited features typical of model-free learning. Behavioural analyses showed a persistence of the learned behaviour (after-effects of 2-3°) on no-jump and no feedback washout trials despite the instruction that the target would not jump and subjects should move to the original target location. One-tailed t-tests confirmed that these errors were significantly different from 0°. Further, reaction times for this group were not different from baseline. These corrections thus appeared to be cached responses, indicative of a reinforcement process not reliant on an internal simulation of outcomes.

In contrast, adaptive responses to larger target jumps (60°, and 90°) reflected model-based learning. Subjects in these groups showed increased reaction times during jump trials compared to baseline, suggesting an increased time requirement for selection of an appropriate motor plan. Additionally, strong flexibility and quick disengagement were observed, as demonstrated by the absence of significant after-effects in catch and no feedback washout trials (errors were not significantly different from 0°).

Notably, jumps of intermediate size (30° specifically) elicited mixed responses, suggesting an intermediate phase of arbitration between the two learning systems. After-effects were present, but smaller than those for the smaller jump groups, and were only marginally significant for the first no-feedback catch trial and no-feedback washout trials. Reaction times were also in an intermediate phase, being slightly different from baseline but not as large as those for the larger target jump groups.

Discussion

Our findings suggest that the motor system employs distinct reinforcement learning strategies - model-free versus model-based -depending on the magnitude of the task performance error. Smaller target jumps appear to engage model-free reinforcement learning, leading to cached responses that are harder to disengage. Conversely, larger target jumps activated a model-based system, characterized by increased reaction times and greater behavioural flexibility. These behaviours align with theories (e.g., Doll et al., 2012) positing that model-based behaviour involves simulating potential outcomes before choosing an action, a process that requires more time. The intermediate behaviour observed for 30° jumps supports the idea of a threshold effect, where the brain arbitrates between learning systems based on perceived task demands or expected utility. The deployment of a more effortful model-based strategy appears to occur only when the simpler, cached, model-free policy is deemed insufficient. These results highlight a critical link between error size and the engagement of distinct learning systems, providing insights into how the motor system balances efficiency and flexibility in the face of changing task demands.

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The Role of Design Aesthetic, Design Source, and Product Category in Shaping Consumer Preferences and Brand Loyalty

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Visual design is a critical determinant of consumer decision-making, shaping perceptions of product quality, brand trust, and purchase intentions. Prior research suggests that minimalist aesthetics often convey modernity, sophistication, and quality, whereas maximalist designs may evoke richness, warmth, and sensory appeal, effects that vary across product categories. In parallel, the rise of artificial intelligence (AI) in creative industries has introduced new authorship cues into consumer evaluations. Source Credibility Theory posits that consumers' trust in a product can be influenced by the perceived origin of its design, with some segments valuing human artistry while others embrace AI innovation. However, the interplay between design style (minimalist vs. maximalist), design source (AI-generated vs. human-generated), and product category (food, skincare, makeup, clothing brand) remains underexplored, particularly when controlling for product attributes. Existing studies largely focus on single categories or omit source attribution. This research addresses these gaps by presenting products from the same brand to control for brand-related perceptions with systematically varied design styles and authorship labels, enabling direct comparisons of aesthetic and origin effects across multiple categories. The study also draws on Categorization and Schema Theory, suggesting that consumers' expectations for design style differ by category (e.g., minimalist skincare implying purity; maximalist food packaging implying indulgence), and Signaling Theory, where design cues act as indicators of quality, authenticity, and innovation. By integrating individual difference measures such as openness to experience and digital literacy, the research further examines moderating effects on these preferences.

This study employed a fully crossed within-subjects factorial design with three independent variables: design style (minimalist and maximalist), design source (AI-generated, human-generated), and product category (food, skincare, makeup, clothing). Each factor was orthogonally combined, yielding 16 unique conditions. Within each category, five fictitious brands were created to ensure generalizability while maintaining experimental control, resulting in 80 distinct stimuli (16 conditions × 5 brands). Stimuli were identical in product type, shape, and text, differing only in aesthetic style and declared source, with discreet "AI-generated" or "Human-designed" labels for attribution. Participants completed the BFI-10 and a digital literacy scale before the task. The task involved presenting 80 stimuli in random order, with breaks every 20 trials. For each, participants rated Attractiveness, Purchase Intention, Brand Trust, and Perceived Quality on 7-point Likert scales. Data were analyzed using linear mixed-effects models (LMMs) with random intercepts for participants and stimuli. Fixed effects include style, source, category, and their interactions. The moderating effects of openness and digital literacy were tested through interaction terms. Post-hoc comparisons will be Bonferroni-corrected.

Participants were recruited via online panels and university pools, with eligibility requiring normal/corrected vision and English proficiency. After consent, they completed the BFI-10 and a digital literacy scale. In the task, 80 stimuli were shown in random order with breaks every 20 trials. We differentiated maximalist and minimalist designs by looking at their visual style and content features. Minimalist designs usually stick to just a few colors, often two or three, and focus on simplicity with only the brand logo, name, and essential information. On the other hand, maximalist designs tend to be more vibrant and detailed, using bold colors, images, taglines, creative fonts, and other visual elements to make the overall layout more expressive and engaging. The AI-generated images used in this study were created using open-source AI platforms, including ChatGPT, Perplexity, Gemini, and Grok.

The main effects of design style show that the minimalist designs were significantly preferred in categories where simplicity conveys purity or sophistication, specifically in skincare and clothing. Conversely, maximalist designs were rated higher in categories where visual richness suggests indulgence or variety, such as food and makeup ($p < .05$). In case of main effects of design source across all categories, human-generated designs scored higher on brand trust and perceived authenticity ($p < .01$). In contrast, the AI-generated designs were rated significantly higher on perceived innovation ($p < .05$) but lower on trust measures. Digital literacy influenced perceptions, with high-literacy participants favoring AI designs more. Minimalist AI designs felt sterile, while maximalist AI designs appeared novel and engaging. Minimalist human designs strongly matched traditional quality cues, especially for premium products. In case of category-specific patterns, the strongest style × source × category interaction emerged in skincare (minimalist–human designs received the highest trust and purchase intention) and food (maximalist–human designs had the highest purchase intention). For makeup, maximalist AI designs were preferred, while clothing showed balanced preferences shaped by fashion trend awareness. High openness and digital literacy reduced bias toward AI, whereas lower digital literacy favored human designs regardless of style.

This study finds that consumer responses to product design depend on aesthetic style, authorship, and product category. Minimalist designs worked best for cleanliness and premium associated goods (e.g., skincare, clothing), while maximalist designs thrived in sensory-rich categories (e.g., food, makeup). Human-created designs conveyed authenticity and craftsmanship, whereas AI-generated designs signaled innovation, especially to digitally literate consumers. Extending Schema and Signaling Theories, results show that style and source cues together shape trust and purchase intent, even without price or product details. From a practical standpoint, the results suggest clear strategic directions that skincare brands should emphasize minimalist, human-created packaging to strengthen trust and loyalty. Snack and food brands can leverage maximalist, human-authored designs to evoke indulgence and variety. For digitally progressive audiences, AI-generated maximalist designs could be positioned as innovative and disruptive in categories like makeup or fast-fashion clothing. Limitations of the study include the explicit labeling of designs as AI- or human-generated, which may have artificially heightened source awareness, and the lack of multisensory cues such as texture or scent. Future research could examine implicit cues to design origin, cross-cultural differences in style preferences, and hybrid AI–human creative collaborations.

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Separating out Distractor Suppression from Attentional Guidance using Predictability of Feature and Location

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Introduction

Attentional selection involves not only prioritising the visual information that is relevant to selection, but also ignoring distractors that are not relevant to the task at hand. Along with the top-down and bottom-up sources of attentional bias, Theeuwes (2025) suggested that selection history itself biases attentional prioritization. He proposed the concept of selection history, which suggests that an irrelevant distractor that is more likely to appear in a specific location as compared to other locations is suppressed. Distractor suppression is characterised as a decrease in the magnitude of attention capture by an additional feature singleton when it is presented consistently at a location (Wang & Theeuwes, 2018). By presenting a distractor at a location consistently, the uncertainty about the target location gets reduced. Failing et al. (2019) analysed whether statistical regularities in feature also modulate spatial specific suppression. Here, they observed that suppression was significantly higher in cases where a feature singleton was presented in its associated high probability location than in the high probability location of another feature singleton. This suggests that location is more critical to distractor suppression as compared to feature or other properties of the visual stimuli. However, we propose that task demands play a role in the prioritisation of location over feature in visual search, as, in classical visual search tasks, while the feature of the target is known, the location of the target is often unknown. Thus, a high probability distractor location may reduce the degree of uncertainty with respect to the target location and help prioritise specific locations over others. In the present study, we investigate how the probability associated with a feature and a location, separately, guides the search process, as previous studies have examined the influence of statistical regularities of a feature in distractor suppression in conjunction with location, rather than independently.

Methods

We performed three experiments by using a modified version of the additional singleton paradigm (Theeuwes, 1992). In the original additional singleton paradigm proposed by Theeuwes (1992), the search target was usually a shape singleton, and the participants were explicitly instructed to look for the shape singleton and report the orientation of the line within. The effect of an additional distractor singleton on target selection and search reaction times was measured. In contrast to the original paradigm, the target in the present study is a line oriented to the left or right, and hence participants do not have to deliberately search for a singleton. Instead, they are required to look for the target line within the shapes presented in the search display. The search display consisted of two singletons and a variable set (4 and 10) of homogeneous distractors, resulting in a search display of set size six and twelve. In the first experiment, both the color and the shape singletons could contain the target, but with differing likelihoods (70% and 30%), such that the target could appear in one of the singletons with a higher likelihood, while it would appear in the other singleton with a lower likelihood. In the second experiment, two locations were chosen to contain the target, one location had a higher probability of containing the target than the other. Thus, we were able to separately investigate the role of feature and location in attentional guidance. The results from the two experiments were compared with those of another control experiment, in which the target could appear in any location or feature without any probability bias, but could appear in every location and in every feature roughly equally. The number of stimuli in the search display varied between six and twelve. We recruited twenty participants for each experiment, including the control experiment, who were between the ages of 18 to 30. In all the experiments, the participants were not explicitly informed about the probability manipulation. Each experiment lasted 25 minutes and consisted of 498 trials in total.

Results

We observed a significant main effect of target feature probability in the first experiment, with no significant main effect of set size. The interaction between target feature probability and set size was not significant. As a result, we observed significantly decreased reaction times and flat search slopes whenever the target appeared in the high likelihood feature singleton compared to the less likely feature singleton. We obtained similar findings in the second experiment with a significant main effect of target location probability, with no main effect of set size and an absence of interaction between set size and target location probability. The search slopes were again flat, and the reaction times were significantly less whenever the target line appeared in the highly likely target location. However, the control experiment resulted in steep slopes indicating difficult, serial search. Additionally, the differences in reaction times when the target line was in either the more likely or less likely feature or location were comparable and faster than the control experiment. This difference indicated that the predictability of the target coming in either the feature or the location had facilitated visual search.

Discussion

We were able to separately investigate the role of target feature and target location in attentional guidance. By manipulating the likelihood of the target appearing in a particular feature or location, the uncertainty of the target feature or location may be reduced. A reduction in uncertainty about the target location or target feature thus facilitates efficient target selection. While we cannot establish the suppression of the feature or location containing the target with lower likelihood, we propose that the manipulation of the likelihood of the feature or location does guide target selection. Moreover, these experiments suggest that the measures of distractor suppression and attention capture are often confounded in the literature.

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Investigating Subtype-Specific Neuroplastic Changes through White Matter tractography in Parkinson's Disease

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Introduction: Parkinson's disease (PD) involves heterogeneous motor deficits linked to disruptions in distinct neural circuits. White matter plasticity, reflected in microstructural changes such as myelination and fiber coherence, can be examined using Diffusion Tensor Imaging (DTI) with measures like Fractional Anisotropy (FA). Rhythmic Auditory Stimulation (RAS) has been shown to induce compensatory plasticity in PD, particularly within the basal ganglia-thalamocortical (BGTC) network (more preserved in rigidity-dominant [RD] patients) and the cerebello-thalamo-cortical (CTC) network (more preserved in tremor-dominant [TD] patients) (Lesiuk et al., 2018). However, most existing studies emphasize network-level reorganization rather than tract-specific plasticity, which is essential for developing subtype-specific, evidence-based Neurologic Music Therapy (NMT). In this ongoing study, we investigated plastic changes in the internal capsule (IC) and cerebellar projections due to their relevance to BGTC and CTC networks, and further examined corpus callosum (CC) differences between TD and RD patients, given its established role in temporal processing—a core element of NMT. This study will provide insight into the subtype-specific neuroplasticity which may be associated with cognitive mechanisms such as auditory temporal processing.

Methods

17 patients with idiopathic PD were assessed using the Unified Parkinson's Disease Rating Scale (UPDRS) and classified into TD (n=11) or RD (n=6) subtypes. Diffusion-weighted MRI (DTI) data were then acquired. The data were pre-processed in FSL following a standard pipeline that takes care of movement related as well as susceptibility and eddy current-related artifacts. FA images were nonlinearly registered to the FMRIB58_FA template and processed using tract-based spatial statistics to examine tract-specific FA differences between subgroups, focused on predefined white-matter tracts.

Results

Comparison of FA values in the IC revealed a significant group difference in the left hemisphere. RD patients exhibited higher FA in the left IC (M = 0.6118) compared to TD patients (M = 0.5793), with the difference reaching statistical significance (p=0.02). No significant differences were observed in the right IC. Significant differences in FA were observed across the subregions of the CC between RD and TD patients. RD patients showed higher FA values in the genu (M = 0.6118 vs. 0.5306, p=0.0005), body (M = 0.7285 vs. 0.6700, p=0.0020), and splenium (M = 0.3354 vs. 0.2089, p=0.0022) compared to TD patients. T-test did not indicate any significant differences in the bilateral cerebellar projections between the two groups. Hence, Principal Component Analysis (PCA) was conducted separately for RD and TD patients using FA values from bilateral superior and inferior cerebellar peduncles (CPs). For the RD group, the first principal component (PC1) was entirely driven by the left superior CP, with a strong negative loading (-1), indicating it was the sole contributor to the variance observed. In contrast, for the TD group, PC1 was characterized by positive loadings from all four CP projections, suggesting a more distributed pattern of microstructural variance across cerebellar tracts.

Discussion

Results show higher FA in the left IC among RD patients which may indicate pathological reorganization of motor pathways related to rigidity and bradykinesia. This finding aligns with the idea that RD may involve more localized or structurally-confined disruptions in motor tracts (Lewis et al., 2011). The group-wise PCA revealed that for TD patients, the cerebellar organisation shows greater cohesion across the bilateral superior and inferior CPs. This cohesion across cerebellar projections is absent in case of RD patients, which suggests reduced CTC connectivity on the left side in RD, possibly contributing to motor rigidity due to impaired motor modulation. Both superior and inferior CPs load positively in TD suggesting coordinated contribution from both bilaterally in defining TD subtype. These tracts support oscillatory loops involved in tremor generation (dentato-rubro-thalamic circuits) and involvement of a broader cerebellar network, supporting tremor generation/modulation (Zhong et al., 2023). Higher FA in the CC in RD suggests more structurally intact or overactive interhemispheric connectivity, which may support bilateral or complex coordinated movements. More specifically, we find higher FA in the body of CC with implications for interhemispheric motor integration; in the genu of CC, reflecting cognitive/emotional compensatory mechanisms more prevalent in RD patients. In contrast, TD is associated with localized, network-based dysfunction, rather than structural anomalies, which is reflected in the cerebellar organisation through PCA. While the TD group included only six patients compared to eleven in the RD group, the PCA results are unlikely to reflect spurious correlations. The unilateral contribution of the left superior CP in RD versus distributed contributions across all CPs in TD suggest biologically meaningful variance structures rather than statistical artifacts. Findings of the current study have translational implications. For instance, NMT protocols such as RAS can be designed to engage both hemispheres simultaneously (Nombela et al., 2013), leveraging this structural advantage in RD patients. Interventions like Musical Attention Control Training (MACT) (Thaut, 2005) or Music-based dual-task training could be more effective in RD patients by utilizing their relative prefrontal tract integrity as observed in terms of higher FA in the anterior CC (Genu). TD patients may benefit from Musical Mnemonics for Sequencing (MST) and Musical Dual-Task (Gao et al., 2017) training as they help in motor learning and sequencing associated with cerebellar projections. We find that RD patients show disruptions in motor tracts (IC), whereas TD patients show reserved organization within the cerebellar projections, having implications for understanding the mechanism for response to therapies such as NMT in PD.

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The effect of statistical learning-induced predictions on memory performance

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Introduction

Statistical learning (SL) refers to the implicit ability of humans to extract regularities and patterns across multiple inputs. Providing the primary means by which we learn about the regularities in the environment, SL is involved in a wide range of basic and higher-order cognitive functions such as vision, audition, motor planning, event processing, reading, speech perception, language acquisition, semantic memory, and social cognition. While episodic memory enables the encoding and retrieval of specific experiences, statistical learning (SL) facilitates the detection of regularities across sensory inputs. This study investigates whether structured learning, characterised by predictable stimulus relationships, enhances episodic memory performance of the predictable stimuli in short-term memory (STM) and long-term memory (LTM) domains compared to random encoding. We hypothesised that SL would improve memory test accuracy by leveraging predictable patterns to optimize encoding and retrieval processes.

Methods

Fifty-six healthy adults (mean age = 22.35 years) from the University of Allahabad were randomly assigned to four groups: STM-Structured (STM_SL, n = 20), STM-Random (STM_R, n = 17), LTM-Structured (LTM_SL, n = 9), and LTM-Random (LTM_R, N = 10). Participants encoded 160 visual stimuli (images from 10 categories, sourced from (Brady, T.F., & Oliva, A., 2008) presented for 1000 ms each, either in predictable pairs (structured) or random order. Encoding required participants to identify man-made objects via keypress to ensure attention. During the 10-minute retention interval (STM condition), participants engaged in unrelated filler activities to prevent rehearsal-based maintenance of encoded material. Recognition tests assessed memory for predictable items after 10 minutes (STM) or 24 hours (LTM), followed by a pair familiarity test to measure explicit knowledge of predictive relationships. Participants were randomly assigned to groups, comparability was inferred from equivalent encoding accuracy and reaction times across groups (all ps > .10), suggesting similar attentional engagement and working-memory capacity during task performance. A 2x2 block design examined Group (Structured vs. Random) and memory type (STM vs. LTM) effects on memory test accuracy (MT_Acc). Independent samples t-tests and two-way ANOV A were conducted using Python 3.12.7, with an alpha level of 0.05.

Results

Assumptions of normality and homogeneity of variances were met (Shapiro-Wilk: $p = 0.1070$ to 0.334 for MT_Acc; Levene's: $W = 1.694$, $p = 0.181$). T-tests revealed significantly higher MT_Acc in the LTM_SL group ($M = 87.23\%$, $SD = 5.14$) compared to LTM_R ($M = 82.70\%$, $SD = 6.44$; $t(15) = 2.217$, $p = 0.044$). A trend toward higher MT_Acc was observed in STM_SL ($M = 83.92\%$, $SD = 6.00$) versus STM_R ($M = 79.62\%$, $SD =9.99$; $t(32) = 1.840$, $p = 0.075$). Two-way ANOV A showed a significant main effect of Group ($F(1,47) = 4.271$, $p = 0.044$, $\eta 2 = 0.080$), indicating better performance in structured groups. No significant differences were found in encoding accuracy, statistical learning accuracy, or reaction times between the structured and random groups. The Group × Memory Type interaction was not significant, $F(1, 47) = 0.003$, $p = 0.959$, indicating that the effect of structured learning was consistent across short-term and long-term memory tests.

Discussion

The findings support the hypothesis that structured learning enhances episodic memory, particularly in LTM domain, where predictable stimulus pairs likely reduced prediction errors, facilitating memory consolidation via hippocampal processes (Schapiro et.al., 2014). The significant main effect of group effect underscores robustness of SL across memory types, with a small to medium effect size ($\eta 2 = 0.080$). The non-significant STM trend ($p = 0.075$) may reflect higher cognitive load during immediate recall or insufficient statistical power due to smaller effect sizes, suggesting that SL's benefits may require consolidation to fully manifest. The lack of differences in encoding accuracy and explicit knowledge (SL_Acc) indicates that SLs advantage stems from implicit pattern recognition, aligning with predictive coding principles, where the brain prioritises expected information, enhancing retrieval efficiency (Friston et.al., 2010). The LTM advantage may reflect the ability of the hippocampus to integrate predictable patterns over extended delays, potentially amplified by sleep-dependent consolidation, which stabilizes SL-induced memory traces (Batterink et al., 2015). These results challenge traditional models separating SL and episodic memory (McClelland et.al., 1995), highlighting the dual role of hippocampus. These results highlight the hippocampus's dual role in integrating statistical regularities and forming episodic memories, extending prior findings on their competitive dynamics (Shermann et.al.,2020). While the primary hypothesis focused on enhanced encoding through structured regularities, we also explored whether these effects persist or strengthen over time, predicting greater benefits in long-term memory if consolidation mechanisms interact with statistical regularities. Practically, structured learning could inform educational strategies by incorporating predictable patterns to enhance long-term retention, offering a foundation for optimizing learning paradigms in educational and clinical contexts, such as sequencing related concepts in curricula, or in clinical settings for memory rehabilitation.

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Effect of Retention Interval on Mnemonic Processing in the Mnemonic Similarity Task

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Introduction

The Mnemonic Similarity Task (MST), developed by Stark et al. (2019), is a standardized paradigm used to assess pattern separation and completion processes in the hippocampal region. MST has participants distinguish between previously seen, visually similar, and novel items, where pattern separation is measured by the accuracy of identifying lure items. Mnemonic tasks require storage and retrieval of information from memories, while perceptual tasks can be done using immediately available information to perform sensory processing. Stark et al. (2019) avoided morphometric alterations in MST to minimize perceptual strategies, opting for naturalistic changes in feature(s). Yassa et al. (2010) demonstrated that the presence of age-related differences in MST, but not in a perceptual task where participants discriminated between sequentially presented lure pairs, target pairs, and foil pairs, emphasized its cognitive specificity. However, the memory demands and retention intervals are different for the two tasks. Therefore, they are not directly comparable, and the perceptual task cannot be used to confirm the mnemonic nature of MST. To demonstrate the presence of underlying factors affecting pattern separation performance, Hanert et al. (2017) assessed MST performance after a 9-hour retention period covering nocturnal sleep or daytime wakefulness, finding that pattern separation was stabilized by sleep-dependent consolidation, with the greatest improvement seen for high-similarity lures. Aldi et al. (2018) conducted a more ecologically valid study, added a background image to give context to the items and suggested that pattern separation performance was unrelated to memory performance. Building on previous studies, we hypothesized that while immediate or short delay between encoding and recall phases may employ mnemonic processing, as delay increases, the mnemonic nature of the task is not apparent. We operationalized our hypothesis by introducing delays of 30 minutes and 24 hours between encoding and recall phases of MST in an Indian population.

Methods

195 participants were recruited and assigned to one of the three versions of the MST (Stark et al. (2019).

1. imm: Encoding - no delay - Recall (N = 103, 45 women, mean age=23.43 ±2.45).
2. del 30m: Encoding – 30-minute delay – Recall (N = 19, 11 women, mean age=23.16 ± 2.96).
3. del 24h: Encoding – 24-hour delay – Recall (N = 73, 16 women, mean age=23.80 ±2.31).

Participants completed questionnaires screening mental health, sleep quality, and alcohol, caffeine, and nicotine consumption. During encoding phase, participants viewed 128 images of common objects and classified them as ”indoor” or ”outdoor”, immediately followed by the recall phase where they were shown 64 repetitions, lures, and foils each. Participants had to classify them as ”Old”, ”Similar”, and ”New”, respectively. In both phases, images were on screen for 2000 ms, followed by a 500-ms interstimulus interval. We added 30-minute and 24-hour delays between encoding and recall phases to test our hypothesis.

Results

First, a MANOVA tested whether distribution of responses to stimuli differed across recall groups. A second MANOVA assessed if accuracy (hits) of identifying stimuli varied between recall groups. Finally, a one-way ANOVA assessed if the Lure Discrimination Index (LDI, p(”Similar|Lure)− p(”Similar”|Foil)) differed across recall groups.

The first MANOVA revealed a multivariate effect for response distributions across recall groups ($F(6,380) = 16.96, p < 0.01, \eta2 = 0.15$) with significant differences for ”Old”, ”New” responses in ANOVA ($F(2,192) = 9.15, \eta2 = 0.09$; $F(2,192) = 16.61, \eta2 = 0.15$, respectively, $p < 0.01$ for both). Tukey HSD tests showed an ”Old” response bias for imm and del 30m ($p < 0.01$ for both) and a ”New” response bias for del 24h ($p<0.01$).

The second MANOVA revealed a significant multivariate effect for stimulus accuracy across recall groups ($F(6,380) = 30.74, p < 0.01, \eta2 = 0.23$) with significant differences in accuracy (hits) across recall groups in ANOVA($F(2,192) = 43.08, F(2,192) = 36.85, F(2,192) = 17.58$, respectively, $\eta2 = 0.31, 0.28, 0.16$, respectively, $p < 0.01$ for all). Tukey HSD tests showed that imm and del 30m had higher accuracies than del 24h for both targets and lures ($p<0.01$ for all), and imm performed better than del 24h for foils too ($p<0.01$). One-way ANOVA showed significant effect for LDI across recall groups ($F(2,192) = 33.75, p<0.01, \eta2 = 0.26$), with Tukey HSD tests revealing that both imm and del 30m performed better than del 24h ($p<0.01$).

Discussion

The results revealed that pattern separation performance was affected by sleep consolidation. The imm and del 30m groups showed an “Old” response bias, while del 24h displayed significant “New” response bias. Both imm and del 30m showed higher stimulus accuracies than del 24h. LDI was the lowest in del 24h. Comparable stimulus accuracies between imm and del 30m point towards successful encoding and short-term retention. However, the results suggest that del 24h experiences substantial forgetting for stimuli and long-term retention is poor. Performance in imm and del 30m could be the lingering of perceptual processing. It may also imply that the mnemonic aspect of MST is short-lived. For a task to be mnemonic, the con- tent must not only be encoded successfully, but also retained durably over time (Cellini, 2023). Additionally, simple visual discrimination can be done by higher visual processing areas without dependence on the hippocampus (Lech et al., 2014), which may reduce the encoding of stimuli for long-term retention (dependent on the hippocampus). Thus, we can observe short-term reten- tion in the standard MST, which is a necessary but not sufficient condition for real-world intervals of recall and pattern separation. We must note that data collection is ongoing for this study. As a result, del 30m has a smaller number of participants than imm and del 24h during the time of submission.

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Impact of Vedic chanting on working memory: A VBM study

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Introduction

Vedic chanting represents a time-honored Hindu tradition that entails the recitation of Vedic texts composed in Sanskrit, which has demonstrated enhancements in memory performance[1,2,3]. Neuroimaging research supports this, revealing brain plasticity resulting from the practice[4,2] in areas such as the temporal regions, anterior cingulate cortex (ACC), and medial prefrontal cortex, alongside an increase in the volume of the posterior hippocampus among those who chant Vedic texts. The current study seeks to explore the impact of a long-established traditional method that necessitates extensive verbal memorization over time. The rigorous memorization required for these scriptures may promote the development of memory-associated regions, like the hippocampus, as indicated by earlier research[4]. Investigations involving children[1] and adults[3,2] have demonstrated that Vedic chanting enhances working memory capabilities. The research conducted by Uttam Kumar et al. (2021) noted an increase in cortical thickness within the right caudate, an area linked to exceptional memory formation[5]. A related study by Hartzell et al. (2016) found a reduction in volume in the anterior hippocampus bilaterally, paired with an increase in the right middle posterior hippocampus, along with heightened gray matter and cortical thickness in both the ACC and ventromedial prefrontal cortex (vmPFC). In addition to changes in hippocampal volume, Hartzell et al. (2016) also reported an increase in gray matter primarily in the bilateral ACC and vmPFC, as well as greater cortical thickness predominantly in the left rostral ACC and dorsomedial prefrontal cortex (dmPFC). These findings underscore the potential of Vedic chanting as a cognitive enhancement tool, particularly in fostering memory development and brain plasticity.

Methods

A total of 24 male subjects (comprising 12 Vedic reciters and 12 age-matched control participants) within the age range of 11 to 15 years engaged in the research endeavor. All subjects demonstrated either normal or corrected visual acuity. The neuroimaging procedures for the children were carried out in the presence of a legal guardian, who was informed of their right to withdraw from the investigation at any moment should they wish to do so. The research protocol obtained endorsement from the Institutional Ethics Review Board at the University of Allahabad (IERB, UoA). The participants were also carefully matched for bilingual proficiency and the medium of educational instruction. Furthermore, the socio-economic status of both participant groups did not reveal any statistically significant differences.

A total of 12 neuroimaging scans of children engaged in Vedic chanting and 12 scans from the control group were performed. In addition, only those children possessing a minimum of 30 months of chanting experience were included in the analysis. The anatomical imaging data were acquired at the National Neuroimaging Facility at the Centre for Brain and Cognition Studies (CBCS), University of Allahabad, utilizing a Siemens 3-T MAGNETOM Skyra scanner outfitted with a 20-channel head coil. T1-weighted structural images were obtained using the magnetization-prepared rapid gradient-echo (MPRAGE) sequence, incorporating the following acquisition parameters: 176 slices, voxel dimensions of 1x1x1 mm, repetition time (TR) of 2530 ms, echo time (TE) of 2.26 ms, field of view (FoV) measuring 220 mm, and a flip angle set at 8°.

Results

Brain Voxel-Based Morphometry analysis comparing VC to CN (Vedic chanters versus Controls) revealed notable bilateral grey matter variations in the Visual cortex, as well as in the left inferior temporal region, right ACC, right cingulate cortex, left fusiform, left intra-parietal sulcus, and left hippocampus ($p<0.001$, $k>30$ voxels). Considerably greater grey matter differences were identified bilaterally in frontal areas, the Cerebellum, along with the left superior temporal gyrus and the right pre and post-central gyrus in Controls compared to Vedic chanters (CN>VC).

Furthermore, Vedic chanters displayed enhanced grey matter volumes in the hippocampus and other memory-related areas, specifically in the Entorhinal and parahippocampal cortices. In contrast, the VBM analysis indicated significantly larger pre-frontal cortex volumes in the control group, which may reflect educational disparities among the participants.

Discussion

To explore the grey matter differences resulting from regular long-term Vedic chanting practices, we compared anatomical changes in children attending Vedic schools with those in typical school-going children. The results underscore the significance of extensive verbal memorization in the enhancement of memory-related subcortical regions, particularly the hippocampus. Additionally, the increased grey matter in the ACC points to improvements in attentional allocation and working memory performance, as noted in prior research[6,7]. The findings indicate that Gurukul-based education promotes the development of memory-related areas compared to traditional educational settings. However, the increased grey matter noted in regions such as the superior frontal gyrus, central gyrus, and intra-parietal sulcus suggests that modern education also plays a vital role in the growth of adolescents. These insights advocate for integrating traditional practices like Vedic chanting into contemporary educational frameworks to enhance cognitive development and memory skills among students.

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Long-term meditators have lower mind-wandering and improved response inhibition

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Introduction

The ability to inhibit actions that are no longer appropriate, termed response inhibition, is critical in everyday life[1]. In laboratory settings, response inhibition is commonly studied using the stop signal task, where participants respond to a go cue but must inhibit their response when a stop cue suddenly appears on a subset of trials. The time taken to stop the incipient response can be estimated and is called the stop signal reaction time (SSRT)[1]. Although most response inhibition studies assume that participants are completely focused while doing the task, oftentimes their mind drifts to task-unrelated thoughts, called mind wandering. Mind-wandering is known to impair response inhibition, i.e., increase SSRT[2]. Interestingly, separate studies have demonstrated that meditation practitioners have lesser mind-wandering[3] and that they have improved response inhibition[4]. This suggests that those with reduced mind-wandering would have improved response inhibition, which we tested in this study. Long-term meditators and naive participants performed the stop signal task and intermittently reported whether they were mind-wandering. We hypothesized that meditators would have lower mind-wandering, lower SSRT, and faster neural metrics of response inhibition. We report two commonly used neural metrics: A) CancelTime, the time when the muscle activity declines after the stop signal in the successfully stopped trials, B) Global motor suppression, the reduction in the motor cortical excitability of a task-unrelated muscle after the stop signal as assessed by transcranial magnetic stimulation (TMS) based motor evoked potentials (MEPs)[5].

Design

In this pre-registered study, Long-term meditators (>5 years of practice) and non-meditators performed two sessions of the stop signal task with mental-state probes presented every 40–55s. Based on this self-report, we classified 6 trials prior to the probe as on-task or mind-wandering episodes, consistent with previous studies. In both sessions, online Electromyography (EMG) was recorded to measure CancelTime from the extensor carpi radialis muscle (little finger) and the first dorsal interosseous muscle (index finger), which were used to make responses in the task. In one session, online TMS was delivered on the scalp, at the region of the primary motor cortex, which is associated with the left Extensor carpi radialis muscle. It was delivered at 140 ms or 175 ms after the stop signal in all the stop trials, or at corresponding 140/175 ms timings in some go trials and in the inter-trial intervals (baseline). In the subsequent session, electroencephalography data were collected while the task was ongoing.

Behavioral data were analyzed from 40 meditators and 59 non-meditators. After excluding participants with noisy EMG signals or insufficient muscle activation trials, EMG analyses included 21 meditators and 37 non-meditators. For TMS, participants with noisy or insufficiently detectable data (<70% of trials) were excluded, resulting in 7 meditators and 26 non-meditators being analysed out of the 20 meditators and 34 non-meditators who participated in the TMS session.

RESULTS

Consistent with our hypothesis, meditators reported significantly fewer mind-wandering episodes compared to non-meditators (t(94.7)=2.82,p=0.0057). SSRT was also significantly shorter in meditators than non-meditators (t(97)=2.83,p=0.0056), indicating better response inhibition. To examine how mind-wandering affects response inhibition, we compared SSRT between on-task and mind-wandering episodes by performing a two-way ANOVA with factors Mental-State (on-task vs. mind-wandering) and Group (meditators vs. non-meditators). There was a significant main effect of Mental-State (F(1,97)=16.48,p<0.001), a significant main effect of Group (F(1,97)=6.9,p=0.009), but no significant interaction (F(1,97)=0.1,p=0.713).

We examined the CancelTime, which indexes the suppression of task-related muscle activity in successful stop trials. We predicted it to mirror SSRT differences between the two groups. However, surprisingly, mean CancelTime was significantly longer in meditators than non meditators (t(56)=2.7,p=0.009). It suggests that although meditators are faster at behavioural stopping, the muscle-level cancellation seems to be able to proceed for a longer duration.

We then compared the CancelTime between different mental-state episodes. Unlike SSRT, where on-task and mind-wandering measures were available for all participants, allowing a repeated-measures ANOVA, the CancelTime dataset had missing mental-state data for some participants. To account for this, we used a linear mixed-effects model with factors Mental-State (on-task vs. mind-wandering) and Group (Meditators vs. non-meditators), and dependent variable CancelTime. This revealed a significant main effect of Group (F(1,100)=8.8,p=0.004), but no significant main effect of Mental State (F(1,100)=1.71,p=0.194), and no significant interaction effect (F(1,100)=2.41,p=0.123).

Based on previous studies, we predicted that global motor suppression would be seen in the successfully stopped trials. However, a linear mixed-effects model with factors Trial Type (Correct Go, Failed Stop, Successful Stop), Timing (140ms, 175ms), and Group (Meditators, non-meditators) showed no significant main effect of Group (p=0.611), or of Timing (p=0.643), or Trial Type (p=0.048, after correction for multiple comparisons). No significant interactions were observed (all $p > 0.05$).

DISCUSSIONS

We find that long-term meditators compared to non-meditators have lower mind-wandering, and improved response inhibition. This is consistent with existing literature and our predictions. However, surprisingly, the results of the neural metrics did not align with our predictions. While there may be other explanations for this, one possibility is that we did not have sufficient data for analysis. Significant data was lost due to electrical noise, or no visible activation of the muscles, leading to fewer detections. In case of mental state wise comparison, many participants reported too few mind-wandering episodes. Another possibility is that our TMS timings, which were based on a prior study where participants had shorter SSRT, were too early to capture the global motor suppression. However, analysis is ongoing, including that of electroencephalography data, which was also recorded in one of the sessions.

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Mind-Wandering Impairs Response Inhibition: Behavioral and Neurophysiological Evidence

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Introduction

In our constantly changing environment, we often need to stop responses that are no longer necessary. This ability, **response inhibition**[1], is commonly studied using the stop-signal task. In this task, participants must quickly initiate an action when a “Go” signal is presented and attempt to inhibit this action when a “Stop” signal is occasionally presented after an interval called the stop-signal delay. While the time taken to initiate a response can be measured directly, the time taken to inhibit a response (**stop-signal reaction time, SSRT**) is inferred based on the independent race model1. In the brain, this stopping process is thought to involve a temporal cascade of neural activity involving the prefrontal–basal ganglia–motor cortical network[2,3]. First, increased beta- band (13-30Hz) activity is observed over the frontal brain regions. Then, there is a widespread suppression of excitability of the motor cortical representation of task-unrelated muscles (**global motor suppression**) as measured using Transcranial Magnetic Stimulation based Motor Evoked Potentials (MEPs). Following this, there is a reduction in task-related muscle activity, called **CancelTime**. And, finally, after a peripheral delay, SSRT. While most response inhibition studies assume focused mental state, this is far from reality, as real-life situations often involve **mind-wandering**, where attention drifts away from the task.

Mind-wandering can have profound implications in high-risk situations, such as driving, which often requires rapid response inhibition. A previous behavioural study4 compared stop-signal task performance between mind-wandering and on-task episodes. They observed that participants had poorer response inhibition, i.e., increased SSRT, during mind-wandering compared to on-task episodes, suggesting that the response inhibition network is affected. Our pre-registered, **multi- modal study** extends this research by uniquely combining EEG, EMG and TMS to test the neural mechanism of the effect of mind-wandering on response inhibition.

Methods

A power analysis (power = 0.8, α = 0.05) indicated that 34 participants were required for this study based on the behavioural effect sizes reported by Jana & Aron (2022, Study 2). However, as data collection was part of a larger project, we analyzed all available participants.

The participants performed the stop-signal task across two sessions, EEG+EMG (N=68) and TMS+EMG (N=52). During the task, after every 40-55s, the participants were intermittently probed to report their mental state, on-task, mind-wandering or mind-blanking (not discussed here). In total, 36 and 48 probes in EEG+EMG and TMS+EMG sessions, respectively, were presented. In the TMS session, a single pulse was delivered over the right primary motor cortex representing the left extensor carpi radialis task-unrelated muscle during task performance. TMS was delivered on every Stop trial, either at 140ms or 175ms after the Stop-signal or during the inter-trial interval. In 72% of the Go trials, TMS was delivered at 140ms or 175ms after the stop-signal delay of the preceding stop trial or the inter-trial interval. Behavioural analysis was performed on 59 participants who satisfied the behavioural criteria and reported at least 4 mind-wandering episodes.

We hypothesized that response inhibition would be slower during mind-wandering compared to on-task, and the temporal cascade of response inhibition-related neural activity would also be delayed:

1. Behavioral response inhibition will be poorer: SSRT will be slower during mind-wandering. [N=59]
2. Global motor suppression will be delayed: In the Successful-stop trials, MEPs during on-task will be lower compared to Correct-go trials at 140ms, but they will be lower during mind- wandering at 175ms. [Analysis on N=26; 12 participants were removed because of extremely noisy data.]
3. Muscle cancellation will be delayed: CancelTime will be slower during Mind-wandering compared to On-task. [Analysis on N=19; 18 participants were removed either because of noisy data or because CancelTimes were detected in less than 3 trials in the mental states.]

Results

The behavioral data from the two sessions were merged as there was no significant difference between the behavioral performances. Behavioral performance was typical (Table 1). Consistent with prediction 1, SSRT (calculated using the integration method1) was significantly slower during mind-wandering (462.3±7.7ms) compared to on-task episodes

(431.7±8.1ms; $t(58)=4.5$, $p<0.001$, $d=0.60$). Following this, to test prediction 2, we performed a linear mixed-effects model with MEP amplitude as the dependent measure and the factors of mental state (On-task, Mind- wandering), trial-type (Correct-go, Successful-stop, Failed-stop), and time (140ms, 175ms). We found a significant main effect of mental state on MEP amplitude ($p=0.040$), with mind-wandering trials producing slightly larger MEPs than on-task trials, independent of trial-type or time. No significant interactions were observed (all $p>0.05$). However, contrary to our prediction 3, CancelTime showed no significant difference between the mental states ($t(18)=1.4$, $p=0.165$, $d=0.33$).

Table 1. Behavior (mean ± s.e.m).

Mental State	GoRT (in ms)	Failed Stop RT (in ms)	Correct Go %	Correct Stop %	Mean SSD (in ms)	SSRT (in ms)
Overall	591(11)	522(11)	95(0.4)	42(1)	197(9)	433(6)
On-task	633(12)	431(8)	95(0.5)	54(1)	196(9)	431(8)
Mind-wandering	619(12)	529(12)	93(0.7)	41(1)	202(11)	462(7)

Discussion

Our results provide behavioural evidence that mind-wandering impairs the ability to stop an initiated response, as indicated by significantly slower SSRTs compared to on-task states. This aligns with prior work4 showing that mind-wandering reduces the efficiency of response inhibition. A linear mixed-effects analysis revealed a modest but significant main effect of mental state on MEP amplitude, with slightly larger MEPs during mind-wandering than on-task (independent of trial-type or stimulation timepoints), suggesting weaker or delayed global suppression. Additionally, we observe numerically that suppression during Successful-stop trials in mind- wandering episodes was greater (smaller MEP amplitude) at 175ms than at 140ms, a pattern not evident in on-task episodes. These trends suggest that mind-wandering might shift the timing of suppression, but the limited temporal resolution of our TMS protocol (two timepoints) and reduced statistical power due to removal of trials/participants due to noisy data may have hindered the detection of subtle effects. Please note that global motor suppression serves as an index of the stopping process, as it is measured from a task-irrelevant muscle; therefore, it cannot be used to infer changes in the go process. However, contrary to predictions, the behavioural slowing was not accompanied by a significant difference in muscle cancellation time (CancelTime) across mental states, possibly due to limited sensitivity from the reduced EMG sample size. Future EEG analyses will examine whether mind-wandering alters EEG metrics that are associated with response inhibition.

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Modelling Inhibitory Control using Stop-Signal Task in the Cortico-Basal Ganglia Thalamocortical Loop using the CBGTPy Framework

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Introduction

Reactive inhibitory control ensures our survival and it is mapped to the cortico-basal ganglia-thalamocortical (CBGT) loop. In mammals, studies have attributed inhibitory control to the hyperdirect pathway involving the subthalamic nucleus (STN). Recent research shows how STN is assisted in stopping actions through the pallido-striatal pathway via globus pallidus (GPe). Using a biologically constrained spiking neural network model of the CBGT circuit, named CBGTPy, it was shown how the arkypallidal neurons of the GPe (GPeA) mediates inhibitory control in a one-choice task. Here, we utilize the capabilities of the CBGTPy framework and model inhibitory control in a two-choice task to understand the effects of targeted stimulation in the network's stopping behaviour.

Methods

We implemented a two-choice stop-signal task where the CBGT network must control the execution or suppression of an action, following the onset of imperative cues. The Go cue was presented first which is applied to the Cx of the two action channels simultaneously, which drives the network towards a decision. During a trial, a decision was made when the thalamic firing rate of an action channel crosses a threshold of 30 Hz. The time between the imperative stimulus and the action onset was recorded as reaction time (RT). The RT measure lacks the movement time component of traditional RTs recorded experimentally. Each trial had a decision window of 300 ms. If no decision was made within a trial window, no choice was recorded which translates to a successful inhibition. Each trial had a stop signal that was presented 70 msafter the Go stimulus. In our study, the stop signal was applied to the three distinct populations in the CBGT that have been experimentally shown to inhibit behavior: iSPNs, STN, GPeA. The stop-signal boosts the activity of the targeted cells and results in the reduction of the likelihood that the thalamic activity will reach an action threshold. The network was modified across four conditions, namely:

- Baseline condition: To model the baseline condition, the network for a two-choice task without the injection of a stop signal was simulated.

- iSPN condition: The stop-signal was applied to the iSPN cells of both the action channels. The primary input of the indirect pathway is traditionally considered to drive proactive inhibitory control by suppressing the thalamus as part of the direct/indirect pathway competition.
- STN condition: The stop-signal was applied to the STN cells of which are the primary basal ganglia input from the cortical hyperdirect pathway. It is considered to provide a fast controlmechanism for action suppression.
- GPeA condition: The stop-signal was applied to the arkypallidal cells of GPe in both the action channels. The GPeA cells have been recently shown to suppress actions.

Results

Stopping probability across conditions in a two-choice task showed significance. (ANOV A: F=180.6719, p<0.00001). Individually, iSPN stimulation produced about 94%, GPeA about 79%, and STN about 37% chance of stopping. Interestingly, even in the baseline condition, the chance probability of stopping was 22% which is significantly higher than that in the one-choice task as reported by Giossi and colleagues (Giossi et al 2024).

Discussion

We directly injected the stop signal into the target population while the stimulation process in Giossi et al 2024 involved using an optogenetic signal to activate the populations externally. We still observed similar trends with respect to the increasing stop probability, with the highest being in iSPN condition. We observed that in our two-choice task simulation, the stop probability is significantly inflated, compared to the study of Giossi et al, 2024. One reason for inflation could be due to the difference in experiment design, which needs to be cross-examined with literature for existing evidence for variation in stopping probability when number of choices increase. Surprisingly, in our no-stop-baseline condition alone, the stop probability is close to 20% while the stop probability in the baseline condition computed by Giossi et al is about 4%. This is an interesting result that needs to be analysed further to get an explanation about this inflation. One explanation could be that including another choice, i.e one choice versus two choice, elicits a competition between the two choices which may lead to higher number of stops due to inconclusive evidence accumulation for either of the choices. To comment at a mechanistic level, we need to follow up simulation studies and implement advanced computational models like the hierarchical drift diffusion model (HDDM).

Regardless, our simulation experiment opens up new possibilities to test how stopping probability is affected by increasing the number of choices.

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Music Embodiment and Emotion Experience

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Introduction.

Emotions evoked during musical experiences are widely explored phenomena. A key question is how these emotions are evoked. Several factors contribute, one being the inherent structure of the music (major and minor tones, tempo). In North Indian Classical Music, the *raga* structure, note configuration, ascension and descension (*aarohan* and *avarohan*), and signature phrases (*pakad*) play major roles in determining the emotions they evoke (Mathur et al., 2015). For instance, *Raga Darbari Kanada*, with its slow tempo, repeated emphasis on flat (*komal*) notes, and heavy use of lower octaves, is known to evoke sadness and seriousness (Mathur et al., 2015). However, emotions evoked by Hindustani music are often culturally affected; thus, traditional structures may not influence contemporary audiences similarly, making the experience subjective. Beyond the intrinsic structure, "the embodied viewpoint holds that bodily involvement shapes how we perceive, feel, experience, and comprehend music" (Jensenius et al., 2010). Cox (2016) explains embodied music cognition through the 'mimetic hypothesis,' or movement-based representation of musical actions, suggesting that we interpret music via overt gestures, covert sub-vocal, or visceral imitation (entrainment of heartbeat or neural oscillations to rhythm). Despite extensive studies on musical embodiment, its effect on emotional experience is not well understood. The present study examined emotional experience (happy, sad, calm) in terms of embodiment through Hindustani Classical Music (HCM), using subjective and neural responses to musical stimuli reflected in frontal alpha and theta activations, shaped by participants' own interpretation and experience of the music.

Methods

A total of 14 participants (mean age = 22.9 years, males = 8; females = 6) from an estimated sample size of 20 (G-power analysis: effect size = 0.6, power = 0.8, p = 0.05) were recruited. The G-power analysis was done *a priori* using one-way ANOVA comparing three emotion groups (happy, sad, calm) for two brain rhythms – alpha and theta. A medium effect size (0.5), significance (0.05), power (0.80), and two-tailed hypothesis were used to determine the sample size. Participants had little or no formal music training to minimize confounding from prior knowledge. Eighteen classical music pieces (30±5 s; Sitar and Tabla) were used – rated1 to evoke happy, sad, and calm emotions (selected from 36 clips; see Appendix 1). As Indian classical music is typically associated with sad and calm emotions (Mathur et al., 2015), pleasant clips were used for contrast. Each trial began with a 10-second fixation cross, followed by a music clip and subjective ratings of valence and arousal. Before the experiment, eyes-open and eyes-closed EEG (15 s each) was recorded as baseline. EEG was collected using an Emotiv headset with 14 electrodes and two mastoid references. Pre-processing involved filtering (0.1–40 Hz), artifact rejection, and Power Spectral Density calculation using Welch's method, normalized across electrodes.

Results

Activations for sad music aligned with expectations (Compton et al., 2019), showing elevated alpha ($M = 0.533$) and reduced theta ($M = 0.449$). Contrary to expectations (Gupta, 2025), calm music did not elicit the highest alpha power. Happy clips showed higher alpha ($M = 0.504$) and theta ($M = 0.454$) than calm music (alpha $M = 0.500$; theta $M = 0.434$), consistent across all 14 electrodes, particularly frontal ones. A Mann-Whitney U test compared subjective emotion ratings between raters and participants, revealing significant differences ($p < 0.001$), as participants experienced emotions differently than intended. After removing one misidentified happy and sad clip each, results showed clearer patterns: sad music maintained high alpha ($M = 0.609$) and low theta ($M = 0.434$), while happy clips showed left-lateralized alpha ($M = 0.513$). Thirty-six music clips were rated by experts and non-musicians; eighteen (6 each: happy, sad, calm) were selected for the main study.

Discussion

These findings support our primary goal that elicitation of emotions is not limited to musical structure alone. Traditionally, the structural properties of pieces based on *ragas* (Bhairav and Ahir Bhairav for sadness; Malkauns and Jog for calmness; Hamsadhwani for happiness) were meant to evoke specific emotions; however, participants uninitiated to the nuances of HCM did not experience them similarly. While previous studies (Gupta, 2025) linked higher alpha and theta power with calm music due to its relaxation-inducing structure, participants' experiences here contrasted with such findings. Although the clips were structurally meant to be perceived as calm, they were not experienced as such, leading to ambiguous or misidentified ratings and inconsistent EEG patterns. This discrepancy highlights the role of *interpretation* over perception of musical pieces. Comparing EEG responses with subjective valence ratings suggests an interpretative framework of musical emotions, where neural activations reflect cognitive and affective processing rather than purely stimulus-driven responses. The alignment

of EEG signals with participants' interpreted emotions supports a framework in which music is embodied through both bodily and cognitive engagement. Prior work (He et al., 2024) similarly associates alpha and theta oscillations with affective entrainment and embodied listening. The study's trends require validation with a larger sample, and variability in participants' engagement and familiarity with HCM remains a limitation. The second part of the study, an ongoing fMRI^2 experiment, investigates musical embodiment through a task involving congruent vs. incongruent tapping with or against rhythmic patterns to examine effects on emotional experience and activation in embodiment-related regions. This task aims to assess how manipulation of embodiment influences emotional experience and brain activation during facilitated versus disrupted embodiment. It is expected that congruent tapping will yield higher valence and arousal ratings, with clearer activations in embodiment regions (premotor cortex, supplementary motor area) and emotion regions (amygdala, insula, temporal poles, hippocampus, ventral striatum). The study underscores interpretation's role in musical embodiment, offering insights into mechanisms underlying music therapy for neurological and psychiatric disorders.
[fMRI task used a block design with tapping to blinking dots and music, followed by valence and arousal ratings]

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Threshold detection for positive and negative affective facial expressions in children: Evidence based on the Child Faces database

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Introduction

Emotions serve as a rich source of information for children, helping in their predictions of environmental events. This rapid learning process can obscure significant developmental changes in how emotions are understood[1]. Evidence suggests that, emotion recognition, and the understanding of emotional expressions, continues to develop throughout childhood and into adolescence[2]. While natural human interactions are highly dynamic, a significant portion of studies in affective neuroscience have relied on images of facial expressions or scenes. However, a limited but growing body of research suggests that studies using dynamic stimuli, such as short video clips, offer better depictions of how emotional expressions are encountered in real-life situations. For example, investigated the development of the six basic emotions in children and adolescents aged 4 to 18 using dynamic emotional expression stimuli (morphed emotions)[3]. Their findings indicated that sadness and anger were the least accurately recognized expressions.

Despite these findings, it remains unclear what factors contribute to these age-related differences in performance. The present study seeks to address this gap by investigating whether these differences are due to a speed-accuracy trade-off or an improvement in the quality of evidence gathered with increasing age.

Method

A total of 89 children, aged 6 to 11 years, participated in the study. Participants were divided into two age groups. The younger group consisted of 41 children (mean age = 7.61 years), while the older group consisted of 48 children (mean age = 9.43 years). All participants were recruited from a local school and had normal or corrected-to-normal vision. The experimental stimuli consisted of 60 images of emotional faces selected from the CBCS Child Emotional Faces Database. These images were used to create dynamic video clips, each 4 seconds in duration. The videos were generated using Adobe After Effects with specific blur settings. Each clip began with a highly blurred version of an image and progressively resolved to a clear, static image of the emotion. The blur effects were applied using a Gaussian blur of 100 and a directional blur of 90 degrees. The experimental task was presented using the PsychoPy software.

Results

We examined performance thresholds for the detection of positive versus negative affective images with respect to accuracy and reaction time (RT) across younger and older children.

Accuracy based detection thresholds

A 2 (Age Group) × 2 (Valence) ANOVA revealed significant main effects of age group, F (1,87) = 3.80, $p = .026$, $\eta p^2 = .042$, and valence, F (1,87) = 64.41, $p < .001$, $\eta p^2 = .423$, but no interaction of age group and valence, $p = .210$. The results indicated that positive affective images had lower accuracy thresholds than negative affective images for both age groups (ps < .001). Younger children were overall more accurate than older children, a pattern supported by regression analysis ($\beta = 0.066$, $p = .002$).

Reaction time-based detection thresholds

The ANOVA showed significant main effects of age group, F(1,87) = 23.97, $p < .001$, $\eta p^2 = .216$, as well as valence, F(1,87) = 41.45, $p < .001$, $\eta p^2 = .322$, with no interaction ($p = .362$). Overall, positive affect (happy) had lower RT thresholds than negative affect (angry, fear, disgust) for both the age groups (ps < .001). Younger children exhibited higher RT thresholds than older children, responding on average 430 milliseconds slower ($\beta = 0.433$, $p < .001$), indicating a speed–accuracy trade-off: younger children maintained higher accuracy but at the cost of slower responses. Confusion matrix confirms the accuracy patterns; i.e. positive affective images are correctly classified more often than negative affective images in both age groups (Younger: 93% vs. 82%; Older: 91% vs. 76%). Younger participants outperform older participants with respect to accuracy for both positive and negative affective images (82% vs. 76%). Misclassification rates for both age groups are small and consistent with the ANOVA results. Signal Detection Theory (SDT) based analysis showed that older children had higher false alarm rates (Negative: 0.1060 vs. 0.0879; Positive: 0.2458 vs. 0.1887) and lower discriminability (d′: Negative: 2.21 vs. 2.50; Positive: 2.10 vs. 2.49) compared to younger children, although the age group difference in sensitivity was not statistically significant ($p = 0.107$).

We also conducted a discrete emotion-wise multidimensional scaling (MDS) analysis to understand how valence would affect perception of discrete emotions across age groups. In both groups, happy stimuli formed a distinct cluster separate from the negative emotions.

However, the negative emotions showed a close cluster (angry, disgust, fear) in younger children, indicating high perceptual similarity, whereas in older children the cluster was more dispersed, with angry positioned farther from fear and disgust.

Discussion

The findings demonstrate that younger and older children differ in both accuracy and reaction time thresholds when processing positive and negative affective images. Across age groups, positive affective stimuli were recognized more rapidly and accurately than negative stimuli. Younger children exhibited higher accuracy but slower reaction times compared to older children, who responded more quickly but with reduced accuracy, suggesting a developmental shift from a cautious, evidence- accumulation strategy to a speed-oriented approach. This shift may reflect older children's greater world knowledge and experience particularly for negative facial expressions. Supporting this interpretation, the multidimensional scaling analysis (conducted to understand the contribution of specific emotions on valence related effects) revealed that, although happy facial expressions formed a distinct cluster in both age groups, negative emotions (anger, fear, disgust) were perceived as more similar in younger children, whereas the same were perceived as more discrete among older children with greater differentiation. This pattern suggests that the perceptual representation of negative emotions becomes more distinct with age, potentially reflecting developmental refinement in discrete emotion categorization[4]. A larger sample size might also provide greater statistical power to confirm these trends and clarify subtler age-related differences in emotion processing.

From a developmental perspective, the results are consistent with constructionist accounts of emotion[5], which posit that emotion perception is shaped by accumulating conceptual knowledge and socially mediated prediction models. Younger children's performance could reflect a still-flexible prediction system less constrained by learned priors, while older children's asymmetries might emerge as their predictive models become more specialized toward frequently encountered, socially reinforced discrete emotions which is also is evident from the results of multidimensional scaling.

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An Investigation of EAL Among Malayalam-Speaking Children With Dyslexia Using a Semantic Priming Task

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Introduction

Dyslexia is a disorder of neurobiological origin that presents itself as a severe difficulty in learning to read (Shaywitz, 2006). It is a neurodevelopmental disorder that primarily affects the phonetic component of language, leading to difficulties in decoding, word recognition, and spelling (Lyon et al., 2003). This difficulty is associated with a deficit in the association between phonemes and graphemes by learners (Dehaene, 2012). Dyslexics show greater cognitive effort in reading tasks (Lodej, 2016) and is a disorder that affects a significant population of young children who are currently enrolled in various schools and are in their developmental phase. Among dyslexics learning a L2 was seen as something undesirable in the past or something that can create confusion for the dyslexic language. However, such notions were refuted by researchers (Sparks & Ganschow, 1993; Wydell & Butterworth, 1999). Studies have shown that bilingualism can be beneficial to dyslexics by improving phonological awareness skills, particularly in second language (Ho & Fong, 2005; Lallier, Thierry, Barr, Carreiras & Tainturier, 2018; van Setten et al., 2017; Vender, Delfitto & Melloni, 2020; Vender, Vernice & Sorace, 2021). It has been suggested that dyslexics are dependent on the cues to associate meaning across associating graphical notation into orthographical account.

Developmental dyslexia is marked by reading achievement that falls substantially below that expected given the individual's chronological age, measured intelligence, and age-appropriate education. In dyslexia, the individual manifests problems in word recognition and reading comprehension. On assessments of reading skill, these persons routinely omit, add, and distort words, and their reading is typically painfully slow. One of the interesting findings has been on transparent languages such as Italian and Spanish influencing the performance of L1 dyslexics. It has been found that dyslexic children learning a phonologically transparent language (such as Italian or Spanish) began to experience improved literacy rates in their first language, English (Kovelman, Bisconti and Hoeft, 2016). We in this study looked at English(L2) as an additional language which is considered rather opaque and unpredictable (Wydell & Kondo, 2003). Although English as a second language presents challenges due to its inconsistent and opaque orthographic system (Butterworth, 1980; 1992), research indicates that second language learning does not negatively impact children with dyslexia. On the contrary, it may offer cognitive or linguistic benefits (de Bree, Boerma, Hakvoort, Blom, & Van Den Boer, 2022). We were interested to look at whether learning an additional language or being bilingual has any cognitive advantage specifically among Malayalam speaking dyslexic children. We looked at cross-domain presentation of semantic information among English-Malayalam dyslexics.

Methodology

Procedure

The study was conducted in Kerala and were with English-Malayalam bilinguals and English Malayalam dyslexics. This study aims to explore how implicit semantic priming impacts reading efficiency in dyslexic and non-dyslexic children. Participants were equipped with a laptop for stimulus presentation. A fixation display of cross (+) for 3 secs was shown on screen. The image prime was presented for 5 seconds on the screen. After the slide two-word pair were shown on the screen, i.e., one is target and one is unrelated for 5 seconds. Participants verbally responded by stating the target word aloud while viewing the words. The screen was recorded and the participants response was registered. The entire screen was recorded from the start of the session to the end of the session to capture all stimuli and participants reactions.

Participant Information

The study included two groups of bilingual children aged 8-14 years. The dyslexic group comprised 20 boys who had been formally diagnosed with developmental dyslexia by a clinical psychologist at the remedial institution using standardized tools from the NIMHANS Specific Learning Disability Battery. These assessments thoroughly evaluated reading (letter and word recognition, comprehension, fluency), writing (copying, spelling, dictation, expression), arithmetic (number concepts, calculation, and problem-solving), and cognitive-linguistic domains such as auditory and visual discrimination, working and short-term memory, and phonological processing. Nonverbal intelligence was measured using Raven’s Standard Progressive Matrices (SPM), which ensured that reading difficulties were specific to dyslexia rather than generalized cognitive deficits. All participants were from two special schools for children with learning disabilities, attended English-medium institutions, and had normal or corrected vision and hearing. Parental consent and permission for recording were obtained before their inclusion.

The control group consisted of 20 typically developing children (8 boys and 12 girls) from regular schools and ten (10) from English-medium and ten (10) from Malayalam-medium institutions. Selection was purposive, based on teacher nominations and reading competence. None of these participants had a record of learning difficulties or neurological concerns. A short reading trial involving picture-word reading confirmed appropriate literacy, pronunciation, and comprehension. Since teacher judgments and the trial validated typical language development, no additional standardized diagnostic tools were used. All control children demonstrated typical academic progress and intact developmental histories. Informed consent was obtained from teachers, and all data were collected within familiar classroom environments.

Experimental Design

The experiment adopted a comparative design to examine semantic priming mechanisms among Malayalam-English bilingual children. The core experimental paradigm was a pictureword semantic priming task aimed at identifying how dyslexic and non-dyslexic readers process semantic relationships across their first (Malayalam) and second (English) languages. Stimuli comprised 50 black-and-white drawings from the Snodgrass and Vanderwart (1980) set, each followed by two words: one semantically related and one unrelated. English target words were sourced from the Montana State University Semantic Priming Project and translated into Malayalam. To reduce potential spatial confusion and decoding difficulties common among dyslexic children, color cues were used instead of spatial "left/right" references. The left position was marked with a yellow sticker corresponding to the verbal response "Yellow", while the right position was marked with a green sticker, corresponding to "Green." This ensured clear and consistent response mapping across all participants. By associating response positions with colors, participants could respond accurately within the 5-second response window without needing to process spatial terms. This approach standardized task demands for both dyslexic and non-dyslexic participants, ensuring fair comparison.

All sessions were conducted in a quiet environment with participants seated in front of a laptop and a pre-recorded video lasting approximately 9 minutes and 29 seconds. The same duration was maintained for both language sessions, with the English video presented first, followed by the Malayalam version. Each participant thus completed 50 experimental trials in English and 50 in Malayalam, along with 3 practice (pre-trial) sessions before the main experiment. Every trial followed a fixed sequence: fixation cross (3 seconds), blank screen (0.3 seconds), picture prime (5 seconds), and word display (5 seconds) featuring the related and unrelated words linked to their color cues. Participants responded within the 5 second window, and each session was recorded for screen and audio data using OBS Studio, with verbal responses captured through the laptop microphone. Reaction times were extracted using timestamps in video recording, and response accuracy was noted along with for verification. Three practice trials familiarized participants with the procedure and ensured clear comprehension of instructions before testing began. The main experimental tools included video preparation software, OBS Studio for recording, the laptop microphone for capturing verbal input, and experimenter logs for response confirmation.

Results

We did ANOVA on the transformed data to check the group differences using RTs and Accuracy as dependent measures. We saw trend in temporal scores differences across groups. Malayalam dyslexics were slower compared to English dyslexics. However, we didn't find any statistical differences across the groups in terms of reaction times, F(3, 76) = 2.328, p =.08. Similarly, we looked at group differences across accuracy scores and found significant differences across the groups F(3,76) = 2.964, p = .037. We further did post hoc analysis to look at mean differences across the groups and found significant differences across dyslexics Malayalam and non-dyslexics Malayalam, t(76) = -2.693, p = .042. We didn't find any difference between Dyslexic English group and non-dyslexics English speakers' group, t(76) = -1.258, p = .592.

Discussion

Semantic priming influence on assessing the lexical account of stored informational representation is investigated. We looked at how semantic activation of this representation informs the activated nodes for lexical access through a semantic priming task. Both L1(Malayalam) and L2(English) access was investigated and we were interested in learning about the role of EAL among Malayalam bilinguals. We observed that L2 has an advantage for the lexical activation investigated through a semantic priming task among English-Malayalam bilingual dyslexic children compared to L1. The performance of dyslexic children was comparable to that of non-dyslexics peers when L2 was investigated. These results sheds light on the consensus that learning an additional language(L2) may facilitate and improve processing of information among dyslexic children. Future studies with more rigorous controls are needed to address limitations such as learners' language exposure and proficiency, sample size and factors like word length and format. Although this preliminary study suggests that learning a second language (L2) appears to improve overall performance, it is not always the case in the native language (L1) of dyslexics. However, this study with EAL does suggest the early adoption of bilingualism among dyslexic children may boost resilience for reading and not worsen dyslexia. Dual language exposure might allow a compensatory mechanism to develop and improve outcomes.

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The Influence of Subliminal Priming on Moral Decision-Making: A Comparative Analysis of Individual and Dyadic Judgments

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Introduction

Moral decision-making rarely unfolds in a vacuum; it is an intricate cognitive-affective negotiation, where ethical principles collide with the pragmatic contextual constraints. This study goes beyond the contrived theatrics of "sacrificing one to save many," by shifting the lens away from the well-trodden battleground between Deontology vs. Utilitarianism. By embedding scenarios mirroring everyday moral trade-offs, this study examines not only *what* choices are made, but *why* they emerge. This study is anchored with the Construal-Level Theory of Psychological Distance (Trope & Liberman, 2010), which explains how the perceived closeness modulates decision-making; and Social Influence theory (Kelman, 1953), which accounts for how mechanisms of compliance, identification, and internalization lead decisions to align with socially desirable norms. The Dual Process Model of moral judgment (Greene et al., 2001) and principles of Pre-Attentive processing (Treisman & Gelade, 1980) together explain how affective and automatic processes activated by subliminal moral primes interact with deliberate cognitive reasoning. This study investigates how subliminal moral priming, decision-making context (individual versus dyads), and social proximity from protagonists shape the nature of moral choices.

Hypotheses

- Participants will make significantly more altruistic decisions when exposed to positive subliminal moral primes, and more egoistic decisions when exposed to negative subliminal moral primes.
- Dyads will exhibit a greater inclination toward altruistic reasoning than individuals, reflecting the influence of collaborative deliberation and social desirability .
- Participants will make significant altruistic decisions in close social distance scenarios, and more egoistic decisions in distant social distance scenarios.

Methods

The study employs a mixed design with *subluminal priming* (positive vs. negative), *group* (individual vs. dyads), *social proximity* (close vs. distant) as independent variables, and *moral decision* (altruistic vs. egoistic) as dependent variable. The sample represents healthy young adults (ages 18 to 30 years; *n*=7 individuals, *n*=10 participants in 5 dyads) from Prayagraj, India. In the individual condition, participants make decisions independently. In the dyadic condition, both participants are instructed to sit together and engage in open discussion for 2 minutes, which is sufficient for meaningful moral deliberation (Navajas et al, 2019). Participants are required to complete the Self-Report Altruism Scale (Rushton et al., 1981). The experiment then begins with subliminal morally valenced lexical primes (e.g., *honesty*, *greed*), presented for 50 ms, and followed by forward and backward masking. The moral dilemma stimulus utilizes 20 moral dilemmas from EMCS scale (Singer et al., 2019).

Result

Descriptive statistics were computed for the two groups across the four experimental conditions: Positive and Negative Prime Accuracy for Socially Close (SC) and Socially Distant (SD) scenarios, as well as for Confidence Ratings. Mean accuracy scores were generally higher for the dyads across most conditions (Positive prime accuracy for SC: M = 3.40, SD = 1.14; Positive prime accuracy for SD: M = 3.80, SD = 1.30) compared to individuals (Positive prime accuracy for SC: M = 3.08, SD = 1.08; Positive prime accuracy for SD: M = 3.50, SD = 1.09). Similarly, dyads reported slightly higher mean confidence ratings (M = 4.23, SD = 0.34) than individuals (M = 4.15, SD = 0.48). The descriptive align directionally with proposed hypotheses suggesting that positive moral priming promotes more altruistic decision-making and dyadic participants tend to exhibit greater confidence and altruistic tendencies compared to individuals. However, no marked difference was observed between groups for negative primes or distant social contexts. While descriptive results support the theoretical direction of H1 and H2, the absence of statistical significance limits firm conclusions. Small sample size, small set of questions (moral dilemmas), and the use of nonparametric test likely contributed to lack of significant findings despite clear descriptive trends.

Discussion

Findings reveal a multifaceted architecture of moral cognition, wherein subliminal primes consistently shape moral decision-making, with positive primes fostering a greater tendency toward altruistic judgments and negative primes subtly increasing egoistic responses.

(Andersson et al., 2017, Liu et al., 2014). Decision patterns shift markedly towards egoism when deciding as individuals, reflecting a social desirability bias (Edwards, 1957). Interestingly, altruism is more often directed toward socially distant protagonists than close ones, hence, a “social distance paradox” emerges, as moral leniency is assumed for close relationships (Fiske, 1992). Altruistic decisions are made with significantly higher confidence, suggesting that prosocial actions are both socially endorsed and internally validated (Cialdini et al., 1997).While this study offers valuable insights, it is not without limitations as the moral dilemmas lack cultural salience for the Indian context. To strengthen the robustness and cultural validity of the study, we intend to expand the research by modifying the EMCS scale to include 40 contextually relevant Indian moral dilemma questions and by increasing the sample population, which is expected to enhance both sensitivity and generalizability of future findings.

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Mild Cognitive Impairment and Dementia: Comparative Analysis of Perceived Stress, Purpose of Life, Perceived Health, and Sleep Variables with Mediation and Moderation Findings

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Introduction

An estimated 8.8 million Indians over 60 suffer from dementia, with Kerala accounting for 8.27% of cases. Understanding the biopsychosocial factors influencing this condition is therefore essential for developing effective interventions. Purpose of life, perceived stress, perceived general health, and sleep characteristics are important aspects of well-being that can influence the risk and progression of dementia. Purpose of life, an existential resource, may buffer against neurological decline, while perceived stress and sleep disturbances are associated with adverse outcomes in dementia. Perceived health reflects overall physical and mental functioning, which in turn contributes to health outcomes. These constructs were observed to be studied individually, but comparative patterns between mild cognitive impairment (MCI) and dementia remain underexplored. Also, the mechanisms by which purpose of life influences perceived general health, and whether these mechanisms operate differently across stages of cognitive impairment, are not fully understood.

Research has shown that older adults with a higher purpose of life have a greater ability to cope with the stressors (Hutchinson & Warner, 2015; Lee et al., 2022), which in turn contributes to improved perceived health (Whitehead & Blaxton, 2021). Accordingly, it was hypothesised that the relationship between PoI and perceived general health would be mediated by perceived stress.

Additionally, a moderation analysis was conducted to explore whether the strength of the association between purpose in life and perceived stress differed by diagnostic group (MCI vs Dementia). The rationale behind this can be attributed to theories such as Frankl's "Will to Meaning" (1969), Stress and Coping Theory (Lazarus & Folkman, 1984), Self-determination theory (Deci & Ryan, 2000), and the Meaning-making model (Park, 2010), all of which state that a strong sense of purpose mitigates stress through adaptive appraisal and coping processes, which in turn promote better well-being. Research has shown that as cognitive decline progresses, individuals' autonomy, competence, self-efficacy (Lamont et al., 2020), stress perception, and coping flexibility (Helvik, 2021) diminish, thus reducing the buffering impact of purpose on stress. Hence, it was hypothesised that the relationship between PoL and perceived stress would be moderated by diagnosis.

Therefore, this study aims to compare MCI and dementia patients on these variables and whether perceived stress serves as a mediator linking purpose of life to perceived general health, and to examine whether diagnosis moderates the relationship between purpose of life and perceived stress.

Methods

Cross-sectional data were collected from 105 individuals (63 males, 42 females) aged 55 years and above with a clinical diagnosis of mild cognitive impairment and dementia. Participants were recruited through purposive criterion sampling. Inclusion was based on informed consent and the availability of a primary informant of individuals attending the neurology outpatient department and memory clinics with clinical suspicion or confirmed diagnosis of dementias, MCI or related conditions. Participants who were non-residents of Kerala were excluded from the study.

Participants completed the Purpose of Life (PoL) Questionnaire, Perceived Stress Scale (PSS), 36-Item Short Form Survey Instrument (SF-36) from which the general health domain was measured, and the Sleep Quality Assessment Tool, which assessed mean sleep duration and sleep quality. PoL is operationally defined as a complex, multidimensional construct that reflects the tendency to derive meaning from life's experiences and possess a sense of intentionality and goal-directedness that guides behaviour. A high score indicates a higher purpose of life. The PSS helps measure the degree to which situations in one’s life are appraised as stressful. Perceived stress scores of 0–13 indicate low stress, 14–26 indicate moderate stress, and 27–40 indicate high stress. SF-36 measures health-related quality of life, which consists of 8 domains. A high score in each domain defines a more favourable health state. The Sleep Quality Assessment tool assesses sleep duration and quality over the past 2 days, and if any medication is needed by the subject to go to sleep. Mean sleep duration is determined in terms of hours. Group comparisons were done using independent-samples *t*-tests and Mann–Whitney *U* tests where appropriate, and mediation and moderation analysis were conducted to examine the relationships.

Results

The sample size of the study was 105. The mean age of the cohort was 70.3, ranging from 55 years to 84 years. The mean age at leaving full-time education was 17.1 years, ranging from 7 years to 25 years. There were 3 illiterates, 8 primary schoolers, 66 high schoolers, 20 graduates, and 8 post-graduates. The sample included 62 persons with dementia and 43 with MCI. Of the patients with dementia, 52 patients were diagnosed with AD, 8 with VCI, 4 with mixed dementia, 2 with semantic dementia PPA, and 1 each with DLBD, behaviour variant FTD, non-fluent aphasia, posterior cortical variant AD, FTD overlap syndrome and CBD. 6 patients could not fill the questionnaire themselves, so caregivers were asked to fill the forms.

The mean ± SD of ACE and CDR - Sum of boxes score among MCI cases were 84.8 ± 10.1 and 1.85 ± 1.45, and that of Dementia cases were 69.8 ± 13.5 and 4.32 ± 2.67, respectively. No significant differences were found between MCI and dementia patients in their purpose in life ($t = -0.49$, $p = 0.62$), perceived stress ($t = -0.85$, $p = 0.39$), and perceived general health ($t = -0.11$, $p = 0.90$). There was a significant difference in mean duration of sleep between groups ($p=0.01$), with dementia patients having a high mean duration, whereas the quality of sleep was not statistically significant among the two patient groups ($p=0.14$). Mediation analysis showed a significant indirect ($\beta=0.654$, $p=0.021$) and direct effect ($\beta=1.760$, $p <0.001$). Hence, perceived stress partially mediated the association between purpose of life and general health. Moderation analyses revealed that diagnosis does not moderate the relationship between purpose of life and perceived stress ($p=0.519$).

Discussion

First, the lack of significant differences in psychosocial factors indicates that they affect both patient groups similarly. Consequently, these factors should be addressed equally, regardless of the degree of cognitive decline. Consistent with earlier research, a significant difference in mean sleep duration, with dementia patients reporting longer sleep, was observed. This can be attributed to neurodegeneration, alteration in circadian rhythms, and impaired arousal mechanisms, all of which are well-documented in dementia. These findings were in line with objective sleep measures. However, sleep quality did not differ between groups, indicating that longer sleep does not necessarily equate to better quality in dementia. Second, the mediation model indicated that people with a higher sense of purpose tend to have better perceived health, partly because they report lower stress. This is consistent with existing literature that depicts stress as a buffering factor. Third, the moderation analysis revealed that the negative relationship between purpose of life and perceived stress is consistent across both diagnosis groups. Together, these findings emphasise the importance of developing a sense of purpose in life as a general approach to improve well-being and encourage health-promoting behaviours that may support cognitive health across patient populations.

Including a matched control group for comparison and understanding the effects of demographic variables such as Educational attainments, co-morbid conditions, socio-economic status, and medication history would be a prospect for future studies.

Pilot observation from randomized controlled study on Cognitive interventions in early dementia.

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Introduction

The growing aging population has led to a rise in Mild Cognitive Impairment (MCI) and dementia, conditions that affect memory, attention, executive functions, and emotional well-being. The Earlier stages of these conditions represent a critical window for intervention, to preserve independence and slower the decline. This study evaluates the effectiveness of Supervised Cognitive Retraining (CRT) and Home-Based Cognitive Rehabilitation (HBCR) in early dementia over longitudinal follow-up.

Method

This randomized controlled trial included 25 participants, 10 in the CRT group [4 male, 6 female; Age (S.D) - 71.8(4.42)] and 15 in the HBCR group [8 male, 7 female; Age (S.D) -70.2 (7.05)] who went through comprehensive neuropsychological assessments at baseline, post-intervention, and one year. 10 participants received 12 sessions of supervised aptitude-based cognitive retraining over a period of 3 months. The sessions were conducted once a week for one hour, during which participants were trained on cognitive exercises aimed at improving various cognitive functions like attention, memory, visuo-spatial construction, executive functioning, language, etc. 15 participants underwent home-based cognitive rehabilitation where they were asked to perform other simple cognitive tasks at home with the help of bystanders at least 3 times per week for the same period. Anxiety, depression, daily living activities, and quality of life were also evaluated.

Data were analysed in SPSS v21. Normality was tested with Shapiro–Wilk; paired t-tests or Wilcoxon signed-rank tests compared pre- and post-scores, and Friedman tests assessed changes over time. Significance was set at $p < 0.05$ (two-tailed).

Results

There were no significant differences in baseline demographic or clinical data between the groups. Table. 1 shows the baseline, 3 month and 1 year follow up scores of the participants on the major cognitive tests for both groups.

Table. 1

	CRT group (n = 10)			HBCR group (n = 15)		
	Baseline	3 month	1 year	Baseline	3 month	1 year
CDR Sum of Boxes	3.55	3.89	4.70	4.43	4.04	3.66
ACE – III total Scores	78.50	81.33	77.80	78.13	82.33	78.87
IADL - CDI	25.80	22.94	29.42	21.83	20.72	15.56
IADL - PDI	2.51	4.70	10.86	2.30	4.50	7.22
HADS - Anxiety	5.00	3.89	2.40	5.2	3.4	3.06
HADS -Depression	5.60	3.11	2.20	3.67	2.50	2.33

CDR = Clinical Dementia Rating, ACE – III = Addenbrooke's Cognitive Examination – III, IADL = Instrumental Activities of Daily Living, CDI = Cognitive Disability Index, PDI = Physical Disability Index, HADS = Hospital Anxiety and Depression Scale.

For the CRT group, CDR – Sum of Boxes scores showed a small increase from baseline (M = 3.56; S.D = 2.13) to post intervention (M = 3.89 S.D = 1.65, p = 0.32) and to 1 year follow up (M=4.70, S.D = 3.74, p = 0.19). For the HBCR group CDR Sum of Boxes showed decrease in scores over time; baseline (M = 4.43, SD = 2.23), post intervention (M = 4.04, SD = 1.93, p = 0.48), 1 year follow up (M = 3.67, SD = 2.38, p = 0.12). Both interventions showed no statistically significant changes over time.

The CRT group showed increase in scores numerically at one year follow up for ACE – III memory subdomain (p = 0.34), RAVLT delayed score (p = 0.65) and significant improvement was only observed for Phonemic Fluency (p = 0.03).

The HBCR group showed increase in scores numerically at one year follow up for ACE – III attention (p = .33), category fluency (p = .26) and visuospatial subdomains (p = .78). A significant decrease in scores was observed for the anxiety subscale of the Hospital Anxiety and Depression Scale (p = .031).

At 1-year follow-up, the CRT group showed a significant improvement in the SF-36 Social Functioning domain (p = 0.04), while other domains in both groups showed a trend toward improvement without statistical significance.

Discussion

The study examined the effects of Cognitive Retraining (CRT) and Home-Based Cognitive Rehabilitation (HBCR) over a one-year period in individuals with early dementia.

No significant changes in CDR-SOB were found in either group. The CRT group showed a slight numerical increase, while the HBCR group showed a reduction in scores. The lack of statistical significance may be due to small sample sizes, individual variability. However, the relative stability of scores in both groups is notable given dementia's expected progressive decline.

In the CRT group, most ACE-III subdomains remained stable, with significant gains only in phonemic fluency, linking structured exercises to improved verbal retrieval and executive function. The HBCR group showed numerical gains in attention, visuospatial skills, and category fluency, suggesting daily mental engagement may help maintain cognition. These findings align with the cognitive reserve hypothesis, which proposes that targeted cognitive engagement can strengthen neural networks and delay symptom progression.

No significant change in IADL measures suggest functional maintenance or improvement in dementia is clinically meaningful, as it directly impacts quality of life and caregiver burden. A key finding was the consistent reduction in anxiety across both groups, with greater improvements in CRT, likely reflecting the benefits of its structured, socially engaging, and problem-solving elements. Depression also trended toward improvement, though without statistical significance—possibly due to limited sample size and variability. While SF-36 scores did not change significantly, several domains showed positive trends, suggesting that subtle psychosocial benefits may be achieved from both structured and home-based approaches. Although SF-36 scores didn't change significantly, trends toward improvement in key domains suggest that cognitive interventions, through enhancing self-efficacy and engagement, can positively impact perceived quality of life.

These preliminary results suggest that both CRT and home-based programs offer benefits in enhancing cognitive functions, emotional regulation, and functional maintenance. Despite potential confounding variables and limited control, the complementary strengths of both approaches provide feasibility evidence. Future large-scale studies following CONSORT guidelines should evaluate an optimized hybrid model integrating supervised and home-based components for optimal dementia care.

Effects of Theory of Mind like abilities in Conversational AI on mind perception by humans

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Introduction

In recent years, Conversational Artificial intelligence technology especially with Large language models has become part of our day to day life. AI systems are becoming more interactive and human-like in their communication and behavior. Recent studies investigating LLMs' ability to solve Theory of Mind (ToM) tasks hint that these systems are at least partially capable of inferring the intentions of their human counterparts (Kosinski, 2023). As a result of these advancements, users often attribute complex mental states such as understanding, intentionality, or even empathy to these AI systems (Thellman et al., 2022). According to Epley and Waytz (2010) the process of attributing mental states to others is called mind perception. Previous research has studied how different characteristics of the agents such as appearance, embodiment, identity, capabilities, behavior, communication style, gender, and voice can affect mind perception (Thellman et al., 2022). Studying how humans perceive AI systems is critical for developing social AI. We investigated whether people's tendency to attribute or perceive a mind in an AI is influenced by the AI's ability to demonstrate theory of mind in natural conversations.

Methods

We used audio-video clips of conversation between Human - Assistant (played by AI or Human) in daily scenarios. Each script has two versions. A. conversation between human and high ToM Assistant, B. conversation between human and low ToM Assistant. High and low ToM abilities were operationalized as follows: whether or not Conversational-AI can showcase abilities like handling false beliefs about human speakers, understanding implicit intentions, emotional states, beliefs of other humans about the speaker, deception and sarcasm. A rating study was conducted to validate the stimuli. A total of twenty-six participants with a mean age 24.7 (SD= 3.76) completed study. Participants rated the AI assistant's ability to recognize emotions, take perspective, understand the needs and intentions of the speaker, and respond appropriately on a scale of 1-5. Contexts with significant differences in High vs Low ToM condition were selected for the main experiment. The main study was conducted with twenty-two healthy graduate students with a mean age of 22.3 years (SD= 2.2 years, 13 females). Participants were randomly divided into two groups. Group 1 watched 4 videos of Human-AI interaction and 4 videos of Human-Human interaction where the assistant had a high ToM. Group 2 watched the same scenarios where assistant had low ToM. After watching the videos participants were asked to fill a Mind Perception Questionnaire adapted from Gray (2007). The questionnaire measured mind perception on experience and agency dimension using ratings on 18 items. Later participants were shown a short clip of Human-AI interaction where AI produces white-lie and then asked to fill implicit mind perception questionnaires, an adaptation from Banks (2021) white lie evaluation.

Results

Scores of 21 participants (11 HighToM AI group and 10 LowToM AI group) on 18 items of mind perception questionnaire were consolidated and analyzed using jasp. These items were loaded on Experience (Hunger, Fear, Pain, Pleasure, Anger, Desire, Personality, Consciousness, Pride, Embarrassment, Joy) and Agency (Self-Control, Morality, Memory, Emotion Recognition, Planning, Communication, Thought) dimensions based on study by Gray et al. (2007). Acrossall participants, the mean Experience score was 2.65 (SD = 0.69) for the HighToM AI and 2.08 (SD = 0.57) for the LowToM AI, while the mean Agency score was 4.08 (SD = 0.53) for the HighToM AI and 3.37 (SD = 0.50) for the LowToM AI.

Welch’s t-tests were conducted to compare the Experience and Agency means between the High ToM (HT) and Low ToM (LT) groups. For Experience, the HT group (M = 2.65, SD = 0.69) showed a marginally higher mean compared to the LT group (M = 2.08, SD = 0.57), t(18.88) = 2.08, p = 0.051, Cohen’s d = 0.91. For Agency, the HT group (M = 4.08, SD = 0.53) was rated significantly higher than the LT group (M = 3.37, SD = 0.50), t(18.97) = 3.14, p = 0.005, Cohen’s d = 1.37, reflecting a large effect. Item-level comparisons using Mann-Whitney U tests revealed significant differences for Hunger (U = 90, p = 0.011, r = 0.64), Morality (U = 84, p = 0.035, r = 0.53), and Memory (U = 84.5, p = 0.022, r = 0.54), with High ToM AI being consistently rated higher. Other items showed no significant differences.

Analysis of implicit mind perception questionnaires showed four participants from the HT-AI group provided mentalistic explanations for AI’s lying behavior. Only one participant from the LT-AI group provided a mentalistic explanation for the AI's white lie. Four participants chose hybrid explanations, but explicitly mentioned that AI was programmed or trained to do so.

Nine participants chose exclusively Mechanistic response (1- HT-AI group and 8- LT-AI group).

Discussion

The ratings on the Mind perception questionnaire showed that a high-ToM AI system was rated significantly higher on agency and marginally higher for experience dimension than low-ToM AI despite having similar technical capabilities. Analyzing participants' explanation about white lies by AI assistants, we found that human's tendency to explain AI's white lies in terms of mentalistic explanations increases as AI demonstrates ToM-like abilities. Participants frequently interpret the AI's positive feedback as intentional, aligning with human-like motivations like kindness or empathy, and social etiquettes. Participants also show a tendency to oscillate between viewing the AI as a social agent and a programmed system. Results suggest, as AI systems demonstrate "Theory of mind-like" abilities humans increasingly attribute mental capacities to these systems. Perception of mind in AI systems has an impact on trust, usability and ethical alignment of the system. Studying human AI interaction with a mind perception lens presents both opportunities for enhancing human-AI interaction across various domains and risks related to user misconceptions and ethical considerations.

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Investigating the latent cognitive variables that facilitate the relationship between suggestibility and placebo responding within the predictive processing framework

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Introduction

The placebo effect refers to a positive response (e.g., pain reduction) to an inactive treatment or procedure. This effect varies considerably across individuals but the neurocognitive sources of this variability remain poorly understood. An important component of the efficacy of placebo interventions is suggestions, a communication for an involuntary change in awareness, perception or behaviour (e.g., "this medication will reduce your pain").

Individuals vary in their trait responsiveness to hypnotic suggestion and verbal suggestions (REVS) (i.e., direct verbal suggestibility) and previous research has suggested that REVS weakly predicts placebo hypoalgesia (pain reduction) in a controlled experiment (Parsons et al., 2021). Bayesian models of pain perception (Strube et al., 2023; Anchisi et al., 2015) attribute placebo effects to an interaction of the prior (e.g., expected pain) and the likelihood. Strube et al. (2023) assessed whether a placebo suggestion attenuates pain ratings by shifting the prior (e.g., lowering expected pain) (prior shift model), or by decreasing the precision of the likelihood (e.g., lowering the attention paid to incoming nociceptive stimuli) (Likelihood precision model), or both. They demonstrated a better fit for the prior-shift model over the likelihood-precision model. This highlighted the prior's central role but did not disambiguate between a shift in the prior's mean versus a change in its precision.

In this study, we sought to compare these competing prior-based mechanisms to identify which best explains variability in placebo hypoalgesia through a re-analysis of a previously-published experiment (Experiment 1; Parsons et al., 2021).

Methods

This study involved a re-analysis of data from Experiment 1 of a study by Parsons et al. (2021), which used a repeated-measures design to assess placebo hypoalgesia responsiveness to a suggested hypoalgesia procedure in a single session. In the original study, participants were given verbal suggestions that a (sham) cream (moisturiser) applied to one region of their forearm (placebo) would reduce pain whereas another cream presented as a sensory control (in actuality the same cream) applied to another region of the forearm would have no impact.

In the experimental phase, participants received electrical stimulation to the two regions over 64 trials and on each trial rated their expected pain and their actual pain. Stimulation amplitude remained uniform across all stimulation areas and trials (60% of pain threshold).

In the re-analysis, trial-by-trial pain expectancy and pain intensity ratings (on a 0-100 visual analogue scale) were analyzed. Pain perception was formalized as a process of Bayesian inference, where prior beliefs (pain expectancy ratings) are integrated with sensory evidence (nociceptive input) to produce a final pain percept (the posterior).

Three distinct computational models were fitted to each participant's pain rating data: 1) a prior-shift model, where the placebo effect is driven by a shift in the mean of the prior distribution; 2) a prior-precision model, where the effect is driven by a change in the precision (inverse variance) of the prior; and 3) a prior-shift-precision model that included both mechanisms. Model parameters were estimated using variational Bayesian methods, and the models were formally compared for each participant using a random-effects Bayesian model selection procedure to determine the most likely generative process underlying the observed data. The best fitting model was selected based on a comparison of RFX probability of each model for every participant. The parameter estimate of the overall best performing model was assessed for correlation with the magnitude of the placebo effect and with suggestibility scores for each participant.

Results

The model comparison revealed a clear and dominant mechanism. The prior-precision model provided the best fit for the pain ratings of the majority of participants (79%). The combined prior-shift-precision model best explained the data for a smaller subset of participants (15%), who notably exhibited larger placebo effects. Thus, the latent cognitive parameter of prior precision was found to be the dominant mechanism implicated in the placebo effect for most individuals.

To further probe the role of prior precision, a correlational analysis was performed between the estimated model parameters and (i) the observed placebo effect (control pain – placebo pain) and (ii) hypnotic suggestibility.

This analysis revealed a significant positive correlation between the average prior precision parameter and the magnitude of the placebo effect ($r = .46$, $p < .001$), indicating that individuals who formed more precise expectations about pain relief experienced greater pain Reduction.

However, no significant relationship was found between suggestibility and the average prior precision (r = -0.087, p= 0.52).

Discussion

These findings provide strong evidence that placebo hypoalgesia is primarily mediated by an increase in the precision of prior beliefs about pain, rather than simply a shift in the expected level of pain. This directly explains a source of the well-known variability in the placebo effect: differences in their latent capacity to form and deploy certain expectations. This parameter, thus, quantifies a key source of individual differences.

The observation that individuals with the largest placebo effects recruit both prior-shifting and precision-enhancing mechanisms suggests that the best results are achieved in placebo pain reduction when an individual both forms a lower expectation and is more confident in his/her expectation. This computational approach provides a robust method for moving beyond descriptive accounts of the placebo effect to formally quantify its latent cognitive architecture. Future work will apply this framework to the dataset from experiment 2 of the study by Parson et al. (2021) which involved a direct measure for REVS.

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Stimulus frequency influences visual filling in differently according to frequency: A comparative study linking visual field and visual binding

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Introduction

People suffering from damage to retina or visual pathways often report scotomas, in which they are blind or have degraded vision in a portion of their visual field. In the case of a blind spot, patterns from areas of the neighbouring visual field ‘fill in’ to occupy the blind region. As a result, we often do not notice the blind spot. It is possible to create an artificial scotoma in a part of the visual field, which can be filled in based upon the quality of neighbouring visual information (Ramachandran & Gregory, 1991). The temporal characteristics of this perceptual filling-in process is not fully understood, and this study aims to investigate the dependency of the filling-in-process on process frequency. Based upon earlier studies (i.e. Elliott, 2014; Elliott et al., 2015; Seifert et al., 2010), certain frequencies might be considered as facilitatory, neutral or inhibitory with respects to visual processing. We used these frequencies to test the time take for the filling-in-process.

Methods

Participants

Seventeen volunteers (*mean age:* 24.05 years, female: 7) participated in the study after providing informed consent. All the participants had normal or corrected-to-normal vision. The study was approved by the Institutional Ethics Committee.

Stimuli, and apparatus

The stimuli were presented on a 24” monitor with a refresh rate of 540 Hz and screen resolution of 1920 x 1080. A homogeneous grey square subtending 2°x 2° was displayed against a background of dynamic (flickering) Gaussian noise (mean = 0, SD = 0.3). This square was 9o away in the left upper quadrant from the central fixation grey square (1°x 1°). The luminance of the grey squares was the same as that of the Gaussian noise (30 cd/cm2). The Gaussian noise subtended an overall visual angle of 25° by 25° covering the overall area of 128 x 128 pixels. The subjects sat 60 cm away from the screen and were told to fixate steadily on the fixation square and avoid eye-blinks. Their task was to press the space key as soon as the left grey square blended with the Gaussian noise. The frequency of the Gaussian flicker was randomly presented from a set of six frequencies categorized as 'Facilitatory', 'Inhibitory', or 'Neutral'. Facilitatory frequencies were 33 and 38 Hz. Neutral frequencies were 31 and 60 Hz. Inhibitory frequencies were 49 and 36 Hz. Participants' response times were captured as the dependent variable. There were total 120 trials (40 trials in each frequency condition). The experiment took place in a dark room and participants viewed the display from 60 cm. Stimulus presentation and timings were controlled using PsychoPy software (version 2024.1.5) (Peirce et al., 2019).

Results

For each participant, trials having response times 2 standard deviations plus or minus the mean for a given condition were removed. Paired sample t-tests were conducted with Bonferroni correction for all the three comparisons involving the facilitatory, neutral and inhibitory conditions. Results showed a significant difference between Facilitatory and Inhibitory frequencies ($t(16) = 2.71$, $p = 0.04$, $d = 0.65$). There was no significant difference between Facilitatory and Neutral ($t(16) = 0.82$, $p = 0.1$, $d = 0.19$) or Inhibitory and Neutral frequencies ($t(16) = 1.04$, $p = 0.18$, $d = 0.48$).

Discussion

The results indicate that the filling-in-process has the faster response time with some stimulus frequencies relative to others. Attributable to an effect of enhanced visual binding (Elliott, 2014) and linked with organization of the visual field (Seifert et al., 2009), this offers further evidence that visual organization is facilitated (and therefore takes place) at some frequencies, but that there are others that are not optimal for this process. Regarding visual field, this differentiation of frequencies seems to be an important description of the process subserving visual filling-in.

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Beyond Statistical Learning: Attentional Engagement Shapes Distractor Suppression

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Introduction

Human visual system is adept at extracting statistical regularities from environment to guide attention. In visual search, such visual statistical learning (VSL) facilitates target detection or distractor suppression based on learned feature–location contingencies. Early work suggested that VSL was automatic, but recent evidence using non-salient distractors indicates it requires attentional engagement. Duncan et al. (2025) proposed that VSL operates via feature–space binding: encoding what appeared and where. We examined whether the strength of distractor regularity modulates attentional engagement using oculomotor measures. By manipulating the regularity of a non-salient, high-probability distractor (HPD): probabilistic 67% condition (Experiment 1) and deterministic 100% condition (Experiment 2), we predicted that suppression would emerge robustly under higher regularity and that eye-movement data would reveal effects not captured by RTs.

Methods

In Experiment 1, we expected a moderate effect due to variable learning, whereas in Experiment 2, suppression might be consistent but subtler in RTs, requiring a larger sample for reliable estimation (n = 30 for Experiment 1, n = 60 for Experiment 2). Both experiments used the modified feature-search task (Duncan et al., 2025). The search array contained six green geometric shapes (a Target, a High-probability Distractor (HPD), and Non-high-probability distractors - NHPDs) arranged in an imaginary circle. Each shape contained either a horizontal or a vertical line inside them. Participants reported the line orientation in the target shape (e.g. Square).

Each experiment comprised a training and testing phase. SR Eyelink 1000 plus eyetracker was used to record participants' eye movements throughout both phases. The participants were informed that their eye movements were being recorded as they searched for the target. In the training phase, the HPD appeared in a fixed location on 67% of total trials in Experiment 1, and 100% of total trials in Experiment 2. In the testing phase, the HPD shape in the training phase became the new target and all shapes appeared with equal probability across locations.

Results

Experiment 1:

We performed RM ANOVA on RTs, during training phase, with Target-location (at the HPD location vs other locations) and Blocks (1,2,3) as within-subject factors. We found significant main effects of blocks $F(2, 60) = 54.13$, $p < .01$, $\eta^2p = .64$, indicating RTs improved across blocks. There was no main effect of Target-location ($F < 1$) indicating target's location did not influence RTs and no interaction between Target-location and Blocks ($F < 1$). RM ANOVA on fixation proportions, with Objects (Target, HPD, NHPD), Blocks and Time-window (50–300ms, in time bins) as within-subjects factors, showed highest fixations to the target over HPD and NHPDs $F(2, 60) = 134.36$, $p < .01$, $\eta^2p = .82$. There was no difference between the fixations to HPD over NHPDs indicating that HPD was not suppressed.

During testing phase, RTs improved across blocks $F(1, 29) = 28.079$, $p < 0.01$, $\eta^2_p = 0.492$ but were unaffected by whether the new target appeared in its HPD location or at other locations. We performed an RM-ANOVA on the proportion of fixations with Object (Old Target, New Target, NHPD), the New-target's location (HPD location vs. other locations), Blocks, and Time-window (50–300ms in time bins) as within-subject measures. We found significant main effects of Object $F(2, 58) = 57.559$, $p < 0.01$, $\eta^2_p = 0.69$, New-target's location $F(1,29) = 4.667$, $p = 0.039$, $\eta^2_p = 0.139$, and Time-window $F(5,145) = 315.464$, $p < 0.01$, $\eta^2_p = 0.91$ only. Pairwise comparison of proportion of fixations showed significantly more fixations to the old target compared to NHPDs $t(29) = 2.16$, $p<0.05$. These findings indicate that participants tried to reorient their attention from the old target to the new target, consistent with the task's changing goal. Experiment 1 shows no behavioural or oculomotor evidence for VSL at 67% regularity.

Experiment 2:

During training phase, RTs were slower when the target appeared closest to the HPD location, $F(2, 116) = 4.96$, $p < .009$, $\eta^2p = .08$, indicating location-based suppression. Further, proportion of fixations favoured the target over HPD and NHPDs, $F(2, 106) = 134.96$, $p < .01$, $\eta^2p = .84$. There was suppression of HPD compared to NHPDs as indicated by significantly fewer fixations towards HPD than NHPDs $t(53) = 3.227$, $p<0.05$. During testing phase, RTs showed significant improvement across blocks $F(2,112) = 33.09$, $p <0.001$, $\eta^2p = 0.37$, owing to practice effect. There was no significant cost in RTs when the new target appeared at its previously suppressed location (HPD Location). In contrast, RM-ANOVA of proportion of fixations revealed significant main effects of Object-type (new-target, old-target, NHPD) F(2,

106) = 28.04, $p < 0.001$, $\eta^2p = 0.35$, Time-window (50-300ms) F(5, 265) = 209.1, $p < 0.001$, $\eta^2p = 0.79$, New-target's location (Previously HPD location vs other locations) F(1, 53) = 8.1, $p < 0.01$, $\eta^2p = 0.13$, and Block F(2, 106) = 5.4, $p < 0.01$, $\eta^2p = 0.092$. The interaction effect between Block (1,2,3), Object (New Target, Old Target, NHPDs), Time (50-300ms) and Target Location (HPD location vs other locations) is also significant F(20, 1060) = 1.75, $p < 0.05$, $\eta^2p = 0.03$. This revealed that the old-target interfered with searching for the new target when the new-target appeared in its previously suppressed location compared to other locations. Overall, 100% regularity yielded clear suppression in RT and fixations during training. While suppression persisted in fixations during testing, it did not produce robust RT costs.

Discussion

The study revealed that VSL's contribution to distractor suppression depends on the strength of the regularities. There was no evidence of HPD suppression at 67% regularity suggesting that moderate probability may be insufficient for learning non-salient distractor regularities. This aligns with Duncan et al's (2025) finding that attentional engagement is a prerequisite for VSL, and such engagement can be minimal under probabilistic, low-salience conditions. At 100% HPD regularity, suppression emerged robustly, with slower RTs and fewer fixations for targets near the HPD location, as well as reduced fixations toward the HPD itself. Because all items were simple geometric shapes of a single colour, participants could not rely on unique object identities, but instead had to learn that a *feature* (the distractor shape) was likely to occur in a specific location. Our findings support a feature–space binding interpretation (Duncan et al., 2025), rather than an object–space binding account. Absence of robust RT costs in testing suggests that top-down goals can override learned spatial biases when they conflict with current objectives (Theeuwes, 2025). The findings are consistent with the updated signal suppression account (Gaspelin et al., 2025), such that attentional engagement likely determines whether statistical regularities are encoded in the first place. These findings highlight that attentional engagement is critical for encoding environmental regularities, with implications for understanding how suppression operates in dynamic visual environments.

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How do we stop? An Investigation of Global and Selective Response Inhibition Mechanisms

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Introduction

Response inhibition is the ability to stop inappropriate responses[1]. Several clinical populations such as Tourette's have deficient response inhibition which highlights the need to understand the mechanisms underlying response inhibition to develop better treatments. Although response inhibition is typically studied using single effector movements, many of our everyday actions involve multiple effectors, like bimanual responses. Previously, studying eye-hand movements in different task contexts, it has been suggested that multi-effector movements can operate in **coupled** or **decoupled** mode, which is read out as differential levels of reaction time (RT) correlations. However, this differential mode of operation has not been tested for bimanual movements. Intuitively, in contexts such as batting in cricket, which require high coupling between the effectors, the two hands may be initiated by a common 'go' process. Whereas, in contexts such as playing the piano, which require decoupling of the effectors, the two hands may be initiated by independent 'go' processes. Does this influence how the effectors are stopped - by a common 'stop' or independent 'stop' processes, respectively? In other words, when these movements need to be rapidly stopped, it could be neurally implemented via the faster, hyperdirect pathway of the basal ganglia (**global inhibition** which affects both effectors) or via the slower, indirect pathway (**selective inhibition** which affects only the relevant effector)[1]. This would have specific behavioural signatures which are tested in this pilot study.

Method

Participants (N=9; age=22.7±1.2 years; females=5; 1 participant not included due to poor behavioural performance) performed a modified stop signal task which had two types of trials: unimanual (500 trials) or bimanual (400 trials). In the unimanual trials, depending on the direction of the go signal, participants responded with either hand. In the bimanual trials, participants responded to the go signal with both hands (**Go RT**). In both types of trials, when a stop signal was presented in 40% of the trials, they stopped one hand but continued with the other hand (**Continue RT**) for bimanual trials. Depending on when the stop signal was presented with respect to the go signal, the participants either succeeded or failed in stopping the response. We calculated the time taken to stop the response (SSRT, stop signal reaction time) using the integration method[1].

To modulate the level of coupling between hands (RT correlations), we had two conditions in which the bimanual responses must be made: blocked (400 trials) and interleaved (500 trials). The blocked condition had only bimanual trials where both hands had to respond to a common go signal. In the interleaved condition, both unimanual and bimanual trials were present in a 60-40 ratio and critically the go signal for the two hands in the bimanual trials was different (the ratio was selected to ensure enough bimanual trials while still being infrequent). We anticipated that this would promote greater decoupling of the effectors in the interleaved condition compared to the blocked condition. Consequently, drawing inspiration from eye-hand studies, we hypothesized that in the blocked bimanual trials, stopping of the coupled hands would be mediated by global inhibition followed by selective reinitiation of the continuing hand. Thus, SSRT would be shorter, but RT of the continuing hand would be longer. In contrast, in the interleaved bimanual trials, stopping of the decoupled hands would be mediated by selective inhibition. Thus, SSRT would be longer, but RT of the continuing hand would be shorter.

Pearson's correlation coefficient was used to measure RT correlations. Wilcoxon signed-rank tests (non-parametric equivalent of one-sided paired samples t-test) were used to test for significance.

Results

Across participants, correlation between the RTs of the left and right hand tended to be lower in the interleaved bimanual (r=0.6±0.3) as compared to the blocked bimanual condition (r=0.8±0.3), suggesting greater decoupling in the interleaved condition. However, this difference was not significant *(*p=0.070*)*. Interestingly, consistent with our hypothesis, SSRT was greater for the interleaved bimanual (264.6±8.6ms) compared to the blocked bimanual condition (218.5±22.5ms; W(7)=32; p=0.027). This suggested that selective inhibition may be mediating the selective stopping of one hand in the interleaved condition while global inhibition may be stopping both hands in the blocked condition (followed by re-initiation of the continuing hand). Then we compared the RT of the continuing hand to the go RT, when one hand was successfully stopped or failed to stop. When one hand was successfully stopped, the continuing RT was significantly greater than go RT in both interleaved

(RTGo=730.8±24.7ms, RTContinue=826.7±38.0ms; *W*(7)=36; *p*=0.004) and blocked conditions (RTGo=714.7±25.1ms, RTContinue=829.2±36.0ms; *W*(7)=36; *p*=0.004). When one hand failed to stop, the continuing RT was significantly lower than the go RT in both interleaved (RTContinue=688.0±20.5ms; *W*(7)=36; *p*=0.004) and blocked conditions (RTContinue=670.8ms±27.4ms; *W*(7)=36; *p*=0.004). This pattern where the continueRT is slower or faster depending on whether the other hand is stopped or not might suggest an interplay between global and selective inhibition which will be investigated in the future.

Discussion

This ongoing study tests whether task contexts influence the mechanism by which multi-effector response inhibition is mediated. The data collection is ongoing, and preliminary analysis suggests recruiting global inhibition in the blocked and selective inhibition in the interleaved task conditions, but this needs further testing. This will be followed by computationally modelling the Go RTs and SSRTs to test whether a common vs. separate stop processes fit the behavioural data better in the different conditions.

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Relationship of Age, Cognition, and Brain Structural Volume in Healthy Adults

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Introduction

Aging is associated with structural and functional changes in the brain, especially in regions important for executive function, memory, and response inhibition (Long et al., 2012). While ageing-related brain changes have been extensively studied, normal aging has often been examined without adequate control for physiological health conditions such as diabetes and hypertension, typically observed in aging. Previous studies have shown a link between temporal lobe or hippocampal atrophy and memory performance (Fletcher et al., 2018; Tisserand et al., 2000). On the other hand, volume of regions like Basal Ganglia (BG) do not have a consistent relationship with cognitive performance (Fjell & Walhovd, 2010). By analyzing the volumetric changes across key brain systems- the prefrontal cortex (PFC), medial temporal lobe (MTL), and basal ganglia (BG), we aimed to characterize additional structural trajectories of aging and their relationship to cognitive performance in a healthy ageing cohort.

Methods

This is an ongoing study. Data from young N= 90 (19–30 years), middle-aged N= 27(40–50 years), and older N= 20 (60-71 years) adults, Telugu natives, without any chronic illness/prescribed medication was analyzed. Participants were screened for MCI using MoCA. Structural T1-weighted scans were collected using 3T-MRI at a diagnostic center along with cognitive tasks measuring working memory (N-BACK), sustained attention (SART), and verbal learning and retention (RAVLT). T1-weighted MRI images were processed using FreeSurfer's standard recon-all pipeline for extracting gray matter volumes. Brain regions were grouped as PFC (caudal-middle-frontal, superior-frontal, frontal pole, lateral orbitofrontal, medial orbitofrontal, pars-triangularis, pars-orbitalis and rostral anterior cingulate), MTL (entorhinal, fusiform, parahippocampal, middle temporal and temporal pole), and BG (caudate, putamen, pallidum and accumbens-area).

Results

We performed one-way ANOVAs using age (young, middle, old) as a between-group factor to assess volumetric differences in each of the three brain regions PFC, MTL, and BG and corresponding cognitive tests. We observed a main effect of age on PFC volume ($F(2, 134) = 26.59$, $p < .001$, $\eta^2 = .28$); MTL volume ($F(2, 134) = 17.93$, $p < .001$, $\eta^2 = .21$), and BG ($F(2, 134) = 11.21$, $p < .001$, $\eta^2 = .14$). Post-hoc tests showed that PFC, MTL, and BG volumes significantly decreased from young to middle age ($p<0.01$) but volumes did not decrease further from middle to old age ($p>0.2$).

To assess the effect of age (young, middle, old) on performance in RAVLT, SART and NBACK tests, we conducted one-way ANOVAs. We observed a main effect of age on delayed recall- RAVLT ($F (2, 128) = 12.487$ $p < .001$, $\eta^2 = .163$), SART accuracy ($F(2, 128) = 12.71$, $p < .001$, $\eta^2 = 0.161$), and but no effect on N-BACK performance. Post hoc tests revealed that delayed recall-RAVLT and SART accuracy significantly decreased from young to middle age ($p<0.01$) but volumes did not decrease further from middle to old age ($p>0.08$).

Partial correlations controlling for age showed no significant relationship between SART accuracy and basal ganglia volume ($r = .09$, $p = .30$), 2-back accuracy and PFC volume ($r = .15$, $p = .10$), and delayed recall and MTL volume ($r = –.07$, $p = .46$).

To assess if age and brain volume predict cognitive function, we used Generalized Linear Model (GLM) with Gaussian distribution. For 1-back accuracy and 2-back accuracy metrics from the N- BACK test, neither age ($p > 0.49$) nor the PFC volume ($p > 0.29$) was a significant predictor. For delayed recall on RAVLT, only age was a significant predictor ($R2\ cs = 0.1593$, $\beta = -0.0759$, 95% CI [–0.109, –0.043], $p < .001$) while MTL volume ($p = 0.46$) was not. For SART accuracy, only age ($R2\ cs = 0.16$, $\beta = -0.0011$, 95% CI [-0.002, -0.001], $p < .001$) was a significant predictor and not BG volume ($p = 0.29$).

Discussion

This study highlights the role of aging in driving structural changes in brain and cognitive performance. We found a similar trajectory for age-related volume loss across PFC, MTL and BG regions and an identical trajectory of performance on SART (BG dependent) and RAVLT (MTL dependent); difference is seen in young-middle and young-old but no difference in middle-old. This trend is consistent with other studies (Aron et al., 2004; Ferneaus et al., 2013; Van Schouwenburg et al., 2010). The plateauing of regional volume and cognitive performance from middle to older adults has been observed in a similar ‘healthy’ cohort (Tisserand et al., 2000).

The N-BACK task, however, remained unchanged with age even with a linear decline in PFC volume with age, (Lamichhane et al., 2020; Li et al., 2005). This dissociation may reflect compensatory mechanisms across the neural networks to preserve working memory performance. This dissociation aligns with the Scaffolding theory of aging and cognition (Goh & Park, 2009) which proposes there are functional changes in brain throughout life to compensate for cognitive decline.

Overall, the study shows that age-related decline follows different trajectories (plateau/compensation) across cognitive domains and may be reflected differently in cognitive performance depending on the underlying neural systems involved. Brain shrinkage may be a marker of aging rather than the direct cause of reduced cognitive function. Age predicts decline, but brain volume does not.

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Keynote 4 **Chair: Niharika Singh**

Towards a typology of language processing

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Do typologically distinct languages (e.g., Subject-Object-Verb vs Subject-Verb-Object languages) employ different processing strategies? Can certain processing strategies or constraints be deemed universal that hold across languages? In this talk, I weigh in on these questions by presenting new data on processing in various Subject-Object-Verb (SOV) languages spoken in India, such as, Hindi, Bengali and Malayalam. From a comprehension perspective, we will first discuss how top-down and bottom-up processes affect processing of verbs, word order and morphology. From a production perspective, we discuss data on planning of verbs and word order. The results highlight processing tendencies that can be understood as adaptations driven by the typology of the language — (a) during sentence comprehension, the top-down process is sensitive to the nature of the clause final verb type, the SOV word order and verbal morphology, (b) during sentence production, there is a tendency to formulate a long-before-short word order and to plan the verb before subject onset in certain linguistic configurations. Interestingly, the results also provide evidence that these processes are influenced by resource considerations that can be deemed as universals holding across languages — (a) prediction of the clause final verb and non-canonical word order during sentence comprehension decreases when the preverbal linguistic complexity increases, (b) in addition to a long-before-short word order, a significant amount of short-before-long word order is also visible during sentence production. Together, these results shed new light on processing of SOV languages and also help us uncover the nature of linguistic representations and processes that subserve comprehension and production across typologically distinct languages. The results highlight how processing strategies are shaped by both typologically-driven features as well as by universal cognitive constraints.

Number-Feature and Noun Representation Distortion in Hindi Sentences

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Introduction

How do working memory constraints modulate the real-time sentence comprehension process in humans? A recent proposal is representation distortion, where the representation of sentence material stored in memory probabilistically distorts into a non-veridical representation over time (Yadav et al., 2023; Futrell et al., 2020). The memory representation can change or even be lost due to distortion, which occurs as a result of deletion errors, insertion errors, or feature misbinding errors. The representation distortion proposal has received reasonable empirical support from self-paced reading, eye-tracking, and acceptability judgment studies (Yadav et al., 2023; Husain et al., 2025). The proposal is theoretically important for two reasons: (i) it completely changes the view of how working memory processes underlie sentence comprehension; the existing theories of sentence comprehension hold that the representation of sentence material stored in memory remains intact, i.e., does not undergo any distortion (Lewis and Vasishth, 2005), and (ii) it aligns well with literature on visual processing literature where feature misbinding errors are observed when the representation of an object is stored in memory (Bays et al. 2016); thus, the proposal can contribute to developing a domain general theory of cognition.

Given the theoretical importance of the representation distortion proposal, we tested whether it holds in Hindi, a verb-final, richly case-marking language. Such languages are important test cases because they show weak evidence for key working memory effects that are well-attested in English.

We investigate whether pre-verbal nouns undergo representation distortion and whether this affects the processing of argument-verb dependencies in Hindi. We use an acceptability rating study to assess the kinds of distortion that may occur during comprehension by examining the differences in how participants rate sentences that are inherently ungrammatical (i.e., that cannot be made grammatical by minor feature changes) and ungrammatical sentences that participants could distort to make grammatical. Husain et al. (2025) observed that case marker deletion/exchange errors occur during Hindi sentence comprehension, and participants distort ungrammatical sentences.

We present a pilot study, where participants did not find the hypothesised distortable ungrammatical sentences more acceptable than inherently ungrammatical ones, indicating that number features on the subject noun are not distorted. However, participants found it easier to distort noun representations in pragmatically unsound sentences to meaningful ones, as compared to those in which animacy was violated. Thus, while the distortion of the subject number-feature was not observed, noun distortion was evident in the case of pragmatically unsound sentences.

Methodology

A pilot was conducted, where we used an *acceptability judgement study* to assess the kinds of distortion that may occur during comprehension by looking at the differences in how participants rate sentences that are inherently ungrammatical (i.e, that cannot be readily made grammatical by making feature changes), and ungrammatical sentences that participants could distort (to a grammatical version) by making minor feature changes (referred to as '*distortable*' sentences further). This paradigm has been adapted from Husain et al. (2025), who observed that case marker deletion/exchange errors occur during sentence comprehension in Hindi; participants distort ungrammatical sentences to a grammatically correct representation.

Participants: N = 12 native Hindi speakers.

Stimuli: Hindi sentences were presented in the form of phrasal chunks.

Procedure

Participants' acceptability ratings were recorded in a PCibex-designed self-paced reading study. They pressed the spacebar to continue reading phrasal chunks. After the last chunk of each sentence, they rated acceptability on a sliding scale (1-100). Some sentences were followed by attention checks (yes/no comprehension questions). Reading times were also recorded.

Experiment Design: Each participant was shown 108 sentences (including 44 fillers, designed to be structurally similar to the experimental conditions). These were sampled using a Latin Square design from the study's two sub-experiments – Number Feature Distortion (40 sentences) and Noun Distortion (24 sentences). The sentences (and their lengths) were balanced for grammaticality in a 1:1 ratio.

Experiment 1: Number Feature Distortion

In these conditions, 8 conditions (2 grammatical and 6 ungrammatical) were designed to capture the impact on agreement processing for different combinations of (mis)matches between the subject noun, the distractor noun, and the verb. The first two conditions are grammatical; however, according to the feature percolation account, in condition *b,* the plural feature on the distractor noun could percolate to the target noun, leading to differences in acceptability ratings and reading times. Conditions *c-f* are ungrammatical but hypothetically distortable. For example, in condition *c*, the plural feature on the distractor noun could percolate to the target noun to make it appear in agreement with the plural verb. However, this would not be observed for the remaining conditions due to the 'Markedness Effect' (only marked features can percolate). Prepositional phrases were added to balance the pre-critical and post-critical regions (critical region: subject-noun phrase). The baseline ungrammatical conditions use the word 'एक' (*one*) as opposed to 'वो' (*him/her*) before the subject-noun phrase. As the former is a number-indicating word, it makes the noun-verb disagreement more apparent, and thus more difficult to distort.

Results

ANOVA and mean acceptability-rating analysis on the number-feature distortion experiment data showed that participants found completely grammatical sentences to be significantly more acceptable than the ungrammatical ones. However, baseline ungrammatical and distortable sentences were not found to be significantly different. ANOVA on Reading Time data revealed no significant difference between any conditions.

Experiment 2: Noun Distortion

In this sub-experiment, six conditions (one grammatical and five ungrammatical) were manipulated to assess the impact of systematically interchanging case markers between animate noun 1, animate noun 2, and the inanimate noun (instrument) in *role relationship sentences* on argument integration at the verb. Prepositional phrases were added to balance the pre-critical and post-critical regions.

Results: An ANOVA on the noun representation distortion experiment data revealed that participants found the grammatical condition significantly more acceptable than the ungrammatical ones. Additionally, pragmatically unsound sentences were found to be significantly more acceptable than ones with animacy violations. ANOVA on Reading Time revealed no significant difference between any conditions.

Discussion

For the number feature distortion experiment, the present results indicate that participants don't easily distort number features on nouns to create a grammatically correct representation. However, it may also be the case that the participants are also distorting subject-noun representations in the baseline ungrammatical conditions, as they are very similar to the distortable conditions.

For the noun distortion study, the trends in the results show that while animacy violations are highly unacceptable to participants, role-reversed sentences —where two animate nouns in a role relationship are interchanged, making them pragmatically non-meaningful— are often distorted by participants into a pragmatically meaningful version. It follows that noun representations are prone to an interchange error when they are both animate, but participants don't readily make interchange errors between an animate and an inanimate noun.

However, another possibility to consider is that sentences with only animate noun interchanges are more plausible than ones with animacy violations. This could lead participants to find the former more acceptable consciously, rather than due to representation distortion processes in memory. For half of the sentences in this experiment, noun order instead of case-marker order was also changed across conditions. The effect of this remains to be analysed.

A full-scale study with a larger sample size is yet to be conducted. Further detailed analysis of reading times at specific sentence regions (noun phrases, verb phrases, etc.), as well as decision time (the time taken to rate a sentence), may reveal differences between the conditions.

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Length and Modality impacts Subject drop: a Corpus study in Hindi

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Introduction: Language production constitutes several interesting phenomena and patterns that seem to emerge to alleviate processing pressures. In this abstract, we consider one such phenomenon, Subject-drop, where the subject of the sentence is dropped when it can be recovered from the context. Previous research[1,2] has found that when the verb is transitive, i.e. when it requires both the subject and the object, the rate of pro-drop is higher than when it is intransitive, i.e. when it requires only the subject. Omission of the subject by this account seems to ease processing pressures by decreasing the overall length of an utterance. In other words, in transitive cases where the verb needed more arguments than intransitive cases, the urgency to drop the subject is higher. In the current abstract we tried to replicate as well as extend these findings by investigating whether factors such as length and modality (in speech versus in writing) impact pro-drop. We probe these questions through a corpus analysis in Hindi, an SOV language which frequently shows subject-drop. For this purpose, our study considered the UD Hindi HDTB[3,4], an annotated corpora of written Hindi as well as the IIT Delhi Hindi Dialogue Corpus[1][5].

Analysis 1: Role of transitivity:

Methods: The two corpora were pre-processed to isolate sentences containing matrix verbs similar to[1]. In the HDTB corpus, from 16,649 sentences, this filtering yielded 14,504 sentences in total. Likewise, for the Hindi Dialogue corpus, from an initial pool of 42,289 sentences, this filtering yielded 16,926 sentences containing matrix verbs. Given the relatively small proportion of ditransitive verbs (5.5% in the HDTB corpus and 3% in the Hindi Dialogue corpus out of the total number of sentences with a matrix verb), the subsequent analysis compared sentences with intransitive and transitive verbs only. This decision was motivated by the need for a robust and statistically meaningful comparison. In our analysis, sentences without subject-drop (where the matrix verb has a subject) were coded as 0 and those with (where the matrix verb lacks a subject) as 1. Regression models (Subject-drop~ Verb transitivity) were fit using the R programming language (version 4.4.1). Dialogue corpus

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[1] Only the Telephonic conversation section of the corpus was used because it is manually reviewed and adjudicated by humans for correctness of dependency relations and parts of speech.

contained subject[2] information, unlike HDTB corpus. A simple linear regression was fit for the data from HDTB corpus and a mixed-effects model including subject as a random effects factor was fit for the Dialogue corpus. lme4[6] package was used to implement both the models.

Results: Written Corpus: For the HDTB corpus, the overall subject-drop rate across both the intransitive and transitive sentences was 19%. The rate of Subject-drop increases when the matrix verb is transitive compared to when it is in transitive. The regression model's outcomes converged with this trend with a significant effect of verb transitivity ($z = 8.28$, $p < 0.001$).

Dialogue Corpus: The overall rate of subject-drop was 46.7%. The rate of subject-drop increases when the matrix verb is transitive than when it is intransitive. This suggests that verb transitivity does indeed influence the likelihood of subject-drop.

The statistical analysis again converged with these trends and indicated that verb transitivity significantly influenced Subject-drop ($z = 6.67$, $p < 0.001$). Overall, verb transitivity influenced the likelihood of subject-drop across both corpora.

Analysis 2: Role of sentence length:

Methods: This second analysis examined the impact of subject length on subject-drop. Given verb-transitivity is intimately tied to the number of arguments, sentence length was counted by removing core arguments of the matrix verb. Hence, our measure of sentence length only constituted 'non-core items'[3]. A generalized linear regression model was fit using R (version 4.4.1). For similar reasons as Analysis 1, two different models were fit for the written corpus and the dialogue corpus. The models were similar except for the dependent variable (Subject drop~number of non-core items). Only sentences where a specific non-core item occurred more than 500 times was utilized.

Results:

Written Corpus showed the impact of None-core items, where no clear relation between Subject-drop and Non-core items is observed. The statistical analysis indicated that the effect of non-arguments was not significant ($z = -1.22$, $p= 0.22$). Dialogue corpus showed the impact of Non-core items where a clear relation between Subject-drop and Non-core items is observed, i.e., when such items increase, the rate of Subject drop decreases ($z = -12.98$, $p < 0.001$).

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[2] Each unique combination of conversation file and speaker ID was treated as a subject.

[3] The exclusions comprised the core arguments of the verb, i.e. dependency relations such as 'nsubj','nsubj:pass','obj','iobj','comp' and 'xcomp'. The auxiliary verbs, which formed a relation with the matrix verb were also removed.

Discussion

Our results revealed three key findings: (1) Subject-drop is influenced by verb-transitivity, similar to [1,2], (2) Unlike[1,2], we found an additional effect of length on subject drop in terms of the number of Non-core items of the sentence, (3) This effect of length was only present in the Dialogue corpus. Taken together, our research extends previous studies which showed that subject-drop could occur to alleviate processing cost, by pointing to how increasing sentence length can simultaneously make inference of the dropped subject more difficult. Our research also highlights the importance of Dialogue/Spoken corpora comparisons to investigate such real-time processing phenomena.

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The Temporal Dynamics of Visual Word Recognition: Morphological Priming in a Morphologically Rich Language

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Introduction

Psycholinguistics research has, since its inception, been invested in trying to build representations of the mental lexicon, and the trajectory of the mechanisms that operate on these representations during word recognition. Contemporary models that have currency in the literature acknowledge the existence of a morphological level, such that word recognition processes recruit morphemes, or the sub-lexical units of a word, through a process of decomposing the word into its constituent morphemes. In order to arrive at the importance of morphological structure, previous work has distinguished the early facilitatory effects of priming in morphological pairs (for example, in playing-PLAY) from shallower orthographic effects, such as through a mere form-based overlap between a pair (in electrode-ELECT), that have yielded early facilitatory effects in some studies[1] and late inhibitory effects in others[2]. An interesting testing ground for tracking the time-course of such effects is in agglutinating languages, which possess rich morphological systems via productive suffixation processes. Here, we make the case for Malayalam, a highly agglutinating language[3]. Situating our study in Malayalam also means that we can study the effects of a script on word recognition that is different from the linear character-based scripts that are traditionally studied, as Malayalam is an alphasyllabary[4], [5].

Methods

Our study implemented a masked priming lexical decision (LDT) paradigm, where participants judged the lexicality of target words after being exposed to a prime for a certain duration. The targets were always past-tense verbs. We varied **Prime type** and **Prime duration** across participants. **Prime type** was a within-subjects factor, with the following levels (see Sample Stimuli):

a. Morpho-PERF: a morphological prime with the perfective suffix, whose verb stem overlapped with the target's stem,

b. Morpho-CONT: also a morphological prime, but with the continuous suffix.

c. Orthographic: a form-based prime whose first syllable overlapped with that of the target without sharing any other morphological relationship.

d. Unrelated: a control, that does not share any morphological/orthographic/semantic relationship with the target.

Prime duration was a between-subjects factor, with levels:

a. 48ms b. 150ms c. 300ms d. 450ms e. 600ms

Each participant saw 50 critical words, embedded in a list where the ratio of critical words to non-words to fillers was in the ratio of 1:1:2. The list implemented a Latin-squares design, and the order of presentation of the items was randomised.

1. **Sample stimuli:**

Prime type				
(a) Morpho-PERF	*(b) Morpho-CONT*	*(c) Ortho*	*(d) Unrelated*	*Target*
thurann-iʈʈunɖayirunn-u open-PERF-PAST ‘had opened’	thura-kkukayayirunn-u open-CONT-PAST ‘was opening’	thuɖa ‘thigh’	muɻal ‘rabbit’	thurann-u open-PAST ‘opened’

2. Participants: We recruited 100 participants, with 20 participants per prime duration.

3. Hypotheses: Each prime duration was treated as a separate model in our analysis, with the following three predictions:

a. If automatic morphological priming occurs independent of form-based priming in Malayalam, then RTs for the two morphological conditions should be faster than the unrelated controls, particularly at shorter[2] prime durations (**(a),(b) << (d)**). Alternatively, if early stages of parsing are driven solely by orthography, we expect to see comparable priming effects between the morphological and the orthographic conditions (**(a),(b) ~ (c)**).

b. As far as the two morphological suffixes are concerned, we expect a differential effect of suffix frequency, with the continuous suffix being more frequent in Malayalam than the perfective.[4] If suffix frequency influences morphological processing, we expect to see an effect such that: **(d) - (b) >> (d) - (a)**

c. We also acknowledge the possibility of observing orthographic facilitation or inhibition during processing. However, given certain inconsistencies in the literature, the precise

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[4] Raw frequency counts of the continuous suffix (1,69,702) vs the perfective (1979) were derived from the Malayalam corpus (721 million tokens) in IndicNLPSuite[6]. These were log-transformed, then scaled.

nature or timing of these effects for an understudied language like Malayalam was not immediately apparent. This aspect of the study, therefore, remains exploratory.

4. **Analyses**

RTs were measured at targets, assuming that lower RTs on average index relative processing ease due to priming. Linear mixed-effects models were fit per prediction over log RTs, with additional covariates relating to the prime like suffix frequency, and relating to the target like whole-word frequency, syllable length[4] (as a proxy for word length), and graphemic complexity[4],[5] apart from prime type.

Results

a. *At 48ms:* We found significant facilitatory effects for the Morpho-CONT condition when compared to the unrelated ($t = -2.025$, $p = 0.04$). Target whole-word frequency ($t = -3.78$, $p < 0.001$), and prime suffix frequency were also significant ($t = -2.35$, $p =0.02$).
b. *150ms:* We found a slow-down in the RTs in the orthographic condition when compared to unrelated ($t = 2.4$, $p = 0.02$). Whole-word frequency was also significant ($t = -3.68$, $p < 0.001$).
c. *300ms:* Only whole-word frequency was significant ($t = -2.77$, $p = 0.007$).
d. *450ms:* Both morphological conditions Morpho-CONT ($t = -3.56$, $p < 0.001$) and Morpho-PERF ($t = -5.1$, $p < 0.001$) was significant when compared to unrelated; Whole-word ($t = -3.917$, $p < 0.001$) and suffix frequency ($t = 2.081$, $p = 0.04$) were also significant.
e. *600ms:* Both conditions Morpho-CONT ($t = -10.041$, $p < 0.001$); and Morpho-PERF ($t = -7.76$, $p < 0.01$) were significant when compared to unrelated; Whole-word ($t =-2.73$, $p = 0.008$) and suffix frequency were also significant ($t = -2.33$, $p = 0.02$).

Discussion

Our intention with this study was to distinguish between morphological and orthographic effects, and chart out the time course of said effects during visual recognition in a morphologically complex language like Malayalam. We find robust and facilitatory morphological priming effects starting at 450ms and continuing at 600ms as well. These durations are much longer than the traditional SOAs used for languages like English, and we speculate that these effects emerge late owing to Malayalam's relatively dense morphology. Orthographic priming effects were, however, sparser, with inhibitory effects appearing relatively early at 150ms, contrary to studies in Hindi, which observe early facilitatory effects[1]. Within the two morphological conditions, we also observed a differential effect of suffix frequency between the continuous and perfective suffixes, as is to be expected.

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Age and Structural Differences in Multilinguals: Effects on Attention and Cognitive Flexibility

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Multilingualism is a complex and multidimensional construct that has long attracted interest within the fields of linguistics and cognitive psychology. Although numerous studies have investigated its potential cognitive advantages, empirical findings remain inconsistent—some reporting enhanced executive functioning among multilinguals (Costa et al., 2008; Bialystok, 2010), while others have found minimal or no difference (Nichols et al., 2020; Anjomshoae et al., 2025). One reason for these discrepancies may be the tendency to conceptualize multilingualism as a categorical rather than an experiential phenomenon.

Recent perspectives emphasize that cognitive outcomes are shaped not merely by the number of languages known but by the nature of multilingual experience, encompassing variables such as proficiency, age of acquisition, frequency of language switching, and typological distance (Yan, Liu, & Xie, 2019). Building on this view, the present study examined two key experiential factors that may influence cognitive performance: (1) the age of acquisition, which could either be simultaneous or sequential, and (2) whether the word order of the languages spoken is similar or different (for example, Hindi and English follow SOV and SVO structures, respectively). This study investigated whether there is any difference in inhibitory control and attention across these groups. It was hypothesized that simultaneous multilinguals would show better inhibitory control and attention compared to sequential multilinguals (Kousaie et al., 2017), and that those speaking languages with different word orders would outperform those speaking languages with similar structures (Nelyubina et al., 2025; Perović et al., 2022).

A total of 99 participants (47 males, 52 females) from the Master’s and PhD programs at the University took part in the study. They were divided into four groups based on the type of language acquisition and word order similarity: (a) Simultaneous Multilinguals with Same Word Order, (b) Simultaneous Multilinguals with Different Word Order, (c) Sequential Multilinguals with Same Word Order, and (d) Sequential Multilinguals with Different Word Order. To assess participants’ inhibitory control, the widely used Stroop Color and Word Test (Golden et al., 1978) was administered. The task consisted of three conditions—Word, Color, and Color–Word—requiring participants to read color names, identify ink colors, and inhibit automatic responses in incongruent color–word pairings. Raw scores were converted into standardized T-scores (M = 50, SD = 10) following the manual for clinical and experimental uses by Golden et al. (1978). To assess attention, an experimental task was created using OpenSesame 4.0.5, although it is not a standard attention paradigm. Each trial began with a briefly presented target word (e.g., *weak*) for 180 ms, followed by four orthographically similar options (e.g., *weak, week, wean, weed*). Participants selected the matching target using the keyboard. A total of twenty trials were administered, and reaction times for correct responses served as the measure of attention efficiency.

A two-way MANOVA examined the effects of age of acquisition (simultaneous vs. sequential) and word order (same vs. different) on the combined dependent variables. Significant main effects were found for age of acquisition, $F(3, 93) = 3.938$, $p < .05$, Wilks' $\Lambda = .877$, $\eta p^2 = .113$, and word order, $F(3, 93) = 6.210$, $p < .001$, Wilks' $\Lambda = .833$, $\eta p^2 = .167$, with a significant interaction, $F(3, 93) = 3.292$, $p < .05$, Wilks' $\Lambda = .904$, $\eta p^2 = .096$. Additionally, to ensure that the number of languages known did not act as a confounding variable, we followed up with separate ANCOVAs controlling for this factor. The pattern of results remained consistent, with significant main effects of age of acquisition ($F(1, 94) =4.43$, $p = .038$, $\eta^2 = .045$) and word order ($F(1, 94) = 5.23$, $p = .025$, $\eta^2 = .053$), and a significant interaction ($F(1, 94) = 9.10$, $p = .003$, $\eta^2 = .088$) for inhibition. For attention, only the main effect of word order was significant ($F(1, 94) = 13.38$, $p < .001$, $\eta^2 = .125$), indicating faster responses for participants managing languages with different word orders.

Results indicate that age of acquisition and word order differences have a noticeable impact on cognitive performance, even when controlling for the number of languages known. Simultaneous multilinguals performed better on the inhibitory control task, consistent with prior evidence that early exposure to multiple languages strengthens the ability to regulate competing linguistic systems (Kousaie et al., 2017; Berken et al., 2016). Furthermore, participants managing languages with different word orders demonstrated higher inhibitory performance, supporting the notion that navigating structurally diverse languages may enhance executive functioning, potentially by requiring greater monitoring and control when managing dissimilar linguistic systems (Perović et al., 2022; Yang et al., 2017). Notably, a significant interaction revealed that the advantage of simultaneous multilingualism was most pronounced when languages differed in word order. These findings highlight that cognitive benefits in multilinguals are shaped not just by the number of languages known but by the age of acquisition and structural characteristics of the languages, emphasizing the importance of early and diverse multilingual experience for developing stronger inhibitory control.

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Mechanisms Underlying Savings in Visuomotor Adaptation

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Introduction

“Savings” in motor adaptation refers to the faster relearning in response to a previously encountered error. Both task performance errors (TPEs), which drive explicit strategy use, and sensory prediction errors (SPEs), which drive implicit updates to internal models during adaptation, are believed to give rise to savings (Huberdeau et al., 2015; Leow et al., 2020; Morehead et al., 2015; Coltman et al., 2019; Yin & Wei, 2020). However, the necessity and contribution of each mechanism remain debated. For instance, while Leow et al. (2020) showed that eliminating TPEs abolishes savings, Yin and Wei (2020) reported SPE-driven savings, with faster adaptation following SPE-only training. These conflicting findings make it difficult to get a unified understanding of whether savings arise from explicit corrections, implicit recalibration, or both. We aimed to address this issue in the current study by experimentally manipulating the presence and interactions between SPE and TPE.

Methods

We recruited 3 groups (16 participants each) of subjects for this experiment that comprised broadly of 3 blocks: learning, washout and test. In group 1, we used an “arc” target and instructed participants to “reach anywhere in the arc”. Feedback about hand motion, provided by means of a cursor, was rotated by 45° CCW, which produced an SPE. However, because subjects could reach in any direction, they would always be successful in hitting the arc target, and therefore no TPE would occur. In washout, the rotation was removed, and veridical cursor feedback was provided. The test block consists of 5 “point” targets (located at 45°, 90°, 135°, 180°, 360° or 0°) with the cursor being rotated by 45° CCW once again. We also inserted a few catch trials (to a 90-degree point target without cursor feedback) during learning and washout blocks to ensure that subjects were actually learning in response to the SPE. In group 2, we used the point targets with 45° CCW cursor rotation during the learning block with “catch trials” inserted in between. This induced both TPEs and SPEs. Participants were instructed to “bring the cursor to the target”. The test block remained the same as group 1. Finally, in group

3 (naive learning group), we designed a long “baseline” block (no perturbation, veridical feedback) with the five-point targets, followed by the test block with a 45° CCW cursor rotation. To assess for savings (faster relearning following exposure to the SPE alone (group 1) and SPE and TPE together (group 2)), we compared the test block performance of groups 1 and 2 to that of group 3.

Results

To quantify learning during the arc training block, we analyzed catch trial (90-degree target without cursor feedback) hand angles and compared them to those of the point training group. The arc group, when catch trials were analyzed, exhibited partial adaptation in the learning block, significantly lower than the point group's near-complete compensation. This dissociation indicated that SPE exposure in arc training was driven largely by implicit recalibration in the absence of a TPE. In contrast, the TPE+SPE exposure in point training facilitated combined implicit adaptation and explicit strategic compensation.

An analysis of the performance of the arc test block compared to that of the naive learning group revealed that prior arc training provided no benefit during the test. That is, subjects who had trained on the arc target adapted to the point targets as if they were encountering the errors for the first time. Thus, no savings were observed. In contrast, clear savings were seen in participants who underwent prior point training (SPE+TPE exposure). During the test, these participants showed robustly faster learning than naive subjects of group 3.

We also analyzed hand path trajectories from the final 50 trials of the learning block of the arc training group. 6 participants exhibited near-complete angular compensation with hand deviations closely matching the 45° perturbation magnitude. This suggests a target-oriented adjustment mechanism. We compared this group to a naïve group during re-exposure; initial relearning bins demonstrated no significant group differences with permutation. The other set of participants (other 10 participants), compared against the naïve group, showed no significant difference. We also tested whether participants showed faster relearning only for the 90° target- the same position where they’d earlier experienced "catch trials". When comparing six participants (who showed strong adjustments during training) to a naïve group, at the 90° target. There was a small hint of faster relearning; a marginal difference was observed. These participants were using catch trials at 90° as the location they were supposed to reach. This is confirmed by the hand trajectories of these participants, who adjusted to 45-degree perturbation in order to hit the catch trial target. In the test phase, these subjects recalled the solution space they built during learning., suggesting they might have recalled some strategy from the learning phase because of the sensory prediction error, despite having no feedback during catch trials. At other targets, no significant difference was observed between the test block of the selected group and the naïve group.

Conclusion

Our results indicate that task performance errors (TPEs) and the explicit strategies they enable are essential for producing savings in visuomotor adaptation, whereas exposure to sensory prediction errors (SPEs) alone is insufficient. These results highlight the distinct contributions of implicit and explicit learning mechanisms and suggest that rapid re-expression of motor memories depends on the presence of explicit error signals and strategic engagement.

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Temporal Dynamics of Sequence Learning: How Response–Stimulus Interval Shapes Chunking and the Implicit–Explicit Transition

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Introduction

Motor sequence learning is fundamental for skill learning. It enables smooth and efficient performance of complex actions, such as typing or playing an instrument. Motor tasks require coordinating between planning, selection, and execution of motor actions to facilitate skilful behavior (Krakauer et al., 2019). This often begins implicitly, with gradual performance improvements emerging through repeated practice. The Serial Reaction Time Task (SRTT) is a common paradigm used to study implicit learning, as participants often respond to sequence patterns without conscious awareness (Nissen & Bullemer, 1987). A critical temporal factor in such tasks is the response-stimulus interval (RSI), the time between a response and the next stimulus. The RSI's duration is hypothesized to influence the type of learning significantly (Destrebecqz & Cleeremans, 2001). Short RSIs are thought to favor the development of automatic, procedural skills, where movements become ingrained as smooth and habitual (Willingham, 1999). Conversely, longer RSIs may allow for increased attention and conscious thought, theoretically encouraging explicit learning, enabling participants to deliberately recognize and recall the sequence (Shanks & Johnstone, 1999). Motor chunk formation, reflected in cohesive units of action and response timing, is a key behavioral indicator of effective sequence learning (Sakai et al., 2003). Previous studies have explored how this shift toward efficiency explicitly happens in Internally Guided Sequencing tasks such as the Grid-Sailing Task (Bera et al, 2021). This study specifically investigated how distinct temporal dynamics (short: 250ms; long: 1000ms RSIs) affect learning, retention, and crucial motor chunk formation and reorganization during SRTT. Our primary aim was to clarify how temporal structure shapes learning type and its progression along the implicit-explicit continuum.

Methods

Fifty-one university students (18-30 years) participated in an SRT task, randomly assigned to 250ms or 1000ms RSI conditions. They learned a hidden 12-item visual sequence over 14 blocks by pressing corresponding keys, with a random block (Block 12) serving as a test block featuring a novel sequence, which helps assess the sequence-specific learning. Participants focused on fast, accurate responses. They were not explicitly informed about any repeating sequence. Learning was assessed through reaction times (RTs) and a post-task free generation test, where participants attempted to reproduce the sequence across 96 trials. We divided participant performance into two learning phases: early (Blocks 1–4) and late (Blocks 8–11). To analyse motor chunking patterns, we used a rule-based method wherein chunk boundaries were identified when a keypress RT exceeded a participant's average RT for that specific learning phase. Subsequent keypresses with similar or decreasing RTs were then grouped into the same chunk, provided the chunk contained at least two keypresses. This approach allowed for a detailed comparison of chunk length and number across both learning phases and RSI conditions.

Results

Both RSI conditions demonstrated significant RT reductions over time, indicating learning. The 1000ms RSI group exhibited faster overall RTs and a steeper learning curve ($SlopeMean1000 = -16.239$, $SlopeMean250 = -11.745$, W = .935 p<.05) supporting a faster RT reduction rate. Sequence-specific learning was confirmed by a significant RT increase in the random 12th block (t(50) = 8.04, p<0.001). In the free generation task, the 1000ms RSI group achieved significantly higher scores ($M1000$ = 2.342, p<.05) indicating better retention. Chunking analysis revealed distinct reorganization patterns. In the short (250ms) RSI condition, average chunk length significantly increased from early to late phases ($EarlyChunkLenmean$ = 2.55, $LateChunkLenmean$ = 2.85, t=2.5, p<.05), but the total number of chunks remained almost unchanged ($EarlyChunkNummean$ = 3.8, $LateChunkNummean$ = 3.56). This suggests reorganization primarily through there combination of existing segments. In contrast, the long (1000ms) RSI condition showed a more profound structural reorganization as evidenced by a significant increase in average chunk length ($EarlyChunkLenmean$ = 2.56, $LateChunkLenmean$ = 2.94, t=3.86, p<0.001) and a significant decrease in the number of chunks ($EarlyChunkNummean$=3.91, $LateChunkNummean$ = 3.54, t=2.38, p<0.05) from early to late learning phases. This indicates that longer reaction times facilitated the integration of multiple smaller segments into fewer, larger, and consistent motor chunks, reflecting a comprehensive reorganization of the sequence.

Discussion

Our findings strongly support that temporal dynamics, specifically RSIs in an SRT task, fundamentally shape motor sequence learning, influencing performance gains and cognitive restructuring through chunking. While both RSIs facilitated learning, the longer RSI consistently led to faster learning, better retention, and an integrated, more explicit sequence representation (Shanks & Johnstone, 1999; Robertson, 2007).

The distinct chunking behaviours are central to these results. At 250ms, chunk numbers stayed stable, but lengths increased, suggesting performance gains within existing motor units, consistent with theories that short intervals constrain processing and favor implicit learning (Willingham, 1999). In contrast, 1000ms showed fewer but longer chunks, indicating deeper reorganization, where added time allowed greater attention and integration into larger, unified chunks.

Such restructuring indicates a shift towards a more explicit, rule-based understanding, supporting our suggestion that motor learning evolves from implicit to explicit, with chunk reorganization as a behavioural marker.

The 1000ms RSI group's superior performance in the free generation task provides strong supporting evidence of better retention with increased RSI. The ability to generate more correct chunks intuitively suggests that knowledge gained under longer RSIs was more explicitly accessible and structurally integrated, compared to the shorter RSI (Destrebecqz & Cleeremans, 2003).

Future work will investigate the neural mechanisms underlying this implicit-to-explicit transition.

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Eyes do not lie: Testing whether eye-tracking can be used to detect Mind-Wandering and Mind-Blanking

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Introduction

During waking hours, instead of being focused on the task-at-hand, our minds often shift to task- unrelated thoughts (called **Mind-Wandering**). Others have also another mental state, where our mind is unfocused or blank (called **Mind-Blanking**)[1]. Both these mental states can have deleterious impact on task performance with potentially dire consequences in high-risk contexts such as driving[2]. Hence, real-time detection of these mental states using methods such as eye- tracking can improve safety in critical contexts. While such attempts have been made in the past with varying levels of success, our study attempts the same by making two key modifications. We test eye metrics in different task contexts which can improve the generalizability of such detections, and we distinguish between the Mind-Wandering and Mind-Blanking mental states which has been overlooked by previous studies.

Methods

Participants (N=16; age=21 ±2years; 7 females) performed two tasks: a reading task and a Go/No- Go task while their eyes were tracked. In the reading task, participants read a (neutral emotion) chapter from *A Short History of Nearly Everything* by Bill Bryson. A sentence or two (35 ± 9 words) were presented in every trial and participants pressed a button to read the next sentence(s). At the end of the task, participants performed a comprehension test (three participants' data had issues and not analyzed). In the Go/No-Go task, participants responded when a circle was presented and withheld the response when a square was presented (20% of trials). In both tasks, after every 55-60 s, mental state probes were presented to self-report their mental state in the preceding trial. The response could be On-Task (focused on the task), Mind-Wandering (thinking about unrelated topics), or Mind-Blanking (experiencing an absence of thought or mental content); Based on these response trial(s) in the ~15s prior to the probe were classified as On-Task, Mind- Wandering or Mind-Blanking episodes for analysis.

Results

In the reading task, participants reported being On-Task 76.1% of the times, followed by Mind-Wandering (18.9%), and then Mind-Blanking (5%). Participant spent ~11s per trial. A one-way ANOVA with reading duration as the dependent variable and factor mental state (On-Task, Mind- Wandering, Mind-Blanking) showed significant difference (F(2, 415)=4.8, p< 0.001). Reading times were longest in Mind-Blanking (13.4±3.7s), then Mind-Wandering (13.3±3.7s), and shortest in On-Task (12.3±3.0s). Pairwise comparisons across all probe trials showed that On- Task differed significantly from Mind-Wandering ($t(398) = 2.7, p< 0.010$) but not from Mind- Blanking ($t(351)=1.8, p=0.059$). Mind-Wandering and Mind-Blanking did not differ significantly ($t(81)=0.2$, $p=0.805$). Although mean reading times followed the pattern Mind-Blanking >Mind- Wandering >On-Task, only the Mind-Wandering–On-Task comparison reached significance, this is likely due to the lower trial count of the Mind-Blanking category (only 5% of total probe responses).

In the Go/No-Go task, participants reported being On task 70.8% of the times, followed by Mind-Wandering (22.2%), and then Mind-Blanking (7.0%). In the No-Go trials, a one-way ANOVA with error percentage as the dependent variable and factor mental state (On-Task, Mind- Wandering, Mind-Blanking) showed significant main effect of mental state ($F(2,38)=7.0$, $p=0.003$). Post-*hoc* comparison with correction for multiple comparison indicated mean errors rates of 2.9% in On-Task, 5.7% in Mind-Wandering, and 8.4% in Mind-Blanking. Post- *hoc* pairwise tests corrected for multiple comparison showed higher error rates in Mind-Blanking compared to On-Task ($t(14)=3.9$, $p=0.002$) and in Mind-Wandering compared to On-Task ($t(14)=2.9$, $p=0.010$), while Mind-Blanking and Mind-Wandering did not differ significantly ($t(14)=1.5, p=0.136$).

Then we analysed eye metrics for the reading task. using a linear mixed-effects model with mental state, word length, and word frequency as fixed effects, and participant as random intercept. With Total Fixation Time (TFT), which is the sum of all fixation durations in a trial, as the dependent variable, we observed that it was significantly greater during Mind-Wandering($\beta=0.025, p<0.010$) but not during Mind-Blanking ($\beta=0.014, p=0.100$) compared to On-Task episodes, suggesting prolonged visual processing during Mind-Wandering. With saccade amplitude as the dependent variable, we observed that it was greater during Mind-Wandering ($\beta=0.023, p=0.050$) compared to On-Task. Similarly, for saccade rate, we observed that it was lower during both Mind-Wandering ($\beta=–0.049, p<0.001$) and Mind-Blanking ($\beta=–0.017, p<0.001$), indicating reduced eye movements in these states.

Similarly, we analysed the eye metrics in the Go/No-Go task. We considered two measures of fixation: Average fixation duration, the mean duration across all fixations within a trial, which captures the general stability of gaze within a trial; and Maximum fixation duration, the longest single fixation within a trial, which captures the transient moments of increased visual engagement.

Reduction in both measures during mental state suggests unstable and fragmented visual attention. With average fixation duration as the dependent variable, we found that it was significantly lower during both Mind-Wandering (β=–21.6, p<0.001) and Mind-Blanking (β=–25.9, p=0.002) compared to On-Task. Similarly, maximum fixation duration is also significantly lower during Mind-Wandering (β=–23.0, p<0.001) and Mind-Blanking (β=–37.2, p<0.001). Pupil size increases with heightened arousal, reflecting cognitive engagement. Maximum pupil size was also lower during Mind-Wandering (β=–72.8, p<0.001) and Mind-Blanking (β=–87.9, p=0.002) compared to On-Task. Taken together, these results show that Mind-Wandering and Mind- Blanking are marked by shorter fixations and smaller pupil sizes, suggesting reduced arousal and lower attentional engagement during these states.

DISCUSSION

Preliminarily, we observed that both eye metrics and behavior were distinct between the MindWandering and Mind-Blanking episodes, underscoring the need to consider these mental states as separate. The trend towards higher error, reduced fixation durations, and smaller pupil size during Mind-Blanking episodes suggests a deeper disengagement from task-relevant stimuli, indicating greater attentional decoupling during Mind-Blanking. Moving forward, we aim to develop a classification model that integrates behavioral and eye metrics to distinguish between these mental states.

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Music, Mood, and Mind: Functional Modeling of Structure-, State- and Trait-Based Modulation of Emotion

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Introduction

Music's structural features, such as chord progression, harmony, rhythm, and tempo, are known to influence emotional experience (Gabrielsson & Lindström, 2020). At the same time, top-down factors like mood, personality, expertise, and familiarity also shape how emotions are perceived (Lepping et al., 2016). However, most studies either isolate these influences or rely on static self-reports, missing their real-time interaction. This study uses advanced statistical modeling, including functional principal component analysis, clustering, and functional regression, to examine how bottom-up acoustic features and top-down psychological states interact dynamically during music listening. Continuous emotion tracking within the circumplex model (Russell, 1980) is combined with validated assessments to provide a fine-grained, dynamic analysis of how music and mind converge to produce emotional experiences.

Methods

The study included healthy young adults with no major neurological conditions except mild mood disorders without any ongoing medication. At the beginning of the experiment, each participant completed standardized questionnaires on mood, anxiety, depression, personality, music perception, and engagement, followed by the main experiment where participants listened to previously validated naturalistic musical excerpts (Mathur et al., 2015). The pieces vary in chord and tempo while controlling pitch, timbre, and loudness. Long silent gaps between excerpts were added to assess transitional states and carryover. Excerpts are presented pseudo randomly to capture stimulus-specific effects. Participants used a joystick to rate valence and arousal within the 2D circumplex model continuously. High-resolution data were recorded at every 16ms, in a controlled room to minimize sensory input. Planned data analyses include advanced statistical modelling such as functional principal component analysis (fPCA) to summarise emotion trajectories, clustering to detect response patterns, and Bayesian functional regression with Markov chain Monte Carlo to link top-down factors to dynamic ratings and examine how they modulate bottom-up responses. Carryover effects (impact of prior music onpost-music silence) and priming effects (influence of previous music on initial ratings of the next segment) were assessed using both ANOVA and Kruskal-Wallis tests and linear mixed-effects models, with participants' specific random effects.

Results

First-order analyses from initial participants ($n = 10$) reveal clear inter-individual differences in valence and arousal ratings, reinforcing the need to examine top-down and bottom-up influences together. Real-time felt emotion rating often diverges from structural predictions, especially in the middle and late parts of music, suggesting modulation by mood or traits. Intended valence and arousal profiles based on musical structure were also found to align with expectations. We also observed that previous music segments influenced initial valence during the subsequent silent segments (ANOVA $p = 0.02$). Initial responses to a music segment were also found to be modulated by preceding music (Mix Effect Model Coef.
= 33.15, $p < 0.001$).

Discussion

These results indicate a complex interplay between bottom-up musical features and top-down psychological states in shaping felt emotion. The mismatch between intended and perceived affect, along with the carryover, shows that structure alone does not fully explain the emotional experience. The observed priming suggests that emotions evoked by one passage can bias how the next is felt, showing how musical emotion unfolds as a continuous, context-dependent process. Ongoing data collection will further refine these findings and support more robust modelling with second-order advanced analyses, including functional regression, which might have higher potential for looking into the observed result from the first-order analysis. Altogether, this work advances our understanding of how personal states and acoustic features interact to shape the rich, evolving emotions music evokes, highlighting music's potential as a supportive or therapeutic intervention for mood and affective conditions.

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Neural Coding of Auditory Features During Music Perception and Imagery

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Introduction

Music cognition transforms auditory signals into perceptual experiences through complex brain processing. Low-level acoustic features, such as timbre, tempo, pitch, loudness, and rhythm, are processed early in the auditory cortex, forming the foundation for higher-order perception[1]. Mid-level features, like Mel-Frequency Cepstral Coefficients (MFCC) for timbre and Chroma for tonal content, aggregate low-level data into perceptual patterns using algorithms like Fourier transforms and pitch-class mapping.

Neuroimaging studies often emphasize pitch, mapping tonotopic organization in the auditory cortex (e.g., Heschl's gyrus), but underrepresent timbre and rhythm, limiting insights into emotional and multisensory aspects[2-4]. Incorporating MFCC and Chroma can address these gaps, enhancing models of timbre discrimination and melody recognition [5,6]. This study analyzes two fMRI datasets: one comparing music perception and imagery, and another examining perception across genres. We hypothesize that MFCC will activate temporal regions for spectral analysis, Chroma will engage subcortical and frontal networks for tonal sequencing, with overlapping auditory hubs but distinct patterns in imagery and genre effects[7].

Methods

Feature Extraction

Stimuli were processed using the Music Information Retrieval (MIR) toolbox in MATLAB [8]. MFCCs were computed via the Fourier transform, mapping frequencies to the mel scale with 40 triangular filters, yielding 13 coefficients. Chroma features were extracted using a short-time Fourier transform with 50-ms Hann-windowed frames, mapping frequency bins to 12 pitch classes. Features were down sampled to match fMRI temporal resolution and convolved with the hemodynamic response function for general linear model (GLM) regressors.

fMRI Analysis

Experiment 1: Identifying neural correlates of Music Perception in fMRI data collected for musical snippets of different genres

Nakai et al.[9] involved 5 subjects listening to 540 music clips from 10 genres. fMRI data were preprocessed using SPM (motion correction, slice-timing correction, MNI normalization, 6 mm FWHM smoothing) on a 3T MRI scanner (T2*-weighted EPI: TR = 1.5 s, TE = 30 ms, voxel size = 3 x 3 x 3 mm).

Experiment 2: Differentiating neural activation of Music Imagery and Perception in musically trained individuals

Zhang et al.[10] included 3 musically trained subjects (average 10.9 years of experience) across 8 trials with 4 conditions (Imagery, Perception, Audio-Visual Perception, Resting State) using Beethoven’s Symphony No. 9 (first 8:22). fMRI data were collected on a 3T scanner (T2*-weighted EPI: TR = 2 s, TE = 35 ms, voxel size = 3.5 x 3.5 x 4 mm).

GLM modeled BOLD signals with MFCC and Chroma regressors, including motion and physiological noise regressors. Group-level random-effects analysis in SPM used one-way ANOVA, with classical estimation and t-contrasts ($p < 0.001$, cluster extent > 20 voxels) for feature-specific activations (e.g., MFCC > baseline, Chroma > baseline).

Results

In Experiment 1, MFCC activations included bilateral superior temporal gyrus (STG), left parietal operculum, and right putamen. Chroma activations involved bilateral STG, left planum temporale, and right angular gyrus. In Experiment 2, MFCC imagery activations included the left occipital pole, right STG, and left frontal operculum, while perception activated bilateral STG and right angular gyrus. Chroma imagery activations included the left thalamus, right STG, and left angular gyrus, with perception activating the bilateral transverse temporal gyrus and left cerebellum.

Discussion

This study examined neural activations driven by Mel-Frequency Cepstral Coefficients (MFCC) and Chroma features during music perception and imagery using two fMRI datasets. The results reveal distinct and overlapping neural patterns for MFCC (timbre-related) and Chroma (tonality- related) features, addressing the initial hypotheses about their roles in music cognition.

In Experiment 1, MFCC activations in bilateral superior temporal gyrus (STG), left parietal operculum, and right putamen suggest involvement in spectral analysis, supporting the hypothesis of temporal region engagement (8). Chroma activations in the left planum temporale and right angular gyrus indicate tonal processing, consistent with pitch-class analysis[12].

In Experiment 2, MFCC imagery activations included left occipital pole and right STG, while Chroma engaged left thalamus and right STG, suggesting distinct networks for imagery and perception[6].

Unlike pitch-focused studies, MFCC and Chroma analyses reveal timbre and tonality processing, addressing gaps in emotional and multisensory aspects of music cognition[3,5]. MFCC's putamen activation and Chroma's planum temporale engagement highlight unique neural substrates. Overlaps in STG suggest a core auditory hub in the human brain, as established in literature throughout the years[1]. Future analyses will explore connectivity patterns between these regions and parameter estimates across music genres to deepen our understanding of their functional roles.

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Understanding Consumer Attention: An EEG Study on Visual Appeal and Taste of food.

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In today's world, food choices are influenced by more than just hunger. They are shaped by taste, packaging, texture, and branding. While past EEG studies focus on basic tastes like sweet, bitter, salty etc. they miss the complexity of real-world foods, especially branded junk food engineered to attract consumers attention. Our study uses EEG to investigate how the brain responds to complex multisensory experiences, specifically comparing the reactions of 25 male and 25 female participants to a well-known branded chip. To strengthen these findings, we also propose extending the analysis to a control group consuming unbranded, unflavoured chips. By analyzing attention shifts to taste and packaging, we aim to reveal how certain products trigger stronger focus or addictive responses, offering insights valuable to neuroscience, marketing, and consumer behaviour.

Attention Capture in Serial Search: Measuring Capture by a Target Singleton

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Introduction

Attentional selection is the process by which we select relevant information from the environment while ignoring irrelevant information. Attentional selection has primarily been studied through two visual search paradigms: the irrelevant singleton paradigm (Yantis & Egeth, 1999) and the additional singleton paradigm (Theeuwes, 1992). These two paradigms investigate how a salient singleton is processed automatically, even when it is irrelevant to the goals and intentions of the participants. While the irrelevant singleton paradigm demonstrates attention capture through a facilitation in reaction time whenever the target is the salient singleton, the additional singleton paradigm serves as a cost paradigm where the attention captured by an additional irrelevant singleton increases the reaction time to find the target. Since the irrelevant singleton paradigm requires a self-terminating serial search, the search slope of the conditions when the target is a singleton, as compared with the conditions in which it is not, gives a direct measure of changes in search priority. However, the additional singleton paradigm gives an indirect measure of the interference by an additional distractor singleton; it fails to provide a direct measure of the changes in attentional priority due to processing of the distractor itself (Schreij et al., 2010). Moreover, in the additional singleton paradigm, participants often engage in parallel search (Theeuwes, 1992). Thus, the salient singletons often stand out from the display, making the search easier. We argue that moving away from a paradigm that examines attention capture through parallel search would help us understand the interference caused by the additional distractor during visual search in a robust manner. Examining attention capture in serial search would also help us understand the rate of change in stimulus processing through search slopes. In the present study, we also attempt to measure attention capture more precisely by bridging the additional singleton paradigm and the irrelevant singleton paradigm. A precise measurement of attention capture would help in studying distractor suppression.

Methods

The first experiment began with a placeholder display of 750ms consisting of square stimuli with four gaps, with one gap on each side of the square. The placeholder display was followed by an irrelevant cue display of 250ms during which one of the placeholders turned red. This red target singleton was absent in half of the trials. However, when it was present, it coincided with the target location in 1/n trials. The cue display was followed by a search display that lasted until response or 3000ms whichever was earlier. The target in the search display was a square with one gap either to the left or right. The distractors were squares with two gaps (Arita et al., 2012). Participants had to report the position of the gap on the target square (left or right) by pressing a key on the keyboard. The second experiment followed the same experimental design as the first experiment, except that it had an additional distractor singleton that appeared in the 250ms window in half of the trials. This additional distractor singleton was never the target. The target singleton was always present and coincided with the target location in 1/n trials. In the third experiment, we examined how attention capture would change when the two singletons and the non-singleton target were present in the search display simultaneously. Thus, in the third experiment, there was no cue display after the placeholder display; instead, the search display followed the placeholder display. We recruited 25 participants for each experiment, and each experiment had 432 trials.

Results

In the first and second experiments, we observed a significant interaction between target type, and display size such that the target singleton produced flat search slopes compared to both a non-singleton target or the singleton absent trials. Experiment 2 also showed the same interaction showing that when the target coincides with the colour singleton, there were significantly lower search slopes. Importantly, in both experiments 1 and 2, we observed no effect of the presence or absence of the additional distractor singleton. In the third experiment, we obtained results similar to the first two experiments in conditions where the target singleton was a colour singleton and the additional distractor singleton was the flicker singleton. However, we failed to observe the same results in the counterbalanced condition when the flicker singleton was the target, presumably because of perceptual difficulties in detecting the gap on the target when it flickers.

Discussion

The findings from Experiment 1 suggest strong attentional capture by the irrelevant singleton, with no change to RT or slope when the singleton was absent, suggesting that the cost of attentional capture by a singleton is not reliably measured in terms of its cost in a serial search task. Experiment 2 showed that even when there are two distractors, one with the possibility of being a target and the other without, it does not change the overall serial search slopes. However, even with the small probability of the singleton being the target drives slope differences suggesting the robustness of this paradigm to measure RT facilitation as a direct measure of capture. The third experiment shows that the measures are sensitive to perceptual properties of the singleton, for example the continuous transients associated with the flicker stimuli disrupted search when it was a target. However, it did not affect search times when it was a distractor. Thus, in the present study, we show how separating out the attentional and perceptual factors leads to a clever measurement of the attentional effects. The study also shows that the mechanisms underlying target processing are more critical in driving attentional control as compared to the suppression of distractions.

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Validation of Game-Based Intervention for Prosocial Skills

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Introduction

Social-emotional learning (SEL) encompasses how individuals acquire and apply the knowledge, attitudes, and skills necessary for effective emotional management, empathy, fostering positive relationships, and responsible decision-making[6]. While SEL programs aim to improve prosocial behavior in adolescents, most studies have focused on simplistic behaviors with minimal relevance to complex adolescent social contexts[3]. Perspective taking, a key SEL factor, has been shown to enhance trust during mutual interactions[7,9]. A recent study by Arvindhane and Kar[8] tested a spaced intervention program with a digital prosocial video game and found an increase in fairness choices post-intervention, though perspective-taking can provide additional insights about the variability of prosocial behaviors[9]. The present study aimed to a) evaluate the efficacy of the same game-based prosocial intervention on adolescents with low baseline prosociality; b) to validate the prosocial intervention with a control intervention (no involvement of prosocial components); and c) to use affective perspective-taking as an additional measure of prosociality.

Methods

14 adolescents (age: 12–15 years) were recruited from a school in Prayagraj. Based on the initial assessment using the Prosociality Scale [1], participants were divided into two groups: Low Prosocial Group (LowPro, N=8) included adolescents with trait prosociality scores <1SD; Control Group (N=6) consisted of those with average scores on the trait prosociality scale. The content of the intervention differed across the two groups. LowPro played a video game (Sky: Children of the Light) and completed a course module (Sky Becoming Us, UNESCO MGIEP) on non-gaming days, while the Control group played a neutral video game (Mekorama) and completed a neutral course module on media literacy. Ethical approval was obtained from the IERB, University of Allahabad. Parental consent and participant's assent were secured, and confidentiality was maintained throughout the study.

Across groups, pre- and post-assessments included three tasks: i) Resource Allocation (fairness decisions across social partners and cost conditions);[4], ii) Trust-Reciprocity (coin-sharing behavior toward different groups)[2], and (iii) Affective Perspective Taking (APT; recognition of basic emotions in dynamic visual contexts)[5]. Interventions lasted 10-12 hours over 12 days per participant. Each participant progressed through various levels in the game across the intervention. The current study modified the previous intervention design, where adolescents of average prosociality were measured on the prosocial scale[9], by including adolescents with low prosociality and adding a perspective taking task.

Results

For both groups, repeated-measures ANOVA was performed across time and task conditions.

Low Prosocial Group

For the Resource Allocation task, no improvement was observed in fairness-related decisions after intervention (p = .783). Fairness also did not vary across partner types or prosocial conditions. Descriptive data suggest a slight increase in fairness, especially toward known partners (e.g., friends), aligning with expected directional changes.

The trust task showed a non-significant trend post-intervention (F(1,5) = 4.75, p = .080) with participants consistently trusting friends more than other interaction partners (F(3,15) =12.46, p < .001). In contrast, reciprocity behavior improved post-intervention (F(1,5) = 7.53, p = .041), indicating increased willingness to reciprocate generous actions, particularly toward socially familiar partners.

For the APT task, only a main effect of the emotion category was observed (F(3,21) = 4.198, p = .018) with no improvement in recognition sensitivity post-intervention (p = .443). Furthermore, happiness and anger were recognised with better accuracy than fear and sadness.

Control Group

Fairness behavior changed over time (F(1,5) = 8.167, p = .035), with participants allocating resources more equitably post-intervention. Fairness also varied by partner (F(3,15) = 7.748, p = .002) and cost conditions (F(2,10) = 6.611, p = .015). Planned comparisons showed gains in fair choices toward antagonists under high-cost conditions (t(5) = -2.712, p =.042, d =1.107). These findings suggest that fairness improved naturally over time, independent of the neutral content.

Trust behavior varied across partner types (F(2.431,12.153) = 4.623, p = .027), with greater trust toward friends, but no changes post-intervention. Reciprocity behavior remained stable, with no effects of Time (between pre and post intervention) (p = .809) or Partner type (p = .732). These findings confirm that trust and reciprocity do not spontaneously improve without targeted intervention. In the APT task, no significant improvement in emotional sensitivity was found over time (p=0.080). Recognition sensitivity varied by emotion type (F(3,15) = 8.996, p

= 0.001), with fear being least accurately identified. Results suggest emotional recognition patterns reflect developmental baselines rather than intervention effects.

Discussion

We investigated the efficacy of the spaced prosocial intervention on adolescents with low prosociality using a digital video game and course module. Results indicated that adolescents with low prosociality improved their reciprocal behaviors after the intervention. Other indicators (fairness, emotional sensitivity, and trust) showed descriptive gains. Meanwhile, only fairness showed improvement for the control group, which completed a neutral game and course module. These results may reflect spontaneous developmental changes or test-retest effects. However, trust and reciprocity showed no difference between pre- and post-intervention (neutral to prosocial components) for the control group. Overall, findings suggest that the prosocial intervention may selectively enhance specific components like reciprocity, especially in adolescents with low pro-sociality. Digital game-based intervention interleaved with course modules could be used to enhance prosocial skills such as fairness in resource allocation, trust, reciprocity, and affective perspective taking, although the current results particularly showed the benefit for reciprocity in social interactions in low prosocial adolescents, which remained stable in the control group. Larger effects on prosocial skills were limited, indicating the need for larger samples, longer interventions, and comparative validation against other groups receiving the same training. We intend to compare the performance of the low prosocial and control groups with that of average prosocial adolescents with a larger sample size in our future work.

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Decoding Genetic and Environmental Influences on Brain Areas through Multilayer Connectomics

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Introduction

Complex brain system evolves under a constant dialog between “nature” and “nurture”[1]. The variability in cognition and behavior across individuals is thus influenced by both genetic and environmental factors[2]. Brain studies estimate about 60%-80% of morphological measures are heritable, and in the case of functional measures the estimate is low (~40%)[1]. Recent DWI studies on structural brain connectivity reported the influence of heritability on brain structural network topology[3]. The heritability studies of brain functions are relatively few, however there is a growing consensus that genetics plays an important role in maintaining the functional specificity (including functional network topologies) of a brain region[4-7]. Environmental factors also play a very important role in the development of brain structure and function during a lifespan, with a recent study, for example, discusses the effects of growing up without siblings in neurocognition and mental health which emphasizes on the importance of nurture[8]. However, graph topological studies of heritability are limited to monolayer graphs analysis, either the structural connectivity or the functional connectivity. Structural network is influence directly by morphological changes and is stable across a longer timescale as compared to the functional network topologies, however the functional topology which is a direct reminiscence of ongoing dynamic brain processes is not exclusively influenced by the structural topology. There are also other biochemical processes affecting the dynamic functional repertoire in the brain, and these processes are influenced by both genetic and environmental factors. A recent advance in the multilayer network analysis methods provide an opportunity to collectively study these two aspects of brain networks[9,10].

Our ongoing study implements the multilayer network approach on the multimodal MRI dataset of HCP Young Adult cohort twin population to investigate which brain regions have topological features that are more likely inherited versus those shaped by environmental factors.

Methods

Each participant's structural and functional connectomes were reconstructed from DWI and resting-state fMRI data, respectively, and parcellated using the Brainnetome as well as the Glasser atlas. The two modalities were integrated into a multiplex network representation: each layer contains identical nodes (ROIs) and the inter-layer edges connect homologous nodes across layers, allowing the integrated assessment of structure–function coupling. For each brain region, a set of multilayer graph-theoretical features was extracted and subjected to principal component analysis to obtain a reduced feature space explaining ≥90% of the variance. Twin-based heritability was then estimated using Falconer's model, decomposing phenotypic variance into additive genetic (A), shared environmental (C), and unique environmental (E) components, with permutation based null distributions and FDR correction applied for significance testing.

Results

We controlled the family to righthanded triplets which has a twin pair and one non-twin sibling. Our ongoing analysis indicates that there are many brain regions which are influence by both the genetic and environmental factors. These areas include dorsolateral prefrontal cortex (DLPFC), cingulate cortex, primary motor, primary somatosensory, lateral visual cortex, parahippocampal DMN regions, hippocampus, etc. In addition, the intraparietal areas, inferior frontal junction, and higher order auditory areas show genetic-only effect. On the other hand, some DLPFC areas and rostral prefrontal areas show environmental-only effect. As more twin families are incorporated into the study, the identity and statistical significance of these regions are expected to further refine.

Discussion

The present study provides a systematic approach to incorporate multilayer network analysis method to study the effect of nature and nurture across different brain regions. Many of the highlighted region are in agreement with the previous research findings. Among those commonly affected areas also, we could identify important cytoarchitectural underpinnings that differentiate between the genetic and environmental effects. For example, in the case of DLPFC the Falconer's estimate A (genetic) is higher than the estimate C (environmental) in the granular cortex region which is characterized by well-developed layer IV. This could signify a higher degree of pre-wired, genetically influenced connectivity critical for receiving and processing sensory inputs. In contrast, the dysgranular posterior DLPFC area shows dominant environmental effect (higher C). While also involved in working memory, this poorly developed layer IV in the dysgranular DLPFC cortex might be more flexible and adaptive in its function, potentially reflecting its higher environmental influence. Altogether, the multilayer approach is very promising for studying the effect of nature and nurture in brain system.

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Modulation of the speed of Intrinsic Alpha Frequency (IAF) with tACS modulates variability of illusory speech perception

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Introduction

Speech perception involves a complex hierarchical processing of multiple sensory modalities,[1] especially in noisy or multi-speaker environments. Speech segmentation and the analysis of phonemes, syllables, and words are crucial for extracting meaning from auditory and visual cues[2].

Visual cues, such as lip movements, significantly influence auditory perception. The "McGurk effect" is a classic example, illustrating how incongruent audio-visual (A V) stimuli create illusory cross-modal speech sounds[3]. Key brain regions for multisensory speech perception include the frontal, parietal, and superior temporal sulcus (STS), primary and secondary auditory cortices, occipital and prefrontal cortex[4]. The STS is pinpointed as a cortical locus for the McGurk effect via fMRI-guided TMS, and fMRI consistently shows V5/MT activation during lip reading[5,6].

Neural integration of audio-visual streams relies on temporal mechanisms like neural tracking of rhythms in multisensory signals[7]. Individual alpha frequency (IAF, 8-12 Hz) is a prominent brain rhythm linked to the temporal window of multisensory integration. Findings suggest, IAF correlates with temporal illusions, making it plausible that the speed of IAF modulates illusion perception8. A recent study found that lower alpha and beta band oscillations over parieto-occipital sensors predicted illusion perception[9]. The speed of alpha band oscillations is also reported to predict the temporal resolution of visual perception. IAF has been linked to cognitive performance in working memory, audio-visual integration (flash-sound paradigm), and visual acuity[10].

Based on these facts, we hypothesize, alpha oscillation speed could modulate the illusion perception. Non-invasive brain stimulation can influence endogenous oscillations[11]. However, the relationship between IAF and the modification of subjective illusory perception and its variability remains unclear. We tried to understand this by applying transcranial electric stimulations (tACS) at IAF and IAF ± 2 Hz (offset) over the occipital region during an ongoing McGurk task and studying the changes in illusory perception.

Methods

We collected EEG resting state and multisensory illusory speech perception task data, along with tACS over the occipital cortex. Data from 20 participants (7 females) were collected and analysed, with a mean age of 24.75 ± 2.2 years. Written informed consent was collected under the experimental protocol, and ethical clearance was taken from IRB.

The experiment spanned two sessions (average interval: 4.35±4.3 days). On Day 1, resting-state EEG (5min) was recorded to estimate individual alpha frequency (IAF; range: 8.15–12.15Hz, mean: 9.85Hz). Participants then completed a multisensory speech perception task, reporting their subjective experiences of audio-visual (AV) stimuli using a McGurk paradigm[12]. On Day 2, participants repeated the task during tACS at O1/O2 (1500µA) delivered at their IAF or IAF±2Hz. Four AV stimuli were used: three congruent syllables (/pa/, /ta/, /ka/) and one McGurk (auditory /pa/, visual /ka/) stimulus eliciting the /ta/ illusion.

Day 1 experiment was carried out for five blocks, each block with 120 trials. Day 2 experiment was carried out for three blocks at IAF, and one block for IAF-2 and IAF+2, respectively. Each block had the four stimulus types (30 trials): Both congruent and incongruent videos were displayed with zero A V lags. The subjects were instructed to report what they heard while watching the articulator, using a set of four keys. The four choices were /pa/, /ta/, /ka/, and "anything else".

The stimuli were presented via Presentation software and displayed through an LED monitor. Articulatory sounds were delivered through headphones.

Results

In the no-stimulation condition, hit rates for congruent syllables /ta/ and /ka/ were 95.56% and 97%, respectively, while /pa/ was 73.19%. Under tACS, hit rates were 96.53% (/ta/), 97.27% (/ka/), and 81.51% (/pa/), averaged across participants. Hit rates for /pa/ were significantly lower than both /ta/ and /ka/ ($p < .001$) in both conditions, with non-significant difference between /ta/ and /ka/($p>.05$). These results align with literature[12]. Additionally, the difference between illusory /ta/ and non-illusory /pa/ during McGurk trials was significant without tACS ($p < 0.05$) but not under tACS at IAF or IAF±2 Hz).

The median of the percentage response of McGurk /ta/ i.e., illusory percept, without tACS was 82.0%, with tACS at IAF was reported to be 75.0%, indicating a shift in the illusory perception among the participants, from more illusory perception in the case of no stimulation to lower illusion perceived upon application of neurostimulation.

Discussion

This study suggests occipital alpha oscillations modulate audiovisual speech perception, especially in resolving cross-modal illusions like the McGurk effect. Participants showed higher accuracy for congruent syllables (/ta/, /ka/) while /pa/ elicited more ambiguous responses due to less distinctive features.

The only parameter changed for the tACS was frequency, as the study attempts to understand effect of modulation of the speed of IAF, hence the current was kept at 1500micro-amperes. tACS at IAF and offsets over the occipital cortex notably reduced illusory /ta/ responses in McGurk trials, indicating that alpha-band modulation can causally affect multisensory Integration[13]. The effect appeared to be driven by stimulation presence rather than precise frequency, suggesting disruption of temporal alignment needed for effective audiovisual integration, however, differences were observed in responses when IAF and offsets were compared. Further analysis is being carried out in this direction.

The use of individualized stimulation and balanced conditions strengthens the findings' reliability. Overall, this work provides strong evidence that non-invasive neurostimulation can alter audiovisual speech integration and reduce multisensory illusions, with grounds for exploring effect of speed modulation of IAF, paving the way for future research and targeted interventions. Larger, more diverse studies are needed to further validate these effects.

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Lateralised eye use in shoal size preference in adult zebrafish

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Introduction

Vertebrates widely exhibit behavioral asymmetries, with visual asymmetries particularly well reported. Such asymmetries are proposed to enhance performance in specific tasks, thereby improving individual fitness. The consistent bias toward using a specific eye to observe certain types of stimuli has been linked to stimulus properties such as novelty and emotional value. Zebrafish are emerging as an important model system for investigating the anatomical and functional bases of brain asymmetry. Visual social lateralization has been reported in zebrafish from early developmental stages and is associated with healthy social behavior. However, visual laterality in response to a social partner has been studied primarily using the mirror test, where zebrafish are exposed to their mirror image and eye-use bias is recorded. Here, we tested zebrafish in a social preference task, where individuals were presented with shoals of different sizes to measure lateralized eye use when comparing shoals.

Methods

A population of laboratory-housed zebrafish maintained under controlled conditions was subjected to a social preference assay using a transparent circular tank surrounded by display tanks. Shoals of different sizes were presented in the ratios 2 vs. 4 and 1 vs. 3. Eye-use time was measured in each preference zone while focal fish inspected the options. Relative eye use was calculated, and deviations from a 50% chance level were used to infer eye preference at the population level. Baseline control tests (4 vs. 0, 2 vs. 0, 1 vs. 0, 3 vs. 0) were also performed to examine whether laterality was expressed in response to a single shoal or only under paired comparisons.

Results

Statistically significant population-level lateralized eye use was observed only in the 1 vs. 3 condition, specifically while fish viewed the smaller shoal of one individual. Males exhibited a significant left-eye bias, whereas females showed a significant right-eye bias when observing the single fish in this contrast. No significant eye-use bias was found in the 2 vs. 4 comparison or in the single-shoal control tests, indicating that lateralization appeared only during comparative evaluation of shoal sizes.

Discussion

This study provides the first report of lateralized eye use in zebrafish during shoaling preference tests, with significant sex-specific differences. The effect was evident only while comparing social options, suggesting that laterality plays a role in decision-making. These findings have important implications for addressing both proximate and ultimate questions regarding behavioral lateralization in zebrafish and vertebrates more broadly.

Cognitive Adaptation and Trust Calibration in Human-AI Collaborative Design Environments

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Introduction

The growing integration of Artificial Intelligence (AI) into creative, decision-intensive work has reshaped User Experience (UX) design practice, accelerating ideation, content creation, and predictive analysis while introducing substantive cognitive demands (Miller, 2019; Shneiderman, 2020). Designers must interpret algorithmic outputs, calibrate trust in often opaque systems, and maintain human-centered values under uncertainty. These demands raise questions central to cognitive science: *How do professionals adapt cognitively to AI-mediated environments, and what mechanisms govern trust and decision-making in these contexts?*

This study informs HCI design while advancing cognitive theory by empirically validating Bayesian models of trust calibration in complex human–AI interactions, illustrating resource-rational integration of AI confidence and self-assessment to optimize collaboration (McLaughlin et al., 2022). By extending these frameworks to professional UX practice reveals trust as an adaptive process, enriching cognitive models of human–AI interaction in hybrid systems (McGrath et al., 2024).

Methods

An exploratory qualitative approach was adopted. Semi-structured interviews were conducted with 18 UX designers and researchers (experience range: 5 to 20+ years). Interviews probed learning trajectories with AI tools, criteria used to evaluate AI-generated outputs, and strategies for integrating or overriding AI recommendations.

Audio-recorded interviews were transcribed and analysed using reflexive thematic analysis following the six-phase approach (Braun & Clarke, 2006). To align with computational theory, the coding framework was structured into three dimensions:

Decision Variables: Perceived evidence strength of AI outputs, perceived reliability
Control Parameters: Allocation of time and effort for verification
Learning Signals: Prediction error, outcome-based feedback

This organization draws on decision-science perspectives that model how people optimize decisions under cognitive constraints (Lieder & Griffiths, 2019). Furthermore, this framework advances cognitive theory by incorporating elements of Bayesian networks to map cognitive alignment between human intuition and AI reasoning, providing a structured way to quantify trust calibration in decision-making under uncertainty (Zheng et al., 2025). This extension highlights how qualitative data can inform probabilistic cognitive models, bridging HCI empiricism with computational cognitive science.

Results

- **Learning and Adaptive Expertise:** UX designers engaged in iterative, feedback-driven processes to refine prompt formulation, task selection, and tool use. These cycles exemplify resource-rational adaptation in cognitive theory, where limited mental resources are allocated efficiently to learn AI competencies (Lieder & Griffiths, 2019; McLaughlin et al., 2022).
- **Decision-Making Under Uncertainty:** A consistent need was identified for lightweight decision scaffolds (e.g., checklists or rules of thumb) that clarify when to rely on, verify, or override AI. In the absence of explicit organizational guidelines, many adopted personal heuristics, especially for high-stakes or time-constrained decisions. This finding advances cognitive theory by illustrating evidence accumulation processes in real-time human-AI decisions, showing how heuristics serve as resource-rational shortcuts to calibrate trust, extending theoretical models to account for contextual uncertainty in collaborative environments (McGrath et al., 2024).
- **Trust Calibration:** Trust increased when systems offered clear explanations**,** confidence indicators**,** and provenance**,** enabling appropriate reliance. Trust was neither binary nor static; it was calibrated through repeated interactions. UX Designers reported greater willingness to rely on AI when systems offered clear explanations, confidence indicators. Beyond HCI, this process supports Bayesian cognitive models where trust updates resemble probabilistic belief revision based on accumulated evidence, providing empirical grounding for theoretical predictions in decision science (Zheng et al., 2025).
- **Productivity vs. Cognitive Overhead:** While AI accelerated generation of variants and summarization of research data, these gains were sometimes offset by verification costs, context switching, and error correction, which increased cognitive load and eroded net efficiency. This trade-off highlights advances in cognitive theory regarding

resource allocation in human-AI systems, revealing how overhead costs influence rational control mechanisms and trust calibration over time (Lieder & Griffiths, 2019).

- **Preserving Empathy:** Designers emphasized that human judgment remained essential for affective and cultural fit; purely statistical recommendations occasionally missed tone, nuance, or ethical considerations. This underscores a key advance in cognitive theory: the irreplaceable role of human metacognition in integrating empathetic reasoning with AI outputs, extending models of collaborative cognition to include socio-emotional dimensions often overlooked in HCI-focused studies (McGrath et al., 2024).

Discussion

The results suggest a computationally interpretable account of professional adaptation in human–AI design. This account advances cognitive theory beyond HCI by offering real-world validation of Bayesian complementarity models, where human and AI confidences are fused probabilistically to enhance decision accuracy and trust calibration in creative domains (McLaughlin et al., 2022).

From these insights, three design recommendations follow.

- **Trust-aware interfaces:** AI systems should present transparent reasoning and confidence in user-comprehensible forms e.g., concise “why” explanations, links to data sources, or local example-based rationales (Ha & Kim, 2023; Ribeiro, Singh, & Guestrin, 2016).
- **Task-conditional performance reporting:** Beyond generic accuracy, designers benefit from contextualized reliability, for instance, success rates on similar tasks or conditions where model performance degrades, helping them build accurate priors and avoid mis-calibrated trust (Lee & See, 2004).
- **Lightweight decision aids:** Embedding optional checklists or explanatory-debugging prompts can reduce mental effort and guide appropriate reliance (e.g., highlighting recommendations with high uncertainty for human review). Prior work shows that explanatory debugging improves users’ mental models and correction efficiency for interactive Machine Learning systems (Kulesza et al., 2015) and can thus operationalize a “verify-when-needed” culture. These aids also advance cognitive theory by operationalizing resource-rational strategies, enabling empirical testing of how such tools modulate trust calibration in Bayesian frameworks (McLaughlin et al., 2022).

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Virtual Reality Intervention for Enhancing Emotional and Cognitive Functioning in Young Adults Indulging in Violent Games

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Introduction

Violent Games (VGs) which is defined in this study as digital games with player-controlled physical aggression, combat systems, weapon usage, or simulated injury toward human or human-like recipients—are one of the most played gaming genres globally. Representative games employed for categorization included Call of Duty, PlayerUnknown's Battlegrounds (PUBG), Counter-Strike: Global Offensive, Grand Theft Auto V, Mortal Kombat, etc. These games were repeatedly identified as prototypical violent games used in cognitive-affective and neuroimaging studies. Collectively, they represent the main structural elements of violent media: habitual exposure to goal achievement weaponized, reward contingencies tied with aggression, and first-person perspective realism that heightens sensorimotor involvement and affective arousal.

Worldwide, VGs are a part of a gaming industry valued at over USD 184 billion in 2023, and in India—with over 550 million active gamers—18-30-year-old players spend 10-13 hours a week playing, a significant portion on violent games. From a cognitive-neuroscientific perspective, prolonged violent game exposure has been linked with functional changes in neural networks that regulate affect processing, executive control, and decision-making. Neuroimaging results indicate heightened activation of the amygdala in response to emotional stimuli and lower ventromedial and dorsolateral prefrontal cortex and orbitofrontal cortex activation, all areas critical for impulse regulation and adaptive thinking (Blair, 2016; Etkin et al., 2011; Goldin et al., 2008). Such habitual exposure could further solidify threat vigilance and reward sensitivity neural pathways and suppress those facilitating cognitive flexibility and prosocial decision-making (Anderson et al., 2010; Montag et al., 2021).

Evidence for VG effects, however, is still mixed. Some meta-analyses associate them with increased aggression and lowered empathy, while others indicate negligible or context-dependent effects on executive function and risky choice (Kühn et al., 2019). These inconsistencies are shown to be moderated by personality characteristics—especially trait aggressiveness—which increases the behavioral and emotional impact of violent play (Anderson & Dill, 2000; Arriaga et al., 2006).

Non-violent virtual-reality (VR) settings, on the other hand, provide interactive, multisensory contexts that induce curiosity, positive affect, and attentional control without violent reinforcement. These settings can engage neural systems associated with novelty, reward, and self-regulation. In this research, "non-violent VR" was used to describe organized, interactive simulations that highlighted creativity, mindfulness, exploration, and prosocial engagement. The four-week intervention utilized five verified VR experiences on Oculus Meta Quest, which included Tripp Meditation (regulation of arousal and mindfulness), Ocean Rift (exploration and awe), Beat Saber (rhythmic coordination and attentional control), Gravity Sketch (visuospatial flexibility and creative problem-solving), and First Steps (orientation and embodied interaction). These were chosen based on theoretical potential and a pilot study to induce adaptive emotion and cognitive engagement in accordance with earlier research that these conditions enhance prefrontal activation and parasympathetic regulation (Riva et al., 2019; Seabrook et al., 2020).

The current study thus sought to:

a. investigate correlations among violent game exposure (VGE), emotional reactivity, set-shifting, and risky decision-making;
b. assess if a structured, non-violent VR intervention is linked to improved emotional and cognitive outcomes in heavy violent gamers; and
c. examine if the associations are moderated by trait aggressiveness

Methods

A true experimental, randomized controlled, pre-test–post-test mixed factorial (between–within) design was employed. Forty young adults (18–30 years; M = 21.80, SD = 2.21) who satisfied the inclusion criterion of ≥10 hours/week VGE for at least six months were purposively sampled and randomly allocated to an experimental (n = 20) or waitlist control group (n = 20). Measures were:

1. Video Game Exposure Questionnaire (Anderson & Dill, 2000) for weekly violent-game hours and intensity ratings;
2. Perth Emotional Reactivity Scale (PERS) for general positive reactivity (GPR) and general negative reactivity (GNR);
3. Wisconsin Card Sorting Test (WCST) for set-shifting ability (SSA);
4. Iowa Gambling Task (IGT) for risky decision-making (RDM; higher net scores = advantageous decisions); and
5. Buss–Perry Aggression Questionnaire (BPAQ-SF) for trait aggressiveness (TA).

Baseline tests were administered before the intervention; post-tests were administered four weeks later. Experimental condition participants had 20-minute daily non-violent VR activities, with controls following regular activity. Statistical analysis used Pearson correlations to test bivariate relationships, 2 (Time: pre/post) × 2 (Group: experimental/control) repeated-measures ANOVA to test intervention effects, and Hayes' PROCESS Model 1 to test moderation by TA.

Results

The correlational analyses revealed that VGE was positively correlated with risky decision-making ($r = .405$, $p = .009$) and negative emotional reactivity ($r = .411$, $p = .008$), but was negatively correlated with set-shifting ($r = –.353$, $p = .024$) and positive reactivity ($r = –.441$, $p = .004$). These findings indicate that higher violent exposure is linked with impulsive and disadvantageous choices, higher negative emotional reactivity, and lower cognitive flexibility and positive affect.

Repeated-measures ANOVA revealed strong Time × Group interactions:

Positive reactivity (GPR) significantly increased in the VR group ($F(1,38)= 54.70$, $p< .001$, $\eta^2 = .590$), reflecting greater responsiveness to positive stimuli;

Negative reactivity (GNR) decreased ($F(1,38)= 24.93$, $p< .001$, $\eta^2 = .396$), demonstrating reduced emotional over-arousal and enhanced regulation;

Risky decision-making (RDM) improved as Iowa Gambling Task net scores increased ($F(1,38)= 20.53$, $p< .001$, $\eta^2 = .357$), reflecting a move toward adaptive, reward-balanced decisions;

Set-shifting capacity (SSA) was enhanced ($F(1,38)= 7.15$, $p = .011$, $\eta^2 = .158$), reflecting greater cognitive flexibility and fewer perseverative errors on the Wisconsin Card Sorting Task.

No similar alterations were found for the waitlist control group, excluding maturation or practice effects.

Moderation analysis revealed that aggressiveness trait effectively moderated the relationship between VGE and positive reactivity ($\beta = –0.082$, $p = .003$), meaning higher aggressiveness individuals showed steeper decrease in positive affect with larger violent exposure. No moderation effects were found for GNR, RDM, or SSA.

Discussion

The results confirm adverse associations between intense violent gaming and emotional–cognitive functioning while highlighting their susceptibility to personality context. Increased violent exposure was associated with lower positivity, higher negativity, poorer cognitive flexibility, and riskier decision profiles. These trends are in line with neural data reporting lower prefrontal control and increased limbic reactivity for heavy violent players (Lai et al., 2018). Moderation effect of trait aggressiveness predicts that violent content does not impact all players to the same degree but amplifies pre-existing affective vulnerabilities as predicted by the General Aggression Model (GAM; Anderson & Bushman, 2002), which suggests repeated exposure to violent cues primes hostile cognitions, consolidates aggressive scripts, and interacts with dispositional traits to influence emotional and behavioral responses.

The four-week VR intervention with non-violent content yielded wide, statistically large, and psychologically significant improvements. Subjects were more emotionally stable and positive, made more beneficial choices on the IGT, and showed enhanced set-shifting efficiency—results that together indicate re-activation of prefrontal-limbic regulatory networks. The large partial η^2 values (ranging .158–.590) reflect medium-to-large effects, validating the efficacy of the intervention despite a small sample size.

These benefits appear attributable to the unique affordances of VR: multisensory immersion, embodied presence, real-time feedback, and active engagement beyond the unisensory or passive quality of video or mindfulness exercises. Each chosen application added unique therapeutic components—mindfulness and parasympathetic activation through Tripp Meditation; awe and relaxation through Ocean Rift; rhythmic entrainment and attentional synchronization through Beat Saber; creative cognitive flexibility through Gravity Sketch; and initial embodied control through First Steps. All together, they constituted a multimodal experiential program that progressively replaced violent arousal loops with adaptive, self-regulating, and prosocial patterns of engagement.

Theoretically, the results advance the General Aggression Model (GAM) as well as social learning theory. While GAM accounts for the impact of violent exposure on aggression, social learning processes explain how repeated emotionally constructive non-violent rehearsals in VR can lead to prosocial and self-regulatory scripts. In practice, the results place VR not just as a form of entertainment but as an applied therapy and prevention tool that can reverse emotional desensitization and cognitive rigidity in frequent violent gamers.

In conclusion, this research demonstrates that (a) the negative consequences of violent gaming are moderated rather than universal; (b) non-violent VR exposure can produce quantifiable benefits in affective and cognitive domains within a span of merely four weeks; and (c) the immersive, bodily, and interactive affordances of VR specially place it as an evidence-based counter-exposure medium for promoting emotional regulation and cognitive resilience in young adults. These findings add to the building body of research on digital mental health and highlight the potential of technology, when appropriately structured, can be redirected from risk to restoration.

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Investigating sensorimotor beta burst dynamics as a robust biomarker for graded force modulation in humans

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Introduction

Brain-Computer Interfaces (BCIs) aim to translate neural activity into commands for external devices, offering significant potential for individuals with motor disabilities (Wolpaw, 2007). A critical challenge is moving beyond simple binary controls to achieve nuanced, graded control of neuroprostheses, such as modulating grasp force. While prior research has shown that event-related desynchronization (ERD) in mu (8-12 Hz) and beta (13-30 Hz) frequency bands correlates with force levels (Tang et al., 2016), these spectral measures often lack the specificity for fine-grained control. Recent work suggests that motor cortex beta activity occurs not as a sustained oscillation, but as transient, short-lived 'bursts' whose characteristics are linked to motor control (Little et al., 2019; Papadopoulos et al., 2024). More robust (higher amplitude) and temporally closer beta bursts are directly linked to a significant increase in subsequent movement slowing (Muralidharan & Aron, 2021). This study investigates whether the specific dynamics of these beta bursts provide a more detailed neural signature of graded force exertion than traditional spectral power measures.

Methods

A pilot study was conducted with healthy participants (N=6, after one exclusion due to a wrong stimulus marker labelling) who performed an isometric wrist-flexion task. At the start of the experiment, we first measured the Maximum Voluntary Contraction (MVC) using a custom-built isometric wrist-flexion dynamometer. We used the same custom-built isometric wrist-flexion dynamometer to apply different force levels during the experiment. The task required participants to apply and maintain force at four distinct levels (10%, 25%, 50%, and 75% of their MVC) for six seconds per trial, guided by real-time visual feedback.

EEG data were acquired using a 64-channel system. We use EEGLAB (Delorme & Makeig, 2004) for data preprocessing. The EEG data underwent down-sampling to 500 Hz, followed by the application of a 1 Hz high-pass filter. Line noise was eliminated using the Zapline-Plusplugin (Klug & Kloosterman, 2022). Subsequently, a 40 Hz low-pass filter was applied, and a common average reference was computed. Independent component analysis (ICA) was conducted using the default runica algorithm (Makeig et al., 1995). Artifactual components, including those associated with muscle activity, eye movements, and channel noise, were identified and removed manually. Finally, the data were epoched from -1 s to 10 s relative to the stimulus onset markers corresponding to the 10%, 25%, 50%, and 75% conditions.

We did an analysis of those trials in which participants were able to maintain the instructed MVC within 10% of that MVC for at least 2 seconds. Analysis focused on two components:

Event-Related Spectral Perturbation (ERSP) to quantify force-related modulation of mu and beta band power, and a beta burst analysis focused on a stable force period within each trial, using a superlet transform (Moca et al., 2021; Szul et al., 2023).

We identified transient beta bursts and extracted their peak amplitude and time relative to stimulus onset. A Generalised Linear Model (GLM) was then employed on all subjects' combined data to determine if these burst parameters could predict the mean exerted force across trials. For GLM, we used the average stable force within each trial as a dependent component, and average beta burst amplitude and average burst time as independent components.

Results

The analysis confirmed that as the level of exerted force increased, there was a corresponding and more pronounced ERD in both the mu and beta bands, consistent with previous findings (Tang et al., 2016). To find the relation of different force levels with the beta burst parameters, we used the Generalised Linear Model (GLM). The GLM showed that beta burst characteristics are a statistically significant predictor of different force levels. Specifically, the peak amplitude of beta bursts exhibited a strong negative relationship with force level ($\beta = -0.4386$, $p<0.001$), while the peak timing of the bursts demonstrated a positive relationship ($\beta=0.0497$, $p=0.003$).

Discussion

These results demonstrate that, beyond traditional spectral power, the specific dynamics of transient beta bursts carry detailed information about graded force exertion. The strong negative correlation between burst amplitude and force suggests that the execution of higher force levels is associated with a more profound suppression of high-amplitude beta events in the motor cortex. These findings provide a granular set of neural features for decoding kinetics from non-invasive EEG signals. These results are from the pilot study (6 participants), and so the results have to be interpreted with caution. We are currently in the process of recording data from more participants (N=16, sample size estimated from power analysis). While C3 is commonly used for left motor cortex analysis but in our main study, we are going to employ Independent Component Analysis (ICA) with dipole fitting to select the component that best localises to the left motor cortex, which provides superior source localisation, artifact separation, and signal quality compared to single-channel analysis. We also analysed C4 channel beta burst amplitude across the four force levels. Beta burst amplitude significantly decreased as force levels increased ($p < 0.001$), with C3 showing a higher amplitude compared to C4 ($p = 0.021$). However, since only six participants were included in this study, these findings cannot be generalised to the broader population. This work is being extended to investigate whether similar beta burst dynamics are present during motor imagery of varied force levels. The ultimate goal is to leverage these detailed neural signatures to develop BCI systems capable of more precise and intuitive control of advanced neuroprosthetic devices, such as a multi-articulated robotic finger.

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Construction and standardization of a reversal learning task for assessing cognitive flexibility

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Introduction

One essential executive function that promotes learning, problem-solving, and adaptive behavior is cognitive flexibility, which is the capacity to change viewpoints and adjust to shifting demands. There are still few standardized instruments designed specifically for the Indian setting, despite the fact that reversal learning paradigms have been widely used in foreign research. The current study aimed to close this gap by creating, standardizing, and assessing the psychometric qualities of a recently developed RLT (Sharma, Gupta, & Sandhu, 2024) tailored for student populations.

The diagnostic value of discrimination reversal learning in comprehending the brain mechanisms behind compulsive and impulsive behaviors was highlighted[6]. They identified inadequate dopamine modulation, especially at D2 receptors, and dysregulation in fronto-corticostriatal circuits as major causes of poor reversal performance. Prior research has provided interpretations of results across paradigms and further described the brain underpinnings of reversal learning[3,4,5,7,10].

The current study built on this foundation by examining various methods of measuring reversal learning and providing updated evidence on the construct validity of RLTs.

Method

Sample

A purposive sample of 100 students. The age range of the students was between 17 to 22 years. Data was garneted from both rural and urban areas. Students irrespective of their gender, caste, creed, religion was be included in the sample.

Tool Development

The initial pool of stimuli consisted of 22 experimental cards created specifically for this task. The cards were designed to vary systematically in size (large or small), colour (two distinct hues) and colour with size (small and large). Each card displayed two stimuli side-by-side, with only one being correct according to the hidden rule in that trial block. The design aimed to create conditions that would require rule learning, followed by reversal when contingencies changed.

Pilot Testing and Item Analysis

The 22 cards were piloted on a smaller group (n = 100) to assess clarity, discriminability, and engagement. Based on performance data, item-total correlations were computed to evaluate each card's contribution to the overall construct. Following analysis, five cards were selected for the final version of the Reversal Learning Task (RLT). Those items with a lower correlation (0.20) were retained for theoretical relevance.

Procedure

In each trial, two abstract patterns were presented side by side, and participants were instructed to indicate their choice by ticking the correct option. Immediate feedback was provided in the form of a green smiley face for correct responses and a red sad face for incorrect responses. Once a participant achieved three consecutive correct responses, the rule automatically shifted, and a new card was presented. Importantly, no explicit announcement of the rule change was made, requiring participants to infer the shift based on feedback patterns. The task continued until all five cards had been completed.

Firstly, the rapport was established with subjects and gave instructions to them about the task. In this task there are six cards and each card has four abstract visual patterns. For each card, the subjects must get three consecutive correct answers before the rule changes and the next card is presented.

The first card was presented with four patterns where subjects have to choose according to size choose either large or small. Feedback is provided immediately chosen one of the patterns as green smiley face for correct response and red sad for incorrect response. After getting three green smiley face, second card is presented where subject must focus on a colour that can correspond to either a large or small size. As the task forwards, a third card requires choosing a small size, followed by a fourth card where subjects are instructed to choose a large size. For the fifth card, subjects have to choose small colour and the last six card focused on large colour. A feedback mechanism of green smileys and red sad faces provides immediate reinforcement after each response and it guides to subjects for adjusting their strategy when the rules are reversed during the task. After all the six cards, final record sheet was downloaded.

Reversal Learning task - (https://reversal-learning-new.vercel.app/).

Scoring

Performance was evaluated using three indicators: (1) the number of correct responses per card, (2) the number of errors committed before meeting the three-correct criterion, and (3) the total number of trials required for task completion across all five cards.

Psychometric Analysis

Psychometric analysis was conducted through item analysis, and item-total correlations were calculated for each of the five cards. Results indicated values of 0.63 for Card 1, 0.43 for Card 2, 0.60 for Card 3, 0.59 for Card 4, and 0.47 for Card 5.

Reliability

Internal consistency for the six-card version was high (Cronbach's $\alpha = 0.836$), indicating that the items measured a cohesive construct.

Concurrent Validity

The RLT was administered alongside the Cognitive Flexibility Scale (Martin & Rubin, 1995) to assess convergent validity. Positive and significant correlations supported its validity as a behavioral measure of cognitive flexibility.

Discussion

Many brain networks and processes are involved in reversal learning, which is widely acknowledged as a crucial indicator of cognitive flexibility. The multi-stage complexity of reversal tasks highlights the significance of reward and control-related regions, in addition to a core saliency network[11]. In a similar vein, cortical and subcortical areas, together with important neurotransmitter systems, promote reversal learning[8]. Adding to this, the type of learned stimulus has an impact on reversal performance in addition to flexibility. According to their research, what seems like less flexibility can really help with adaptive decision-making in ecological settings[1]. Additionally, highlighted the prefrontal cortex's function in flexible goal-directed behavior by connecting individual variations in task structure dependence with prefrontal activity[2].

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Embodied Cognition in Action: Foot Pressure Influences Fronto-Central and Temporal EEG Oscillations

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Abstract

Embodied cognition emphasizes the influence of bodily states on higher-order brain functions, including attention and emotion. The present study investigated how peripheral somatosensory input, operationalized through foot pressure, modulates cortical oscillations during integrated attention–emotion processing. Electroencephalography (EEG) was recorded in healthy adults performing cognitive–emotional tasks under two foot-pressure conditions. Event-related spectral perturbations (ERSP) were analyzed within the delta, theta (0.1–8 Hz), alpha (8.1–13 Hz), and beta (13.1–14 Hz) bands during the 100–250 ms post-stimulus window. Statistical comparisons revealed significant modulations at frontal, central, and temporal sites, suggesting that somatosensory feedback from the feet contributes to early neurocognitive mechanisms underlying emotional and attentional integration. These findings provide novel evidence for sensorimotor contributions to emotion–attention coupling and highlight translational applications for stress monitoring, emotion regulation, and neurorehabilitation.

Methodology

Participants

Twenty healthy adults (10 males, 10 females; age range: 18–35 years, mean = 26.4 years, SD = 4.2) participated in the study. All participants had normal vision, were right-handed, and reported no psychiatric or neurological history. Recruitment was conducted via campus advertisements, and written informed consent was obtained in accordance with the institutional ethics committee of the National Institute of Technology, Raipur.

Experimental Design

A within-subject design was implemented, with participants performing combined attention–emotion tasks under two foot-pressure conditions. In the high-pressure condition, participants were seated barefoot with sensors attached to the toe, midfoot, and heel regions to enhance somatosensory feedback. In the low-pressure condition, participants wore footwear containing identical sensors but without additional load. Each condition involved visual stimuli depicting emotional facial expressions (happy, sad) and hierarchical attention tasks (local vs. global shapes), enabling analysis of emotion–attention interactions under varying somatosensory states.

EEG Recording and Preprocessing

EEG was recorded using a 16-channel AD Instruments system with electrodes positioned according to the international 10–20 system. Electrode impedance was maintained below 10 kΩ, and signals were sampled at 1000 Hz. Data were band-pass filtered between 0.1 and 40 Hz, visually inspected for artifacts, and segmented into stimulus-locked epochs.

Time–Frequency Analysis

Event-related spectral perturbations (ERSP) were computed via wavelet transform for the 100–250 ms window corresponding to early perceptual and attentional (Klimesch 2012; Cavanagh & Frank 2014) ERP components (P1, N1).
Frequency bands included:
- Delta/low-theta (0.1–4 Hz)
- Theta (4.1–8 Hz)
- Alpha (8.1–13 Hz)
- High-alpha/Beta (13.1–14 Hz)

Mean power changes were extracted from frontal (Fp1, Fp2, F3, F4), central (C3, C4), and temporal (T3, T4) electrodes associated with emotional regulation, attentional allocation, and multisensory integration.

Statistical Analysis

A repeated-measures ANOVA was conducted with Foot Pressure (high vs. low) and Stimulus Type (emotional vs. attentional) as within-subject factors. Significance was set at $p < .05$, and effect sizes were reported using partial eta squared (η^2p).

Results

Delta–Theta Band (0.1–4 Hz and 4.1-8Hz, 100–250 ms):

Frontal and temporal regions showed significant modulation:
- Fp1: $F(1,19)=5.105$, $p=0.050$, $\eta^2p=0.362$; Fp2: $F(1,19)=9.655$, $p=0.013$, $\eta^2p=0.518$: enhanced theta power under high foot pressure, particularly in males.

- T3: F(1,19)=9.368, p=0.014, η^2p=0.510: pronounced modulation in females, suggesting left lateralized temporal processing.

These findings indicate somatosensory modulation of frontal–temporal delta–theta oscillations, reflecting early attentional orientation and emotional salience detection.

Theta–Alpha Band (4.1–13 Hz, 100–250 ms):

Central electrodes exhibited significant alpha suppression:

- C3: F(1,19)=10.667, p=0.010, η^2p=0.542; C4: F(1,19)=9.626, p=0.013, η^2p=0.517: reduced theta power indicating heightened cortical engagement.
- T3: F(1,19)=6.460, p=0.032, η^2p=0.418: robust modulation in females.

Alpha suppression is typically linked to attentional focus and cognitive engagement, suggesting that increased foot pressure enhances sensory integration demands.

Beta Band (13.1–14 Hz):

Frontal and temporal regions exhibited emerging modulations:

- F4: F(1,19)=6.811, p=0.028, η^2p=0.431;
- T3/T4: trends toward significance ($p \approx 0.05$–0.08).

These results imply that higher-order integrative and hemispheric processes are sensitive to peripheral somatosensory feedback.

Discussion

The results confirm that peripheral somatosensory input, operationalized through foot pressure, significantly modulates early cortical oscillations associated with emotion–attention processing.

1. **Frontal Theta Enhancement**: Elevated theta activity at Fp1 and Fp2 under high-pressure conditions reflects stronger frontal engagement in attentional control and emotional evaluation. Theta oscillations serve as key markers of cognitive control and affective regulation.
2. **Central Alpha Suppression**: Reduced alpha power at C3 and C4 signifies increased sensorimotor activation, consistent with the embodied cognition view that posture and proprioceptive feedback dynamically influence cortical excitability and attention allocation.
3. **Temporal Lateralization**: The pronounced T3 activation suggests left-hemispheric

bias, often associated with approach-related or positive emotional processing.
Together, these findings reinforce the concept that bodily feedback is an integral component of early cognitive–emotional coupling, extending the embodied cognition framework to dynamic sensorimotor contexts.

Conclusion

Foot pressure significantly modulates early EEG oscillations in frontal, central, and temporal regions, highlighting the integral role of peripheral sensorimotor feedback in emotion–attention integration. These findings advance embodied cognition theory and point toward novel applications in clinical evaluation, neurorehabilitation, and human–machine interaction. Future research combining EEG with autonomic (ECG) and hemodynamic (fNIRS) measures could establish multimodal biomarkers of emotional regulation and cognitive resilience.

The Modulation of Emotional Relevance on Proactive Cognitive Control

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Introduction

Cognitive control refers to the brain's capacity to guide thought and action in line with goals, especially amid distraction or conflict (Miller & Cohen, 2001). Two modes are distinguished: reactive control, a late stage corrective response, and proactive control, an anticipatory form involving maintenance of goal information (Braver, 2012). Proactive control enables flexible, goal-directed behavior by anticipating and avoiding errors rather than correcting them after happening.

Research has shown that emotional information significantly impacts reactive control, often biasing attention and increasing sensitivity to distraction (Pessoa et al., 2008; Yiend, 2009). However, less is known about how emotions modulate proactive control (Kalanthroph, 2013). This gap is critical as proactive control helps avoid interference, and its sensitivity to emotional stimuli remains unclear. Present article aims to understand emotion automatically disrupt proactive processes, or is its influence contingent on the relevance of emotional content to task demands.

The present study investigates the interaction between emotional information and proactive control. Participants performed the task under two conditions: one in which emotional faces were irrelevant to the decision rule, and another in which emotional faces were integral to the rule. This design allowed us to isolate whether emotion modulates performance only when integrated into task goals. We hypothesize that emotional stimuli will affect proactive control only under the Emotion-Relevant condition, with no effects in the Emotion-Irrelevant condition.

Methodology

The study involved 27 participants (15 male, 12 female, aged 20-26). The study used a modified AX-Continuous Performance Task (AX-CPT) with emotional face stimuli. The experiment had a within-subjects design with two main conditions: Emotion-Irrelevant and Emotion-Relevant. Each condition consisted of three blocks, each featuring a different emotional face (happy, angry and both). The order of conditions and blocks was counterbalanced.

Task

Each trial started with a fixation cross, followed by a cue letter (A or B), a delay, and then the probe. In Emotion-Irrelevant, probes were letters X or Y with emotional faces above; in Emotion-Relevant, probes were emotional or neutral faces. Participants were instructed to press the 'M' key for a specific target pair (A-X) and the 'Z' key for all other combinations. This rule was reversed for half the participants. Each block comprised 163 trials, with 70% of them being the A-X target trials which is the proactive control trial and other trials types as reactive control trials. Breaks and practice sessions with feedback preceded in each condition.

Result

A repeated-measures ANOV A was conducted to examine the influence of emotional faces on reaction times (RTs) and accuracy in Emotion-Irrelevant and Emotion-Relevant conditions of the AX-CPT.

Reaction Times

In the Emotion-Irrelevant condition, across angry, happy, and mixed blocks, no significant main effects of prime, probe, or emotion were observed ($p > 0.05$). A significant effect of prime and probe was observed in angry [F (1, 26) = 44.868, $p < 0.001$], happy [F (1, 26) = 27.314, $p < 0.001$] and mixed block [F (1, 26) = 21.349, $p < 0.001$].

In the emotion relevant condition, there was a significant main effect of prime, probe and emotion were observed in angry [F (1, 26) = 24.827, $p < 0.001$] and mixed [F (1, 52) = 6.250, $p < 0.004$] blocks. In the angry block, A-angry trials elicited longer RTs than B-angry trials (t = 5.196, p = .001), which means that angry emotion does not facilitate proactive control. In the happy block, A-happy trials were also longer than B-happy (t = 7.415, p = .001).Which means that happy emotion also does not facilitate proactive control. Similarly, in the mixed block, both A-angry and A-happy trials were longer than both B-angry (t = 5.191, p = .001) and B-happy (t = 7.376, p = .001), which align with the idea that emotions does not facilitate proactive control. A paired t test between A-angry and A-happy across blocks showed no significant effect(t = 0.880, p = .387). Which means that emotion across blocks as well does not facilitate proactive control. Descriptive statistics showed, A-neutral trials showed the highest RTs (~0.40s), whereas B-trials showed the lowest (~0.26s) and A-angry and A-happy with RTs of around 0.360s. Overall, the result suggests that emotional faces (angry and happy) do not affect proactive control.

Accuracy

No significant effects found in the Emotion-Irrelevant condition. In the Emotion-Relevant condition, however, main effects were found. A-emotional (angry, happy) trials showed dramatically higher accuracy than A-neutral (angry: t = 22.823, p < .001; happy: t = 45.001, p < .001). In the mixed block, both A-angry and A-happy trials outperformed A-neutral (t = 20.207, p < .001; t = 40.125, p < .001), while B-neutral responses exceeded both B-angry and B-happy (all p < .001). Descriptive trends indicated A-neutral trials had the lowest accuracy (M ~5%), whereas A-happy trials reached the highest (M ~53%).

Discussion

Consistent with our hypothesis, when emotional faces were task-irrelevant, proactive control remained resilient, effectively filtering out emotional distraction without impairing reaction times or accuracy. This supports that proactive mechanisms shield goal-directed behavior from incidental affective interference (Braver, 2012; Criaud et al. 2012; Mäki-Marttunen et al. 2019). Emotion-relevant conditions did not show facilitation for proactive control. This indicates that emotion does not improve preparation even part of the goal, emphasizing modulation of proactive control does not depend on emotions' relevance to goal (Hur et al., 2019).

According to the approach and avoidance hypothesis, emotional cues (like happy or angry faces) should influence reaction time, potentially leading to faster RTs for approach-motivated stimuli (happy) and slower RTs for avoidance-motivated stimuli (angry) (Marsh et al., 2005; Pawliczek et al., 2013; Gupta & Singh, 2021; Gupta & Singh, 2023) but in case of proactive state a sustained, anticipatory maintenance of task goals is inherent to proactive state leading to better able to suppress emotional interference. Dual competition framework suggests happy faces would take less cognitive resources (Gupta et al., 2016; Gupta & Srinivasan, 2015) as compared to angry faces, and that would appear as faster RTs for happy faces as compared to angry faces but present study result does not align with it. Overall, it can be concluded that the presence of emotional information relevant or irrelevant to the goal does not affect proactive inhibition.

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Effects of Mindfulness Training on Negative Self-talk and Metacognition in Young Adults

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Mindfulness, defined as purposeful and non-judgmental attention to the present moment, has been associated with greater awareness of internal experiences and improved regulation of thought and emotion. Negative self-talk, a self-critical internal dialogue, can distort self-perception and contribute to emotional distress, whereas metacognition, the capacity to reflect on and regulate one's own thinking, supports accurate self-monitoring and cognitive flexibility. The present study examined whether mindfulness training reduces negative self-talk and enhances metacognitive awareness in young adults and explored the feasibility of neurofeedback training (NFT) as an adjunct intervention. Thirty participants (aged 18–25) were randomly assigned to an experimental group that underwent structured mindfulness sessions or to a control group that completed only pre- and post-assessments. Standardised measures included the Five Facet Mindfulness Questionnaire (FFMQ), Metacognition Self-Assessment Scale (MSAS), and Self-Talk Questionnaire (STQ). Paired-samples t-tests revealed significant increases in mindfulness (t(14) = –2.97, p = .010) and significant reductions in negative self-talk (t(14) = 3.18, p = .007) within the experimental group, with a trend toward improved metacognition that approached significance (t(14) = –1.85, p = .083). The control group showed no significant changes across measures. Between-group comparisons using Welch's ANOV As showed that, after the intervention, the experimental group demonstrated significantly higher mindfulness (F(1,26.8) = 12.60, p = .002) and lower negative self-talk (F(1,27.8) = 5.80, p = .023), with a marginal difference in metacognition (F(1,24.2) = 3.92, p = .058), suggesting that while metacognitive change was modest, the intervention may have stabilized or slightly improved metacognitive awareness compared to the control group, which showed mild decline. In an exploratory Neurofeedback case study, the participant exhibited progressive increases in alpha amplitude (8–12 Hz) across five sessions, suggesting enhanced neural relaxation and attentional regulation, and supporting NFT's potential as a complementary tool to mindfulness training. These findings collectively indicate that mindfulness practice effectively modifies self-related cognitive patterns by increasing mindful awareness and reducing self-critical internal dialogue in young adults, with preliminary evidence suggesting possible improvement in metacognitive processes. The inclusion of NFT

points toward a promising multimodal approach to cognitive-emotional regulation. Conceptually, these results reinforce the role of mindfulness in fostering adaptive self-reflection and resilience by facilitating de-centering from negative cognitive content and promoting a more objective, compassionate stance toward oneself. Given the rising mental health challenges among young adults, such interventions hold meaningful implications for educational and therapeutic contexts by offering accessible, skill-based strategies for managing intrusive or critical thoughts and enhancing self-understanding. Future research with larger samples, extended training periods, and integrated neurophysiological measures is warranted to clarify the long-term impact of mindfulness and its potential synergy with NFT on cognitive and emotional well-being.

Oddball Paradigm Investigation of Emotion–Math Interaction in the Brain

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Introduction

Emotional facial expressions are powerful social signals that capture attention and influence higher-order cognition. In academic contexts, emotional cues can modulate performance on cognitively demanding tasks such as arithmetic processing. Emotional expressions may interfere with arithmetic processing by diverting attentional resources or increasing cognitive load. The present study therefore investigated how emotional facial expressions interact with mathematical processing in the human brain under an oddball versus control block structure using a 16-channel EEG system. To do this, we employed three facial expressions namely, happy, sad, and angry faces, on which simple arithmetic equations of addition and subtraction were superimposed. Reaction time, reaction accuracy and EEG of participants were analysed in the context of oddball vs control blocks. We hypothesized that emotional faces would interfere with arithmetic verification performance, reflected behaviourally by longer reaction times and reduced accuracy, and electrophysiologically, by modulations of ERP components linked to attentional allocation (P300) and cognitive conflict (N200), with smaller P300 amplitudes for emotionally incongruent or interfering stimuli. Moreover, we expected that this emotional interference might differ between addition and subtraction operations, which rely on partly distinct neural mechanisms.

Methods

Procedure

Twenty students aged 25-35 were recruited in the study. 16-channel EEG system (AD Instruments, Australia) following the international 10-20 system was used. Three experiments—one for each facial emotion—were conducted. Participants completed two types of blocks: (1) Oddball block, in which one category of stimuli (addition (correct/ incorrect) equations) appeared frequently (80% of total trials i.e., 160 trials) among infrequent oddballs (subtraction equations (correct/ incorrect) composing 20% of total trials i.e., 40 trials), and (2) control block, where all stimuli appeared with equal probability. The experiment employed a within-subject 2 (Block: oddball, control) x 3 (Emotion: happy, sad, angry) × 2 (Operation: addition, subtraction) × 2 (Correctness: correct, incorrect) factorial design. Only female facial expressions were used to minimize gender-related variability in emotional face processing. A total of 200 trials were presented in each block. Stimulus presentation was randomized.

The stimulus consisted of simple arithmetic (addition/subtraction) equations superimposed on happy, sad or angry facial expressions. A total of 12 stimuli were used in this study. The task involved arithmetic verification in which participants were asked to press ‘1’ for correct and ‘2’ for incorrect equations. Each stimulus was presented for 750 ms. After the stimulus, blank screen appeared where the participants responded by pressing either ‘1’ or ‘2’. Reaction time and accuracy were assessed during the experiment. Impedance was measured using UFI checktrode and maintained below 5 kΩ. Stimulus appeared on a 16-inch monitor kept at a distance of 80 cm. A sampling rate of 1000 Hz was used. Stimulus presentation was done using Super Lab software (5.0 version) whereas Labchart software (8.1.5 version) was used to record EEG. An online bandpass filter (0.1-49 Hz) was set during EEG recording.

Behavioural Data Analysis

Reaction time (RTs) from correct trials in the oddball block was assessed using 4-way repeated measures ANOVA with Block, Emotion, Operation and Correctness as within-subject factors. Reaction accuracy was analysed using the same model on proportion of correct data.

ERP Analysis

ERP components were analysed at time windows selected a priori based on previous research: N170 (150–200 ms), N200 (200–300 ms), and P300 (300–500 ms).

Preprocessing of EEG data was carried out in MNE python. This involved baseline correction (100 ms pre-stimulus), artifact rejection (eye blinks, muscle activity) by ICA followed by re-referencing to the common average. A threshold of +/-125 µV was set to remove high amplitude artifacts. Offline bandpass filtering was done to obtain theta (4.1-8 Hz), alpha (8.1-13 Hz) and gamma (30.1-49 Hz) frequencies. Trial averaging was then performed for each stimulus which was followed by averaging over participants to get the grand average data.

Results

Behavioural results

In the oddball block, the slowest reaction time was observed for Happy-Subtraction-Incorrect stimulus (703.86 ms) whereas the fastest reaction time was observed in the case of Angry Addition-Correct stimulus (434.26 ms). A main effect of emotion was observed with F(2,26)

$= 18.349$, $p < 0.001$ and $\eta 2p = 0.592$. In addition, a main effect of correctness was also observed with $F(1,13) = 6.645$, $p = 0.023$ and $\eta 2p = 0.338$.

Post-hoc test revealed a significant difference between happy vs sad ($p < 0.001$) and happy vs angry ($p = 0.001$) conditions.

Angry-Addition-Correct stimulus showed the highest reaction accuracy among the participants (96.7%) whereas the lowest accuracy was noted in Happy-Subtraction-Correct stimulus (87.5%).

EEG Analysis

Ongoing ERP analysis has revealed the presence of P200, N300 and P400 components that vary between happy vs angry conditions.

Discussion

The current study contributes to the growing body of research in the understanding of the differential effects of emotions on the arithmetic processing in the human brain. Studies on the interference of emotions on arithmetic processing have provided mixed results. Some studies suggest that negative emotions have an adverse effect on cognition whereas others point to enhanced reasoning and quicker arithmetic processing[1][2]. The results from this study support the latter by showing that participants responded faster to angry stimuli compared to happy facial expression. This may be due to the evolutionary significance of negative faces which may help in reallocation of attentional resources in the brain[3][4].

The present findings show that emotional context significantly influenced participants' behavioural responses during arithmetic processing. The large main effect of emotion, $F(2,26) = 18.349$, $p < 0.001$ and $\eta 2p = 0.592$, indicates that emotional facial expressions affected reaction times irrespective of equation type. Participants reacted fastest to angry faces, particularly when paired with correct addition equations, and slowest to happy faces combined with incorrect subtraction equations. This pattern may show enhanced attentional engagement or arousal in response to negative emotional faces, facilitating faster cognitive processing.

A main effect of correctness, $F(1,13) = 6.645$, $p = 0.023$ and $\eta 2p = 0.338$, further suggests that participants were sensitive to the accuracy of the mathematical equations, showing differential behavioral responses depending on whether the equations were correct or incorrect. The high accuracy in the Angry-Addition-Correct condition (96.7%) and low accuracy in the Happy Subtraction-Correct condition (87.5%) are also consistent with this pattern and suggests that emotion and correctness together influence cognitive performance.

The emergence of a clear P300 component in the oddball block supports the idea that emotional and task-relevant stimuli evoked heightened attentional and evaluative processing. These findings collectively suggest that emotion modulates arithmetic performance, possibly through changes in attention allocation and motivational significance. Ongoing ERP analyses will further elucidate the temporal dynamics underlying this emotion–math interaction.

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Effects of Ketamine and Citalopram on Zebrafish (Danio rerio) Cognitive Judgment Bias: A Commentary on the Traditional versus Novel

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Introduction

The bidirectional relationship between cognition and emotion posits that cognition aids the production of emotion, and emotional moderation of cognitive information processing helps appropriate reaction formation. Emotional influences on cognition are termed Cognitive biases. Cognitive Judgment biases are relative reactions to an ambiguously valenced stimulus, expressing an 'interpretation' of the stimulus and an 'expectation' about the consequences of the reaction (Boleij et al., 2012). These biases are implicated widely in the development and maintenance of multiple psychiatric disorders, especially mood and anxiety-related disorders. There is a need to understand the mechanisms of current pharmacological interventions in relation to cognitive judgement biases. The Cognitive Neuropsychological (CNP) Theory posits early shifts (within days or weeks) in cognitive judgment bias as the basis for later antidepressant effects aided by subsequent positive environmental associations in SSRI action (Godlewska & Harmer, 2020). New glutamatergic antagonists like ketamine move beyond this theory by producing rapid antidepressant effects upon acute administration. The current study, therefore, investigates the effects of Citalopram (SSRI) and Ketamine on Cognitive Judgment Bias in zebrafish (*Danio Rerio)*.

Methods

The study employs a T-maze judgment-bias (JBT) test apparatus with two reference arms perpendicular to an 'ambiguous' arm (Espigares et al., 2021). Operant conditioning is used to associate a negative (N)/positive (P) visual cue with punishment/reward, respectively, for adult wild-type zebrafish. The study employed a within-subjects design across two experiments: the Citalopram Trials $(n = 12)$ and the Ketamine Trials $(n = 12)$. Each experiment consisted of a Training phase, Experimental Pre-Drug and Experimental Post-Drug phase. The Training phase remained consistent across the two experiments, where red and green placards were placed for punishment (mild electric shock) and reward (social reward) association over 8 consecutive training trials separated by a five-minute break each. The Experimental Pre-Drug Phase was followed to ensure successful conditioning and record baseline response to the ambiguous2 stimulus. Drug bath procedures were used to administer treatment drugs (Citalopram and Ketamine) across respective experiments, followed by The Experimental Post-Drug phase to record the response to the ambiguous stimulus post-acute drug administration. Time spent by the fish across each arm (positive reference, negative reference, and ambiguous) upon first entry (FT) and total time spent by the fish in each arm (TT) were taken as measures for judgment bias for the current experiment.

Results

Paired analysis of positive and negative reference arms yielded a significant difference for time spent during first entry (FT) data across both experiments as an indicator of successful conditioning. FT data was maintained for further analysis across both experiments. TT data was analyzed but not considered due to the potential effects of desensitization.

Experiment 1 (Citalopram Trials)- Within-subjects analysis of Experimental Pre-drug ambiguous FT and Experimental Post-drug ambiguous FT yielded no significant difference after acute citalopram administration. No significant differences were observed between pairwise comparisons between positive-ambiguous and negative-ambiguous during the Experimental Post- Drug phase across FT and TT. Graphical comparisons of FT data implied the potential role of individual differences in the subject preference for positive stimulus before drug administration and reaction to ambiguous stimulus after citalopram administration.

Experiment 2 (Ketamine Trials)- Within-subjects analysis of Experimental Pre-drug ambiguous FT and Experimental Post-drug ambiguous FT yielded a significant difference after acute ketamine administration with a large effect size of 0.78. However, no significant differences were observed between pairwise comparisons between positive-ambiguous and negative-ambiguous during the Experimental Post-Drug phase across FT and TT. The increase in FT ambiguous post-ketamine administration remained consistent despite individual differences in subject stimulus preference before drug administration.

Discussion

The novel treatment drug ketamine was found to have a significant positive effect on zebrafish judgment bias with a large positive effect size upon acute administration, while the traditional treatment drug citalopram was found to have no overall significant effect on zebrafish judgment bias upon acute administration. The study is the first to specifically investigate the role of Citalopram and Ketamine in zebrafish cognitive judgement bias using a JBT paradigm, adding to the growing literature around *Danio Rerio* models and the validation of JBT paradigms for judgement bias studies. The results of the study are discussed within the context of the CNP theory of antidepressant action and the larger pharmacodynamic differences between citalopram and ketamine action. The conceptualization of drug action within the cognitive judgment bias paradigm offers a new direction to explore possible mechanisms behind the delayed onset of traditional antidepressant action and the rapid antidepressant effect of newer glutamatergic drugs, paving the way to understand neural mechanisms and drug pharmacodynamics in tandem with cognitive judgment bias to understand different drug actions within cognitive models of emotional processing and biases.

The methodological limitations of the study, including the limited wait time (30 minutes) for acute citalopram administration, manual operation of the apparatus, zebrafish stress response, and the need for longer habituation periods, were discussed. Recommendations for long-term explorations with larger sample sizes were highlighted to make conclusive claims about the antidepressant actions of both ketamine and citalopram. The observed individual differences warrant a further targeted investigation into the role of baseline cognitive disposition in mediating individual remission rates of antidepressant drugs.

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Age-associated slowing down of speed of transitions during naturalistic movie watching

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Introduction

The human brain perpetually reconfigures its functional network architecture in response to ongoing sensory and cognitive demands. Dynamic functional connectivity (dFC) captures these moment-to-moment fluctuations, revealing transient "states" of coordinated activity that static measures overlook[1]. Normal aging is accompanied by widespread structural decline, dedifferentiation of neural systems, and altered network modularity—factors hypothesized to reshape these fast-evolving connectivity patterns. Yet, most evidence for age-related changes in dFC comes from resting-state paradigms; far less is known about how aging affects network dynamics under naturalistic stimulation that requires a richer repertoire of cognitive functions. Naturalistic movie viewing provides a highly ecologically valid experimental context: recent evidence demonstrates that functional connectivity measured during movie watching, compared to resting state, yields more accurate predictions of behavioral and cognitive traits—highlighting its unique value for studying how aging influences the brain's ability to transition between functional states in realistic scenarios[2].

Studies of dynamic functional connectivity (dFC) reveal that the speed and stability of brain network reconfigurations are sensitive markers of age-related changes in neural organization. Older adults display slower, and more random transitions between connectivity states, signaling diminished neural flexibility[3]. Naturalistic movie-watching paradigms show that temporal stability of functional states maintains task-dependent hierarchies across the lifespan, yet the magnitude of reconfiguration shifts markedly with age[4]. Developmental work further reveals that rising network stability—especially within Theory-of-Mind circuitry—tracks cognitive maturation, reaching adult-like profiles by roughly age 5[5]. These patterns justify the use of velocity of dFC (vdFC) as a biomarker for understanding neurodevelopmental and aging processes, particularly through real-world tasks such as movie watching, and bridge rest and active tasks.

In this study, we systematically probe age-associated alterations in dFC across the adult lifespan while participants watch a complex movie. By characterizing (1) the repertoire of connectivity states, and (2) the speed and directionality of state transitions, we aim to elucidate how aging reshapes the dynamic coordination of large-scale brain networks. Insights from this work will advance our understanding of the neural mechanisms underlying cognitive aging and may inform biomarkers for age-related cognitive decline.

Methods

Participant Data:

Movie watching functional magnetic resonance imaging(fMRI) data of 648 participants was taken from the Cam-CAN stage II[6]. Participants with Framewise Displacement (FD) > 0.5 mm, peak FD > 3 mm, or global temporal signal-to-noise ratio ≥ 2 SD were removed from the analysis, resulting in 543 participants, taken from a previous work[7]. The participants were divided into three age groups – young (N = 181, 18–44 y, SD = 6.66, 92 women), middle-aged (N = 180, 44–65 y, SD = 6.17, 89 women) and older (N = 182, 65–88 y, SD =6.12, 87 women).

Preprocessing:

fMRI data were processed with CONN Toolbox (SPM12 engine) through a custom MATLAB batch script. The first four volumes of every 4-D BOLD run (TR = 2.470 s) were discarded and the remaining images underwent (i) realignment-with-unwarping and re-centering, (ii) slice-timing correction in descending order, (iii) ART detection of outlier volumes using 3 SD global-signal and 0.5 mm motion thresholds, (iv) structural re-centering, (v) unified segmentation of the T1 image followed by indirect MNI152 normalisation of both anatomical and functional data, and (vi) spatial smoothing with a 6 mm FWHM Gaussian kernel.

Denoising employed CONN's linear regression framework: white-matter, CSF, six head-motion parameters, ART scrubbing regressors, and a boxcar regressor modelling the continuous movie were removed while simultaneously despiking, linearly detrending, and band-pass filtering the data (0.008–0.10 Hz, regbp = 1). Standard CONN QA plots were inspected to confirm adequate data quality.

Evaluating Transition Rates in Dynamic Functional Connectivity:

The brain was parcellated into 70 regions using the Desikan-Killiany cortical atlas, and time series data were extracted with Nilearn. BOLD time-series from every brain region were segmented with an overlapping sliding window. In each window we computed a full functional-connectivity matrix by correlating all region pairs, yielding an ordered sequence of connectivity snapshots (the dFC stream). Consecutive matrices in the stream were vectorised (upper triangle only) and the correlation distance was calculated by the formula: vdFC = 1-corr [FC(t1),FC(t2)]. This distance represents the instantaneous velocity of dynamic FC—i.e., how much the network changed from one window to the next. Calculation of vdFC speeds across the entire stream produced a time-resolved vdFC profile, where larger values indicate faster reconfiguration of connectivity patterns. This series served as the primary measure for comparing the speed of state transitions across age groups. The dFC related value extractions were completed with the dFC-walk toolbox[8]. The frequency distribution of vdFC speeds were analyzed within three sliding-windowgroups to sample neural dynamics across complementary timescales. Each time point (TR) lasted 2.47 s, so the SHORT group encompassed 4–7 TRs (≈9.88–17.29 s), the MEDIUM group 8–24 TRs (≈19.76–59.28 s), and the LONG group 25–90 TRs (≈61.75–222.30 s). The significance of vdFC speed distribution across age groups was tested with the Kolmogorov–Smirnov test.

Results:

Difference in vdFC and speed of state transitions with respect to age: Comparisons of dynamic functional connectivity (vdFC) speed distribution across age groups with Kolmogorov–Smirnov tests showed that velocity distributions increasingly diverged with age, and the vdFC became slower with increasing age. For short windows, the difference between young and middle adults was not statistically significant ($p = .0892$), while the difference between middle and old adults was highly significant ($p = 2.01 \times 10^{-23}$), as was the difference between young and old adults ($p = 7.93 \times 10^{-18}$). For medium windows, all group comparisons were statistically significant: young vs. middle ($p = 3.25 \times 10^{-8}$), middle vs. old ($p = 5.37 \times 10^{-39}$), and young vs. old ($p = 5.70 \times 10^{-69}$). Similarly, for long windows, young vs. middle ($p = 4.06 \times 10^{-58}$), middle vs. old ($p = 3.58 \times 10^{-120}$), and young vs. old ($p = 1.13 \times 10^{-214}$) comparisons all demonstrated extremely strong statistical significance, indicating robust age-related differences in vdFC across all temporal scales.

Conclusion:

Our study demonstrates significant age-related differences in the dynamics of brain functional connectivity during movie watching. Younger adults show higher vdFC values and faster network reconfiguration, while older adults exhibit slower dFC dynamics, consistent across different time scales. These results highlight that aging is associated with a reduction in the flexibility and speed of large-scale brain network coordination, supporting the potential of vdFC as a biomarker for cognitive aging[3,4].

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The Role of Written Emotional Autobiographical Memory in Regulating Emotions: A Thematic Analysis

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Autobiographical memory (AM) encompasses recollections of one's personal history (Robinson, 1976). This effective recollection of personal experiences plays a pivotal role in identity formation, problem-solving, and goal direction (Gamble et al., 2019; Liu et al., 2013). Beyond its role in self-construction, AM serves important regulatory functions, as recalling and reflecting upon personal experiences, which in turn facilitate emotional regulation. Emotion regulation refers to attempts to regulate the emotions of others and self (McRae & Gross, 2020). It is crucial to acknowledge that individuals vary in their ability to regulate emotions; while some excel, others may struggle (Gross, 2002), which highlights the importance of conscious emotion regulation in helping those with low emotion regulation capability. This study examines the influence of perspective shifts in autobiographical memories of varying emotional valence (positive, negative, neutral, and traumatic) and their role in the emotion regulation of individuals. It is hypothesized, consistent with previous findings, that writing of negative and traumatic autobiographical memories benefits more in the reduction of emotional intensity than autobiographical memories that are positive.

A sample of college students (n = 95) was chosen for this study. Only participants with proficiency in English were included to ensure consistency in understanding and responding to the study materials. Of the final sample, 47 were men and 48 were women, with a mean age of 21.7 years and an age range of 18 to 29 years. The present study forms part of a larger project in which participants were asked to write about their emotional autobiographical memories (EAMs) across three sessions. The current analysis focuses on data from session 1, during which participants generated specific autobiographical memories drawn from the past five years as well as across their lifetime. For this session, participants were instructed to briefly describe thirty-six personally and socially significant memories. The questions consisted of memories associated with positive, negative, neutral, and traumatic experiences. Emotion regulation was measured by four different reliable and valid questionnaires. After writing each memory, the phenomenological characteristics of each memory were also assessed using a rating scale ranging from 1 (least) to 7 (highest). These ratings included reliving the memory, the emotional intensity of the memory, the perspective on the memory, the rehearsal of the memory, and the belief about the memory. A thematic analysis of the written autobiographical memories was conducted to understand how writing about emotional autobiographical memories, encompassing both negative and positive emotions, helps reduce emotional intensity.

To gain a deeper understanding of emotional autobiographical memories (EAMs), manual thematic analysis was conducted on the written autobiographical memories of ninety-five participants. The EAMs were analyzed using Braun and Clarke's (2006) six-phase framework for thematic analysis, a flexible qualitative method involving data familiarization, coding, theme development, review, definition, and final reporting. The thematic analysis framework adopted was an essentialist/ realist epistemological stance. Coding was primarily theory-driven, guided by the questions asked and existing literature relevant to the study. The main themes identified were self-awareness, identity formation, emotional development through experiences of the past, gendered emotional expressiveness, emotional openness and vulnerability, emotional salience of negative events, pride & achievement, and unexpected emotional intensity. As mentioned in the methodology section, phenomenological rating scales suggested that most of the memories were written from the egocentric perspective, i.e., from their own point of view.

The present study examined the role of written emotional autobiographical memories (EAMs) in emotion regulation. Thematic analysis of participant's EAMs revealed four major interrelated themes that highlighted the intricate relationship between autobiographical memory, self and emotion. The first major theme encompassed self-awareness, identity formation, and emotional development, particularly salient as most participants were aged 18-21-year, a critical period for identity and emotional development. Writing and reflecting on personal experiences evoked nostalgia and self-reflective feelings, as well as instances of detailed emotional expression (when the participants were asked to write in brief), and motivated future behavior. These findings are consistent with previous research, which suggests that personal memories motivate future behavior (Biondolillo & Pillemer, 2015). The second major theme was gender differences in emotional expressiveness, openness to experience, and sharing their vulnerability. The finding that women tended to be more expressive in their language and emotional experiences than men was consistent with previous research (Kring & Gordon, 1998; Brody & Hall, 2009). However, both genders shared moments of vulnerability equally, which helped them in overcoming fear and anxiety which is consistent with previous literature of Raeder et al. (2019). The third theme identified the emotional salience of both positive and negative events, as well as the unexpected intensity of these events. Irrespective of gender, both positive and negative events were described in a more nuanced manner, and the unexpected increase in emotional intensity was also evident in the EAMs. Additionally, not only arousal but also other factors, such as threats to one's safety (Forester et al., 2020), attaining a goal (Levine & Edelstein, 2009), and valence (Holland & Kensinger, 2010), played a pivotal role in the expression of emotional autobiographical memory. The fourth theme pride and achievement, showed that participants wrote about those memories in similar emotional richness as negative events, underscoring the importance of positive experiences. The final theme that emerged pertained to emotion regulation strategies of venting-out (i.e., catharsis), wherein participants reported feeling relieved after writing not only about the positive memories but also the negative and traumatic memories. This finding was further supported by post-session feedback, in which many participants described the writing process as emotionally cathartic. Notably, male participants reported greater perceived emotional relief compared to female participants.

Overall, these results shed light on the dynamic interplay between autobiographical memory and emotion regulation. These findings are also consistent with previous research indicating that writing about personal emotional experiences serves as a crucial mechanism for self-reflection and emotional processing. Writing emotional autobiographical memories could be a valuable therapeutic tool for young adults, given the challenges they often face with self-esteem and identity development. Additionally, it could also be included as an intervention for individuals who are unable to regulate their own emotions, as writing helped the participants in the study with the emotional processing and emotional clarity of the majority of their memories.

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Hemispheric E/I Balance as a Neural Marker of Innate Spatial Attention Biases

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Introduction

Visual information from each hemifield is processed predominantly in the contralateral visual cortex[1]. Consequently, anatomical and functional differences between the two brain hemispheres can lead to visual processing biases across the hemifields[2]. In some extreme cases, such as visuospatial hemineglect, patients fail to allocate attention to an entire hemifield[3]. Although neural markers of voluntary, biased attention have been studied extensively using cue-manipulation, the neural mechanisms underlying innate attentional asymmetries – those occurring in the absence of external cues -- remain poorly understood[4]. Here, we tested whether healthy adults exhibit attentional hemifield biases using a continuous performance search task (CPST). We further investigated the neural correlates of these biases, using encephalography (EEG) to characterize oscillatory and aperiodic (E/I) components, and magnetic resonance spectroscopy (MRS) to quantify glutamate and GABA concentrations.

Methods

Task design, EEG acquisition and analysis: 28 healthy adults (all right-handed) performed a CPST task that involved detecting a neutral cued target appearing among seven other symbols in a circular configuration. EEG was recorded concurrently from occito-parietal electrodes with a high-density configuration (128-channel; Biosemi). Alpha-band power (8–12 Hz) was estimated using multi-taper spectral analysis. To quantify the excitation-inhibition (E/I) ratio, we estimated the aperiodic exponent from unfiltered EEG data using the *Fitting Oscillations and One Over F* (FOOOF) method[5]. Unless otherwise stated, pairwise comparisons were performed with the Wilcoxon signed rank test, and correlations with *robust* correlations.

MRS acquisition and analysis: For 20/28 participants we measured Glutamate (Glx) and GABA+ in the bilateral occipital cortex using MRS (3T Siemens Prisma). MRS was recorded with participants either resting (n=10) or performing the CPST task (n=10). T1 weighted (DICOM) and GABA-edited (RDA) scans were processed with the MATLAB-based Gannet toolbox. MRS analysis included spectral alignment, artifact/motion checks, model fitting (Lorentzian for Glx, Gaussian for GABA), voxel co-registration, and tissue-composition correction.

Results

Behaviorally, we hypothesized that the sensitivity and reaction time would differ across hemifields, even in the absence of spatial cues suggesting a presence of innate attentional biases. Participants exhibited a clear asymmetry in performance: sensitivity (d′) on the CPST task was higher for right- than left-hemifield targets (*p* <0.001). Reaction times (RT) were also faster for right-hemifield targets (*p* <0.001), discounting speed-accuracy trade-off as a potential explanation for the d' results. Because CPST requires active suppression of distractors, we first investigated alpha-band power as a neural marker for these hemifield asymmetries, hypothesizing higher alpha power would facilitate behavioral performance. Parieto-occipital alpha power correlated significantly, albeit weakly, with the overall d' (r = 0.39, p = 0.04), suggesting a putative role in target detection. However, alpha lateralization (left - right hemisphere difference) did not correlate either with the asymmetry in sensitivity (r = -0.04, p = 0.81) or RT (r = 0.12, p = 0.51). By contrast, the EEG spectral aperiodic exponent (as estimated with FOOOF), a marker of the E/I ratio, correlated significantly with RT asymmetry (r = -0.65, p <0.001), but not with d' asymmetry (r=-0.24, p=0.21).

Finally, we examined the neurochemical basis of these asymmetries. Higher GABA levels correlated with greater d' asymmetries (r = -0.54, p = 0.01), but not with RT asymmetries (r=0.36, p=0.11). Moreover, none of the other MRS derived measures correlated with behavioral or EEG derived E/I asymmetries.

Discussion

Our findings show that healthy adults exhibit a consistent attentional bias in target detection sensitivity toward the right hemifield. To our knowledge this study is novel in its multimodal approach, combining behavioral, EEG and MRS within the same individuals. This approach allows us to investigate whether E/I asymmetries underlie lateralized behavioral performance. While previous EEG studies have shown alpha lateralization to be a reliable marker of biased spatial attention, we found this neural metric to be unrelated to innate d' asymmetries. By contrast, inter-hemispheric asymmetries in EEG E/I balance were strongly associated with RT, but not d' asymmetries. Finally, apart from the observed GABA-sensitivity asymmetry correlation, no other MRS derived measures were related to behavioral or EEG based E/I asymmetries, underscoring the need for further investigation.

In sum, neural markers traditionally linked to voluntary spatial attention may not be involved in inherent attention asymmetries and suggest E/I balance as a key factor mediating innate attentional biases. Future work will investigate whether modulating E/I balance – for example through neurofeedback or neurostimulation – can alter these biases, potentially revealing causal mechanisms.

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The Influence of Disgust on Moral Dilemma Processing and Decision - Making Speed

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The evolution of human emotions has resulted in a complex range of affective states adapted for social connection and survival. Among these emotions, disgust is considered a primary emotion triggered by stimuli perceived as unclean or offensive, leading to avoidance behavior. Morality, on the other hand, is a social construct that helps define right and wrong. Recent research focuses on the intersection of these two constructs in decision making. According to recent studies, disgust can skew moral judgments, increasing sensitivity to norm violations and affecting how people handle moral quandaries. In a controlled laboratory context, the current study, "The Influence of Disgust on Moral Dilemma Processing and Decision-Making Speed," aimed to empirically investigate how visually induced disgust affected moral decision-making and cognitive speed.

With 20 postgraduate students from Banaras Hindu University (14 males and 6 females; ages ranging from 22 to 28 years, M = 23.66, SD = 1.39), the study used an experimental design with purposeful sampling. Participants were split into experimental and control groups at random. A pilot-screened version of the Moral Judgment Task (Moore et al., 2008) was used to present moral quandaries, while pictures taken from the Nencki Affective Picture System (NAPS) were used to evoke disgust. Changes in affect before and after the induction of disgust were verified using the Positive and Negative Affect Schedule (PANAS), and physiological markers such as heart rate, blood pressure, oxygen saturation, and Galvanic Skin Response (GSR) were noted. PsychoPy was used to present the stimuli, and customized coding was used to carefully assess reaction times.

The experimental group's contempt was successfully induced, according to the findings. Pre- and post-induction PANAS scores varied considerably ($t = –3.05$, $p =.014$), but the control group did not exhibit this variation. These findings were further supported by physiological validation: the experimental group's blood pressure was significantly higher ($t = –3.28$, $p <.05$), oxygen saturation dropped ($t = 3.23$, $p <.05$), and GSR readings were significantly elevated ($t = 22.70$, $p <.001$), all of which were consistent with heightened emotional arousal brought on by disgust. These physiological changes are consistent with research showing that disgust triggers powerful autonomic reactions that prime the body for avoidance and alertness.

Two patterns in cognitive performance were found. First, although the difference was not statistically significant (p >.05), processing speed (the amount of time needed to read dilemma scenarios) was somewhat faster in the disgust condition (M = 78.25) than in the control condition (M = 90.64). This pattern implies that disgust increases perceptual attentiveness and speeds up basic information processing through attentional bias processes and evolutionary readiness. Second, the distaste condition (M = 16.15) resulted in a slower decision-making speed (time taken to reply to problems) than the control condition (M = 12.79). This tendency indicates that distaste makes higher-order moral deliberation more difficult, even though it is not statistically significant. This could be because moral reasoning necessitates the integration of both affective arousal and abstract concepts, which can produce cognitive conflict and delayed responses.

Together, the results show that disgust has two effects: it slows down perceptual processing and delays evaluative decision-making. The cognitive load hypothesis, which contends that increased affective arousal introduces extra processing demands that slow deliberative reasoning, and the attentional bias hypothesis, which holds that disgust stimuli demand immediate attention and increase vigilance, are both supported by this. The work advances affective neuroscience and moral psychology by showing that disgust has quantifiable physiological and cognitive impacts when moral dilemma tasks are performed. It builds on previous studies by empirically confirming disgust induction in a sample of Indian university students and demonstrating its impact on moral judgments as well as the temporal dynamics of decision-making.

Nonetheless, it is necessary to recognize some restrictions. Both generalizability and statistical power are limited by the small sample size (N = 20). Some respondents felt that the moral quandaries were unrealistic or ambiguous because they were taken from Western frameworks and might not accurately represent the sociocultural background of Indian participants. Furthermore, although trends were noted, larger-scale replications are required to establish these effects with greater statistical confidence, as indicated by the non-significant results in processing and decision-making speed. In order to directly examine neural correlate of disgust during moral cognition, future research should use advanced approaches like neuroimaging (fMRI, EEG), construct culturally grounded moral dilemma instruments, and include larger, more diverse samples. Furthermore, investigating the function of disgust in fields like law, ethics, and therapeutic practice could yield insightful interdisciplinary perspectives, especially considering the increasing significance of emotions in applied contexts.

This study concludes by showing that disgust prolongs moral decision-making, modestly speeds up cognitive processing, and dramatically changes affective states and physiological arousal. The findings connect evolutionary viewpoints with modern moral psychology by highlighting the significant influence of fundamental emotions on higher-order cognition. This study contributes to our understanding of the intricate relationship between emotion and morality by demonstrating how a basic survival mechanism affects ethical reasoning.

Characterizing the aperiodic neural dynamics during response inhibition

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Introduction

Inhibitory control of actions (e.g., response inhibition) the ability to stop prepotent responses is critical for adaptive behavior. Most research on response inhibition has focused on **periodic neural activity**. In particular, beta oscillations (13–30 Hz) that increase over the right inferior frontal cortex and pre-SMA during stopping, along with beta/mu modulations over the sensorimotor cortex, are established signatures of action gating and motor suppression[1,5–9]. By contrast, the role of **aperiodic neural activity**, captured by the 1/f slope and offset (which are thought to reflect cortical excitatory/inhibitory balance), has received far less attention[2,3]. The specific role of aperiodic spectral features in response inhibition remains poorly understood. Because aperiodic parameters may reflect the underlying E/I balance, behavioral measures from response inhibition that could be modulated by changes in this balance such as **trigger failures** and their variability—could be meaningfully explained. Trigger failures represent situations when a stopping process is not initiated despite the presence of a stop cue[10–13]. By extracting neural dynamics during successful and failed inhibitory control using a **stop-signal paradigm**, we aim to explain these behavioral differences in both stopping behavior and trigger failures.

Methods

Participants and Data Acquisition

We analyzed publicly available EEG data from Dataset-2[8]. Analysis included 23 subjects from Dataset-2[9]. Individuals mean Stop Signal Delay (SSD) and Stop Signal Reaction Time (SSRT) parameters were obtained from behavioral performance. These parameters defined participant- specific time windows for epoch extraction.

Trial Classification and Epoch Extraction

Correct Go (CG) Trials: CG trials contained left and right go cue events with correct responses and no stop signal. Theoretical stop signal onset times were calculated by adding individual mean SSD to go cue onset times. New event markers were created at these calculated times. Epochs were extracted with time windows from -(SSD + 100ms) to +(SSRT + 100ms) relative to theoretical stop signal onset. This ensured temporal alignment with stop-signal trials.

Successful Stop (SS) Trials: SS trials had stop signals with successful response inhibition (no response within SSRT window). Trials were aligned to actual stop signal presentation time. Epochs were extracted with time windows from -(SSD + 100ms) to +(SSRT + 100ms) relative to actual stop signal.

Failed Stop (FS) Trials: FS trials had stop signals with failed response inhibition (response within SSRT window). Trials were aligned to actual stop signal presentation time. Individual response times were calculated for all valid FS trials. Maximum response time was determined across all FS trials. Epochs were extracted with time windows from -(SSD + 100ms) to +(maximum response time + 100ms) relative to actual stop signal. This ensured consistent epoch dimensions while capturing complete response periods. Power spectral density (PSD) was computed using two complementary methods. The Welch method used windowed periodogram with 512-point FFT length and 256-point overlap. The multitaper method used Thomson's technique with time- bandwidth product of 4 and 7 tapers for improved estimation. PSD was computed on individual trial epochs across all three trial types for each participant. Frequency range was 1-45 Hz to capture neural oscillations while excluding line noise. PSD was computed across all EEG channels for comprehensive spectral characterization.

Spectral Parameterization Using FOOOF

Unlike traditional spectral analysis that treats the entire power spectrum as a single entity, FOOOF separates the non-oscillatory background activity from discrete oscillatory peaks, providing a more precise characterization of neural dynamics. Neural power spectra were parameterized using FOOOF algorithm to decompose spectral power into periodic and aperiodic components. This quantifies oscillatory activity (peaks) and broadband spectral characteristics (aperiodic slope and offset) fundamental to neural dynamics. FOOOF analysis was performed separately for each trial type to examine condition-specific spectral signatures. Algorithm parameters: peak width limits 2- 8 Hz, minimum peak height 0.1, maximum 6 peaks, aperiodic mode 'fixed'. Frequency range was 2-45 Hz for physiologically relevant oscillations. FOOOF fitting was applied to all EEG channels for both datasets. Aperiodic parameters (offset and exponent) and periodic parameters (peak center frequency, power, bandwidth) were extracted where oscillatory activity was detected. Model fit quality was assessed using R^2 metrics. Only high-quality fits ($R^2 > 0.95$) were retained for analysis[1].

Trial-Level Analysis: FOOOF parameterization was performed at the **trial level** for each subject, condition, and electrode combination. For each subject, the number of trials varied by condition: Correct Go trials (n=291), Failed Stop trials (n=44), and Successful Stop trials (n=47). This resulted in approximately 38,000 individual FOOOF fits across all subjects, conditions, electrodes, and methods (Welch vs. multitaper).

Data Points and Frequency Resolution: Each PSD contained 78 frequency points (2-40 Hz, 0.49 Hz resolution), and FOOOF was applied to all frequency points within this range.

Results

Aperiodic Spectral Analysis

The aperiodic component of the EEG power spectrum was characterized using the Fitting Oscillations and One Over F (FOOOF) algorithm, yielding two key parameters: offset and exponent. The offset reflects the broadband power at 1 Hz (intercept of the log-log fit), while the exponent describes the slope of the 1/f component, indicating how rapidly power decays with increasing frequency.

Aperiodic Offset (Broadband Power): CG trials consistently exhibited the highest aperiodic offset (-14.256 in Dataset 2), indicating greater overall broadband power compared to stop-signal trials. FS and SS trials showed similar offset values, with FS trials showing slightly higher offset than SS trials in dataset.

Aperiodic Exponent (Spectral Slope): The pattern of aperiodic exponents for FS trials consistently demonstrated the steepest slopes (1.248 in Dataset 2), indicating the most rapid decrease in power with increasing frequency. SS trials showed intermediate slopes (1.197 in Dataset 2), while CG trials exhibited the shallowest slopes (1.116 in Dataset 2). The rank order of aperiodic exponents was FS > SS > CG. This pattern suggests robust differences in neural spectral characteristics between response inhibition conditions, with failed inhibition associated with the steepest spectral slopes as shown in. Statistical comparisons between conditions were performed using paired t-tests on the average aperiodic parameters. False Discovery Rate (FDR) correction was applied to account for multiple comparisons. Statistical analysis revealed significant differences in aperiodic offset across response inhibition conditions. In Dataset 2 (n=23), where CG trials demonstrated significantly lower offset than both SS trials ($p < 0.001$) and FS trials ($p < 0.001$). These findings indicate that correct go responses are associated with reduced overall broadband power compared to stop-signal trials. FS trials showed the steepest slopes, followed by SS trials, and then CG trials (all $p < 0.001$). The difference between SS and FS trials reached significance in Dataset 2 ($p = 0.0019$). Topographical analysis was performed using one-sample t-tests to examine whether aperiodic parameter differences between conditions were significantly different from zero across individual electrodes. Specifically, we conducted three main comparisons: Failed Stop vs

Correct Go (FS- CG), Successful Stop vs Correct Go (SS-CG), and Successful Stop vs Failed Stop (SS-FS). For each comparison, separate one-sample t-tests were performed for both aperiodic offset and aperiodic exponent differences using both Welch and multitaper methods. This resulted in multiple one-sample t-tests across electrodes, parameters, and methods. To control for multiple comparisons, False Discovery Rate (FDR) correction was applied using the Benjamini-Hochberg procedure (α = 0.05) across all t-tests within each comparison. The number of FDR-corrected significant electrodes is reported for each comparison. Topographical analysis revealed widespread differences in aperiodic offset across scalp regions. Dataset 2 FS-CG comparisons showed significant positive differences across 56 electrodes, while SS-CG comparisons revealed significant positive differences across 64 electrodes, both confirming that stop-signal trials had higher broadband power compared to correct go trials. Aperiodic Exponent Topographical Results from Dataset 2 revealed more robust topographical patterns. The FS-CG comparison showed significantly positive differences across 64 electrodes, while the SS-CG comparison demonstrated significantly positive differences across 62 electrodes, both confirming that stop-signal trials had steeper slopes than Correct Go trials. Most importantly, the SS-FS comparison showed significantly negative differences across 36 electrodes, with widespread effects spanning frontal (FP1, FPz, FP2, AF7, AF3, AFz, AF4, AF8, F5, F3, F1, Fz, F2, F4), central (FC3, FC1, FCz, FC2, FC4, T7, C5, C3, C1, C2, C4), and parietal (TP7, CP3, CP1, CPz, CP2, CP4, P3, P1, Pz) regions, demonstrating that Successful Stop trials had shallower slopes than Failed Stop trials.

Discussion

Our findings highlight the utility of FOOOF parameters as potential neurophysiological markers of inhibition performance. The aperiodic exponent, in particular, demonstrates strong discriminative power between successful and failed inhibition, with consistent patterns across both global and topographical analyses. This suggests that aperiodic spectral characteristics may serve as objective biomarkers for response inhibition ability, with potential applications in clinical assessment and intervention. The fact that these differences are observable at the individual electrode level and show consistent regional patterns indicates that FOOOF parameters capture meaningful neural dynamics that are not merely artifacts of global brain state changes. The robust statistical differences observed across multiple comparisons, even after stringent FDR correction, further supports the reliability of these parameters as neurophysiological markers. The topographical analysis revealed that aperiodic spectral differences were most prominent in frontal and central regions, which are critical for response inhibition and cognitive control processes. The sensor-level EEG data shows consistent patterns that align with known neural substrates of response inhibition, where frontal and central electrodes capture activity from canonical inhibitory nodes implicated in initiating global motor suppression via fronto–basal-ganglia pathways. Future research should investigate the relationship between aperiodic spectral parameters, behavioral measures and other measures of neural dynamics, such as functional connectivity and network topology.

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Tracing Mental Processes Through Visualization: A Study of Mental Rotation

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Mental rotation (MR) is a key spatial ability that allows individuals to mentally simulate object rotations, supporting both daily activities and complex tasks in fields such as engineering and surgery (Tang et al., 2023). Studies indicate that mirrored images place greater cognitive demands than identical ones, often resulting in slower response times and increased error rates (Paschke et al., 2012). MR does not operate as a single, uniform process but instead varies across individuals and situations, typically involving either holistic rotation of the entire object or sequential, part-by-part (piecemeal) rotation (Just & Carpenter, 1976; Khooshabeh et al., 2013; Khanikar & Mitra, 2024). Eye-tracking research has been instrumental in differentiating these strategies, showing that focused gaze patterns correspond to holistic processing, whereas more dispersed fixations reflect piecemeal processing (Xue et al., 2017; Nazareth et al., 2019). Furthermore, findings suggest that being able to flexibly switch between strategies can be more effective than rigidly relying on one method (Nazareth et al., 2019). Overall, eye-tracking provides valuable insights into how visual attention and cognitive strategies interact during MR, emphasizing the importance of adaptability, task demands, and visual processing in shaping spatial reasoning.

The experimental design was approved by the institute's ethics committee (No. IIT/SRIC/DR/2019) prior to implementation. This study was conducted on 31 graduate students, age range between 20-35 years (mean = 27.87, SD = 3.42). The participants had a normal or corrected-to-normal vision and reported having no history of neurological or psychological illness. The experiment was conducted in a well illuminated, noise free room. Participants were seated at 60 cm distance from the display (24 inches 60 Hz with screen resolution of 1920 x 1080 pixels) of a computer. The Tobii Pro X3-120 eye tracker was fixed below the computer display. Before data collection, the eye tracker was calibrated with participants' eyes. A subset of 30 stimuli from the computerized three-dimensional shapes for investigating mental rotation processes (developed by Ganis & Kievit, 2015) were used in this study. Each stimuli had one baseline shape and one target shape. This study was performed with two different trials (identical and mirrored) and 15 stimuli per trial. Participants were instructed to say ‘Yes’ for first 15 stimuli if the target shape was identical with baseline shape if mentally rotated and for rest of the 15 stimuli if the target shape was mirror image (through vertical plane) of the baseline shape if mentally rotated. Participants’ eye metrics were recorded by eye tracker. Participants were scored 1 for answering correctly and 0 for answering incorrectly for each problem.

The Wilcoxon Signed-Rank test was conducted to examine the accuracy differences between identical and mirrored trials (paired differences were not normally distributed). The results revealed a significant difference in median performance accuracy between the two trials ($Z = -2.61$, $p=0.009$). The eye-tracking metrics between both trials were compared by Generalized Linear Mixed Model (GLMM). Fixed effect of trial condition (identical versus mirrored) was checked on eye metrics. Greater total fixation duration ($p<0.01$), average visit duration ($p<0.01$) and total visit duration ($p<0.01$) on the combined AOI group (containing both baseline and target shape) for mirrored trial indicated participants’ more engagement in this trial. Participants’ total fixation duration ($p<0.01$), fixation count ($p<0.01$), average visit duration ($p<0.01$) and total visit duration ($p<0.01$) on target shapes were significantly greater for mirrored trial. The GLMM results indicated that participants analysed target shapes faster in finding identical shapes. For identifying mirrored shapes, participants had thoroughly verified the shapes. Previous literatures proved that identifying mirrored shape is harder than identifying identical shape. The mirrored trial required more intensive visual processing and cognitive resources. The increased fixation counts suggested detailed analysis of the target shapes, possibly reflecting greater difficulty in recognizing or processing the mirrored configuration. Longer visit durations further imply sustained attention, supporting the notion that mirrored trials typically demand more visual exploration and cognitive effort.

In addition, eye metrics were divided into distinct clusters for both identical and mirrored trial. Five different clustering algorithms were applied separately to identify the visualization strategies based on similarity of eye metrics’ pattern. These clustering methods were compared and the K-Means clustering method came to be the best method and had shown two visualization strategies for both the trials - one resembles more with the holistic strategy and another resembles more with the piecemeal strategy. The strategy which elicited overall better performance for identical trial resembled more with the holistic strategy and for mirrored trial it resembled more with the piecemeal strategy. The mean values of time to first fixation and fixations before on all AOIs were greater and mean values of all other fixation and visit based eye metrics were lesser for better performers for identical trial. The mean values of time to first fixation and fixations before on all AOIs were lesser and mean values of all other eye metrics were greater for better performers for mirrored trial. The analysis revealed that task demands modulate the strategy effectiveness. In identical trial, when the stimuli require recognition of orientation-preserved objects, holistic processing facilitated faster and more efficient mental rotation. Conversely, mirrored trial favoured the piecemeal strategy, indicating that structural differences or orientation reversals necessitate detailed, local comparisons to resolve discrepancies between objects. This pattern highlights that cognitive strategy is not fixed but context-dependent, supporting prior work showing that mental rotation engages both global and analytical processes depending on task complexity.

The number of strategy switches for each participant were calculated for both trials. The participants were divided into two groups based on their switch counts: a) low flexibility group (switch count was lesser than the median value) and b) high flexibility group (switch count was greater than the median value). The overall sensitivity (denoted by d') to discriminate between correct and wrong stimulus was higher for identical trial than mirrored trial which again suggested mirrored trial as more cognitively demanding. Plotting participant categories against d' showed that, the high flexibility group had higher mean value of d' than the low flexibility group in identical trial. For mirrored trial, the high flexibility group had lower mean value of d' than the low flexibility group. This finding indicates that strategy flexibility benefits identical trials more than mirrored ones. While holistic processing is typically effective for identical items, some rotations require part-based analysis, making adaptive strategy use advantageous. In contrast, mirrored trials rely on consistent, detailed comparison using a piecemeal approach, where switching strategies may cause confusion and reduce performance.

This study highlighted the importance of eye metrics to understand the mental rotation process. Understanding visualization strategy is important to develop some tutorial systems where individuals would be guided with cues for effectively performing mental rotation, a skill central to STEM learning and highly relevant to everyday problem-solving.

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Media Polarization and Doomscrolling Behavior: Investigation Through the Lens of Ingroup Bias

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Introduction

Humans consistently organize their social world by distinguishing between ingroups and outgroups, a process that gives rise to ingroup bias, i.e., the tendency to favor those perceived as part of one's own group (Tajfel & Turner, 1978; Brewer, 1991). This bias is remarkably robust, manifesting across contexts such as moral decision-making, cooperation, prejudice, and discrimination (Hewstone et al., 2002; Balliet et al., 2014; Amodio, 2014). Importantly, even when groups are artificially constructed under minimal conditions, individuals display reliable ingroup favoritism (Tajfel, 1970; Otten & Moskowitz, 2000; Dunham et al., 2011). While these biases serve important psychological functions of identity and belonging, they also underlie intergroup conflict and polarization.

In today's digital environment, mass media plays a critical role in shaping intergroup attitudes. Media outlets not only reflect but also reinforce social biases through mechanisms of framing, agenda-setting, and selective exposure (Scheufele & Tewksbury, 2007; Kubin & von Sikorski, 2021). The rise of echo chambers, where individuals are repeatedly exposed to belief-congruent content, has been shown to amplify ingroup favoritism and deepen polarization (Del Vicario et al., 2016; Barberá, 2020; Hobolt et al., 2024). At the same time, the temporal dynamics of media consumption—whether individuals engage in deliberate evaluation or rapid, doomscrolling-like judgments—shape how information is processed. Longer deliberation may foster more balanced reasoning, whereas speeded judgments are more vulnerable to heuristic-driven biases, particularly negativity bias (Baumeister et al., 2001; Bago et al., 2020).

The present study investigates how media presentation format (echo chambered vs. non-echo chambered) and deliberation time (timed vs. untimed) jointly influence the manifestation of ingroup bias in news believability. Using the minimal group paradigm, participants were assigned to arbitrary groups and asked to judge positive and negative news headlines about their ingroup and outgroup, attributed to sources of varying reliability (low and high). Across four experiments, we systematically varied news presentation design and timing: (1) non-echo chambered, untimed; (2) non-echo chambered, timed; (3) echo chambered, untimed; and (4) echo chambered, timed. This design allows us to disentangle the independent and interactive effects of media diversity and deliberation time on the strength and expression of ingroup bias.

Methods

Participants

Unique groups of university students participated in each of the four experiments. Sample size of 37 was used across all experiments after excluding participants who failed to learn the reliability of the news sources. All participants had normal or corrected-to-normal vision, were right-handed, and provided informed consent as approved by the Institute Ethics Committee. Participants were compensated for their time.

Stimuli and Design

The study employed the minimal group paradigm, where participants were arbitrarily assigned to one of two novel groups (Rupraa or Jawaai). In the main task, participants judged intergroup news headlines as True or False, with each headline framed as either positive or negative about their ingroup or outgroup. Headlines were attributed to two news sources of differing reliability (high: 75% accurate; low: 25% accurate), learned in a familiarization phase. Stimuli comprised 72 intergroup headlines (36 positive, 36 negative), balanced across ingroup and outgroup. The design was a 2 × 2 × 2 within-subjects factorial structure with factors: Source Reliability (high vs. low), News Valence (positive vs. negative), and Group Membership (ingroup vs. outgroup). The critical manipulation across experiments was in presentation format and deliberation time:

- **Experiment 1**: non-echo chambered (randomized presentation), untimed.
- **Experiment 2**: non-echo chambered, timed (6s headline + 2s response window).
- **Experiment 3**: echo chambered (blocked presentation), untimed.
- **Experiment 4**: echo chambered, timed (6s headline + 2s response window).

Procedure

In Phase 1, participants completed a source-learning task where they judged general knowledge headlines from two news outlets (ABC News, XYZ News) with and without feedback, establishing high and low reliability. In Phase 2 (main task), participants performed the intergroup news judgment task according to their assigned experiment’s presentation and timing condition. For blocked (echo-chambered) conditions, all ingroup news was presented in one block and all outgroup news in another; for randomized (non-echo chambered) conditions, headlines were intermixed. In timed conditions, each headline was shown for 6 seconds, followed by a 2-second response window.

Statistical Analysis

Data from participants who failed to learn the source reliability were excluded (<5% overall). A 2 × 2 × 2 repeated-measures ANOVA was conducted with Reliability, Valence, and Group Membership as factors, and percentage of news believability as the dependent variable. Post hoc comparisons (Tukey's HSD) were used to further examine significant interactions, with particular interest in the Valence × Group interaction (positive ingroup vs. positive outgroup; negative ingroup vs. negative outgroup).

Results

A 2 × 2 × 2 repeated-measures ANOVA was conducted separately for each experiment, with Source Reliability (high vs. low), Valence (positive vs. negative), and Group Membership (ingroup vs. outgroup) as factors, and percentage of news believability as the dependent variable. Across all experiments, reliable sources were judged significantly more believable than unreliable sources, and positive headlines were judged more believable than negative headlines. The main effect of group was not significant in any experiment. The critical effect of interest—the Valence × Group interaction—varied systematically across the four experiments, as summarized below.

- **Experiment 1 (non-echo chambered, untimed):** Participants showed only a weak, non-significant tendency to favor positive ingroup over outgroup news but showed significant disbelief of negative ingroup over outgroup news.
- **Experiment 2 (non-echo chambered, timed):** Significant ingroup bias emerged, with positive ingroup news judged more believable than positive outgroup news, and negative ingroup news judged less believable than negative outgroup news.
- **Experiment 3 (echo chambered, untimed):** Strong ingroup bias was observed again, replicating the pattern of Experiment 2.
- **Experiment 4 (echo chambered, timed):** A strong negative news bias was observed (ingroup negative < outgroup negative), but the positive bias effect (ingroup positive > outgroup positive) was attenuated and non-significant, similar to patterns observed in Experiment 1.

In sum, ingroup bias was weakest when participants were exposed to diverse (non-echo chambered) information with unlimited time (Exp 1). Introducing time pressure in the same diverse setting (Exp 2) induced significant ingroup bias. Echo-chambered exposure (Exp 3) again elicited strong ingroup bias under untimed conditions, while echo chambers combined with time pressure (Exp 4) shifted judgments toward a negativity-driven pattern, reducing the positive ingroup advantage.

Discussion

The present study examined how media presentation format and deliberation time jointly shape ingroup bias in news believability. Ingroup bias was weakest when participants were exposed to diverse, non-echo chambered information with unlimited time (Exp 1), suggesting that both exposure to varied perspectives and the opportunity for careful deliberation can reduce polarization. However, introducing time pressure in the same diverse setting (Exp 2) induced significant ingroup bias, highlighting how limited deliberation leads individuals to fall back on heuristic-driven judgments that favor the ingroup. In contrast, echo-chambered exposure (Exp 3) elicited strong ingroup bias even under untimed conditions, underscoring the amplifying role of segregated, belief-congruent content in fostering polarization. When echo chambers were combined with time pressure (Exp 4), judgments shifted toward a negativity-driven pattern: participants were especially sceptical of negative ingroup news, while the positive ingroup advantage was reduced. This suggests that under speeded and polarized conditions, negativity bias dominates, consistent with prior evidence that threat-related information exerts disproportionate influence on social judgments. Taken together, these findings demonstrate that both the diversity of exposure and the time available for evaluation critically moderate intergroup bias, offering important insights for understanding how contemporary media ecosystems shape polarization.

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Ganzflicker: Pseudo-hallucinations depend on Flicker Frequency

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Introduction

Recent work on time and consciousness has indicated that our conscious experiences are scaffolded by the timescale at which these experiences occur. Hallucinations provide us a method to understand the structure underlying conscious experiences as they are not mediated by external stimulus-based stimulation and its structure. Since these phenomena are not easily controllable in labs, an alternative set of hallucinations, called Pseudo-hallucinations (PH), has been used to study different aspects of hallucinations. One method for inducing PH is Ganzflicker, which has been used to study the content, complexity, and rhythmicity of the flicker, neural correlates and co-dependent patterns in the contents of the PH (Reeder, 2022). Another advantage of Ganzflicker is that different timescales can be studied using different flicker frequencies, allowing manipulation of the structure that scaffolds our experience. To understand conscious experiences at different timescales, we manipulated the flicker frequencies corresponding to each timescale of interest and measured the occurrence and nature of PH.

Methods

Participants

Thirty volunteers (age range = 20-30 years) from the institution provided consent and participated in the experiment. The study was approved by the IRB.

Stimulus and apparatus

A flickering red-black stimulus was presented for 15 minutes, followed by a 5-minute black screen (to observe post-PH). The flicker frequencies were 0.3, 3.3, 10, and 30 Hz (Amaya et al., 2023; Singhal & Srinivasan, 2021). A brown noise was played via headset to enhance sensory deprivation and facilitate the PH (Shenyan et al., 2024).

Procedure

Participants sat 60-70 cm from the monitor. Each participant took part in four sessions (one frequency per session, order counterbalanced). They were informed that there is a 50% chance of them seeing something other than flicker, and they would need to report these experiences verbally. They pressed the left and right arrow keys, respectively, to mark the onset and offset of each specific experience. Verbal reports and drawings were also recorded. The procedure for data collection remained the same for the post-flicker session as well, which followed immediately after the 15-minute PH session. A post-session semi-structured interview, along with a six-question survey comprising the Elementary and Complex Imagery dimensions of the 5D-Altered States of Consciousness rating scale (Shenyan et al., 2024), was conducted. After the entire experiment, they completed the Vividness of Visual Imagery Questionnaire and the Tellegen Absorption Scale (Reeder, 2022; Amaya et al., 2023)

Results

The collected data included the number of PH, durations, verbal reports, drawings, 5D-ASC scores per frequency and questionnaire scores. Here we report the results for quantitative analysis. The qualitative data, including the different questionnaires used, are currently being analysed. One-way ANOVA across frequencies was significant for the proportion of PH during flicker, F (3, 87) = 8.18, $p < .001$, proportion of PH post flicker, F (3, 87) = 5.44, $p = .002$. During flicker, 10Hz showed the most PH, followed by 3.3Hz and 30Hz. Post flicker, the PH increased with frequency. Duration of the experiences was not affected by flicker frequency for both flicker and post-flicker, with $p > 0.05$. The Elementary Imagery dimension showed significant correlations with the number of PH for 0.3Hz ($\rho = .72$, $p < .001$), 3.3Hz ($\rho = .70$, $p < .001$) and 30Hz ($\rho = .47$, $p = .009$). The Complex Imagery dimension correlated with number of PH only for 30Hz ($\rho = .40$, $p = .028$).

Discussion

The results revealed that the number of experiences was frequency-dependent, with 10Hz producing the highest number of PH, supporting earlier findings suggesting these could be due to intrinsic rhythms, attentional cycles or possibly link to alpha-band neural activity in the brain. The lowest frequency, especially 0.3Hz, showed fewer PH, suggesting that slower flickers may not give sufficient stimulation for PH. The post-flicker results indicate a direct proportional relationship with the number of PH experiences, and dissociation during flicker results indicate differences in mechanisms that underlie these experiences. Interestingly, the 5D-ASC scores seem to correlate with frequencies other than 10Hz, indicating verbal reports do not seem to be influenced by 10Hz, but with timescales for time consciousness. Overall, these findings show the frequency-dependent differences in flicker-induced altered states and require further and continued research in the phenomenology of flicker-induced hallucinations and their relationship with the timescale of experience.

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Dynamics of Reward Cognition - Quantifying Costs of Reward Driven Cognitive Effort

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Introduction:

Human motivation and behavior are orchestrated by the brain's reward system, which assigns motivational value to environmental stimuli to guide decision-making and action. Reward processing, a covert yet dynamic mechanism, involves sequential neurocognitive operations typically examined through neuroimaging to reveal neural activation patterns. Despite extensive mapping of the reward circuitry, the underlying sequential and psychological mechanisms remain elusive. Considering its centrality in everyday decision-making and its dysregulation in disorders such as schizophrenia, addiction, and mood disorders, the present study adopts a cognitive–behavioral approach to examine intra-individual differences across the stages of reward processing. The process has been conceptualized through converging neurobiological and cognitive frameworks. The *Incentive Salience Theory* (Berridge) posits that dopamine mediates the motivational "wanting" component of reward, attributing salience to cues independent of hedonic "liking." The *Dopamine Prediction Error Theory* (Schultz) proposes that dopaminergic neurons encode discrepancies between expected and received outcomes, reinforcing learning when rewards exceed predictions. Complementarily, the *Expectancy Value Theory* highlights the cognitive dimension, suggesting that goal-directed behavior is shaped by the perceived likelihood of success and the subjective value of reward. Grounded in these frameworks, this study explored the determinants of reward behavior by employing *effort* as a quantifiable cognitive mechanism. Specifically, it examined how *Reward Responsiveness (RR)*—the capacity to detect and recognize rewards, *Drive*—motivational force propelling action, and *Information Processing Capacity (IPC)*—the cognitive system's upper limit for manipulating information, interact to sustain *Cognitive Effort (CE)*—the mental exertion devoted to attaining reward goals. Prior research underscores the role of both physical and cognitive effort in shaping subjective effort-cost valuation, cognitive control, information integration, and reward anticipation (Bogdanov, 2022; Fromer, 2021; Rowe, 2008; Vassena, 2014). It was hypothesized that RR, Drive, and IPC would predict the level of CE an individual is willing to invest when the stimulus itself is perceived as rewarding, elucidating how monetary incentives differentially induce motivational drive across individuals.

Method:

H0: Reward Responsiveness, Drive, & Information processing would have no significant effect on Cognitive Effort.

H1: Reward Responsiveness, Drive, & Information processing would have a significant effect on Cognitive Effort.

Design:

An individually administered behavioral experiment employing the Effort Discounting Paradigm was developed using standardized, culturally sensitive, and validated neuropsychological tests. A pre-test/post-test design was adopted, involving participants (N = 20) screened using the Adverse Childhood Experiences Scale, Monetary Value Perception Scale, and BIS/BAS Scales. Baseline assessments of RR, drive, and IPC included the BIS/BAS Scales and the Test of Information Processing Skills (TIPS). Reward responsiveness was operationalized as the ability to perceive monetary incentives and cues as pleasurable, reflected in the difference between *BIS/BAS Responsiveness* and *Fun-Seeking* scores across Challenge Round 4 and Challenge Round 6. Drive defined as the motivation and willingness to exert cognitive effort to perform efficiently on *SB5* tasks, assessed through task accuracy, completion of Level 6, and post-incentive changes on the *BIS/BAS Drive* subscale. Information processing capacity was measured through *TIPS* scores and *SB5* accuracy, along with the number of successful and failed task attempts. The experimental phase introduced audiovisual monetary reward cues alongside a physical stimulus (cash). The Stanford–Binet Intelligence Scales (SB5) served as the cognitive effort task, with non-verbal IQ Levels 4 & 5 and Levels 6 & 7 forming two challenge rounds under a constant time constraint (40 minutes) to induce time pressure. The incentive cues were: “If you complete Level 5, you gain ₹50, and if you complete Level 6, you gain ₹100.” Cognitive effort was defined as the ability of the incentive to motivate participants to complete Level 4 and Level 6 challenges of the *SB5* within a 30- minute timeframe, despite increasing task complexity across domains of Knowledge, Visuospatial Processing, Quantitative Reasoning, and Working Memory. It was further assessed through differences in subjective difficulty ratings and perceived effort scores between the two challenge levels. Participants received performance-based monetary rewards corresponding to task outcomes.

Results:

Non-parametric, median-based analyses were conducted due to covert variables on ordinal scales and a small stratified sample (ages 19–25, non-working, lower-upper middle SES, urban residents). The Related Samples Sign Test (p =0.035) and Kendall's Coefficient of Concordance (p = 0.020) showed significant pre–post changes in RR, with strong agreement in rankings. Cross-tabulations and the Chi-square Test of Independence confirmed RR's significant effect (α = 0.024) on CE, supported by high Kappa and Gamma values (0.014), indicating sustained RR enhances capacity for difficult tasks. For Drive, the Sign Test and Kendall's Coefficient (W = .004) showed no significant pre–post change as bidirectional shifts nullified the net effect; however, Chi-square revealed a significant effect (α = 0.001) on CE, with high Kappa (.783) and Gamma (.800) indicating that lower drive deters, and higher drive fosters effort. For Information Processing, the Kruskal–Wallis Test upheld the null hypothesis of no effect on CE, though Spearman's Rho revealed correlations among visual–visual and visual–auditory modalities (r = 0.658), kinesthetic aptitude–visual modality (r = 0.536), and a negative correlation between visual modality and working memory (r =0.407), suggesting processing operates independently, while CE is primarily driven by RR and Drive.

Discussion:

Findings provide substantial evidence partially accepting the main hypothesis (H1), "only RR and Drive significantly influence CE." Sustained RR appears critically shaped by the multidimensional construct of Drive, encompassing both intrinsic and extrinsic motivation. The transition from reward expectation to anticipation is modulated by task challenge, stimulus appeal, and intrinsic drive—where high drive promotes engagement in cognitively demanding tasks and low drive diminishes effort. This bidirectional activation underscores how effort costs and reward-related motivation jointly guide decision-making (Crawford et al., 2022). Contrary to assumptions, Information Processing Capacity showed independence from CE, as individuals performed efficiently despite processing differences when intrinsically motivated. Neural evidence corroborates distinct pathways for processing and reward systems, with cortico-subcortical regions, particularly the ACC and striatum, allocating resources in response to incentive cues (Vassena et al., 2014). These insights extend to understanding risky and addictive behaviors, wherein heightened reward circuitry activation may reinforce maladaptive tendencies. Interventions enhancing drive and motivation could therefore optimize cognitive performance, underscoring the value of integrating cognitive investigations with real-time imaging for a comprehensive and translational understanding across contexts.

Deconstructing the AI Placebo Effect: A Bayesian Computational Modeling Approach to Individual Differences in Performance

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Introduction

The belief that an AI system is assisting with a task can alter user performance, a phenomenon termed the "AI placebo effect." A foundational study by Kosch et al. (2022) demonstrated that while the mere description of a supportive AI did not produce an average performance increase at the group level, it did generate a significant positive correlation between an individual's performance expectations and their objective task success. This suggests the placebo effect in Human-Computer Interaction is highly subject-specific, yet the cognitive mechanisms driving this individual variability remain unquantified. This study aims to bridge this gap by computationally modeling these mechanisms. We conduct a formal re-analysis of data from Kosch et al. (2022) to investigate how the belief in AI assistance translates into performance changes. Specifically, we sought to determine whether the AI placebo effect operates by altering the mean (the expected level of performance), the precision (the certainty of that expectation), or a combination of both, within an individual's prior beliefs about their own capabilities.

Methods

This study involved a computational re-analysis of data from Experiment II of Kosch et al. (2022). The original experiment involved 75 participants (after data cleaning) in a within-subjects design where they performed a word-puzzle task under two counterbalanced conditions: a "No Adaptivity" control condition and a "Physiology-based Adaptation" placebo condition, where they were led to believe a non-existent AI was adjusting task difficulty based on their physiological state.

To model objective task performance, we employed a hierarchical Bayesian framework. This approach conceptualizes performance as the result of a Bayesian integration process, where a prior expectation about performance is updated by incoming evidence from the task itself (the likelihood). Three distinct models were constructed and compared: a 'Shift' model, where the placebo only alters the mean of the prior belief; a 'Precision' model, where it only alters the precision (inverse variance); and a 'Combined' model, allowing the placebo to modulate both the mean and the precision simultaneously. Parameter estimation for each model was conducted using Markov Chain Monte Carlo (MCMC) sampling. To determine the model that best explained the observed data, we performed model comparison using leave-one-out cross-validation (LOO). Subsequently, we used Pearson correlation coefficients to assess the relationship between individual-level changes in the winning model's estimated parameters and the observed individual differences in objective task performance between the placebo and control conditions.

Results

Model comparison revealed that the 'Combined' model provided a substantially better fit to the data than either the 'Shift' or 'Precision' models, as indicated by its superior LOO score. This supports the hypothesis that the AI placebo effect involves a modulation of both the mean and the precision of an individual's prior beliefs about their performance. At the group level, the analysis did not find statistically significant average changes in the estimated parameters for prior mean or prior precision. This computational result mirrors the original study's behavioral finding of no average performance difference between the placebo and control groups. At the individual level, however, the analysis provided a mechanistic explanation for the original paper's correlational findings. A significant and very strong positive correlation was found between the estimated change in an individual’s prior mean and their change in objective performance ($r = 0.973$, $p < .0001$). This indicates that individuals whose prior performance expectations were shifted higher by the placebo achieved greater performance gains. Contradicting our initial hypothesis, we also found a moderate, significant positive correlation between the change in prior variance (the inverse of precision) and the change in performance ($r = 0.595$, $p < .0001$). This unexpected result suggests that individuals whose beliefs became less certain (i.e., lower precision) also tended to exhibit greater performance improvements.

Discussion

This study provides a quantitative cognitive mechanism that explains the individual-specific nature of the AI placebo effect first reported by Kosch et al. (2022). While the original study showed *that* a correlation exists between expectation and performance, this re-analysis shows *how* it operates: the magnitude of the placebo effect on an individual's performance is powerfully predicted by the degree to which their prior expectation about their performance level is shifted.

The superiority of the 'Combined' model suggests the placebo manipulation influences not only what individuals expect to achieve but also their certainty in that expectation. The counterintuitive relationship between precision and performance—whereby decreased certainty correlated with performance gains—is a particularly novel finding. A less rigid, less precise prior belief may allow an individual to be more open to learning from task evidence or to explore performance strategies more flexibly, ultimately leading to improvement. This challenges the intuitive notion that a highly precise, confident belief is always beneficial for performance.

In conclusion, this work moves beyond demonstrating the existence of an AI placebo effect to explaining its underlying cognitive drivers. By using a Bayesian computational framework, we were able to quantify latent cognitive changes and show that the effect is a nuanced phenomenon driven by individual-specific shifts in both the level and certainty of performance beliefs. Future research should aim to replicate these findings and further investigate the unexpected but important role of belief precision in mediating human-AI interaction.

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