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Hierarchical Account of Emotional Mimicry: Executive Control and Resource Constraints

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Abstract

Emotional mimicry, the spontaneous mirroring of another person's facial expression, has often been described as an automatic perception-action response. However, increasing evidence suggests that it is adaptively shaped by social context and motivational demands. Such context-sensitive regulation is likely to depend on working memory resources, particularly those involved in maintaining goal-relevant behaviour while suppressing task-irrelevant affective responses. The present study tested this possibility using a dual-bottleneck framework informed by Load Theory and multicomponent models of working memory. Across two experiments, participants maintained a low or high working memory load while executing a selective attention task that was superimposed on task-irrelevant happy and neutral faces. Concurrently, facial electromyography (EMG) was used to measure zygomaticus major activity in response to these background expressions. In Experiment 1, taxing visuospatial working memory did not selectively attenuate mimicry, and Bayesian analyses supported the absence of a Load × Emotion interaction. In Experiment 2, depleting central executive resources with a numerical working memory task was associated with relatively greater zygomatic activity to happy versus neutral faces under high-load conditions. This pattern aligns with a breakdown in the top-down inhibition of affective motor responses. Overall, these results indicate that the overt expression of emotional mimicry is more sensitive to executive control than to concurrent visuospatial storage demands. We propose a hierarchical account in which rapid affective activation is followed by an executive regulatory stage that gates whether mimicry is expressed, providing initial mechanistic evidence that emotional mimicry is a cognitively regulated and context-sensitive social behaviour.

Keywords: Emotional mimicry, Working Memory, Executive function, EMG

Introduction

Social engagement is rooted in our ability to perceive and share in the emotions of others. One primary mechanism implicated in social interaction is emotional mimicry, the subtle, often uninstructed mirroring of another person's facial expressions. Early accounts described mimicry as a largely automatic motor response (Chartrand & Bargh, 1999; Dimberg et al., 2000).

However, more recent research indicates that mimicry is a motivated social behaviour. The Emotional Mimicry in Context (EMIC) model (Hess & Fischer, 2013; 2014) proposes that individuals do not simply mirror isolated facial movements. Instead, mimicry functions as an affiliative signal that relies on the perceived goals of the target and the relationship between the interacting parties. According to EMIC, mimicry helps signal affiliation, build rapport, and navigate complex interpersonal dynamics (Fischer & Hess, 2017; Seibt et al., 2015), reflecting a process that is shaped by context and the observer's social goals rather than a purely automatic reflex (Wang & Hamilton, 2012).

In contrast to the context-dependent account of mimicry, earlier models characterised mimicry as an automatic, reflex-like process (Hatfield et al., 1993). The automatic notion of mimicry is grounded in the ideomotor framework (Prinz, 1997), and the 'chameleon effect', which is the tendency to mirror motor responses without awareness (Chartrand & Bargh, 1999). Furthermore, automatic notion implies visual perception of a motor movement (like a facial expression) elicits a matching sensorimotor representation in the observer. Facial electromyography (EMG) studies showed that emotional facial stimuli will elicit muscle resonance, such as zygomaticus major activation in response to smiles (Dimberg, 1982; Lundqvist & Dimberg, 1995). These motor responses emerge even when faces are presented below the threshold of awareness or when participants are instructed to suppress their reactions, suggesting that mimicry can be initiated without deliberate intent (Dimberg et al., 2000).

Whether execution of mimicry proceeds without consuming cognitive resources, is a separate question that subliminal paradigms alone cannot resolve. Since these paradigms typically present masked faces in isolation, they successfully isolate conscious awareness but fail to test whether the underlying motor response relies on available working memory capacity. If emotional mimicry were a purely automatic motor reflex, it would be elicited uniformly, independent of the social environment. However, maintaining a view of strict automaticity has become difficult with the contextual and motivational dependencies outlined by the EMIC model and related theoretical accounts (Fischer & Hess, 2017; Wang & Hamilton, 2012).

A body of literature demonstrates that specific social appraisals and relational goals, like interacting with an out-group member, navigating a competitive environment (Bourgeois & Hess, 2008; Likowski et al., 2008), pursuing affiliation motives (Celeghin et al., 2017; Kaltwasser et al., 2019) or managing emotional responses (Etkin et al., 2015; Seibt et al., 2015), can significantly attenuate or suppress the emotional mimicry. Further, Blocker and Mcintosh, (2016) suggest that while mimicry of liked individuals may be relatively effortless, mimicking neutral or disliked targets requires active regulatory effort. Taken together, these results indicate that emotional mimicry is reliant on top-down modulation.

However, characterising top-down modulation requires precision about what automaticity means in the context of emotional mimicry. Rather than invoking distinct levels of conscious awareness, a resource-based account offers a more precise way to define automaticity here (Moors & De Houwer, 2006; Schneider & Chein, 2003). A process can be considered automatic to the degree that it proceeds without consuming limited cognitive capacity. Given the fundamental capacity constraints inherent to

human information processing (Kahneman, 1973; Lavie et al., 2004), evaluating automaticity through the lens of resource consumption is theoretically essential. A resource based framework is required to understand how affective social behaviors are actually executed or abandoned outside of idealized, resource-abundant conditions.

The motivational and contextual dependencies outlined by the EMIC model raise a natural question: through what cognitive mechanism do social appraisals modulate mimicry? The EMIC model identifies the relevant social variables, such as group membership, relational context, and affiliative goals, but does not specify the cognitive architecture by which these variables exert their influence. Modulating these motor responses based on social context and motivation demands cognitive capacity. The influence of top-down modulation suggests that emotional mimicry is a resource-dependent process. Specifically, observers must engage in active top-down control to appraise their social environment and maintain relational goals (Etkin et al., 2015; Wang & Hamilton, 2012), processes that require attention and working memory.

Wróbel & Imbir (2019) suggest that top-down modulation may take the form of a 'correction' process, where initial reflexive tendencies are adjusted to align with social norms or personal goals. However, the cognitive mechanisms underlying the correction process remain underexplored. While it is acknowledged that mimicry is not purely automatic, there is little clarity regarding the specific attentional and working memory constraints required to modulate these responses (e.g., Hatfield et al., 2014; Miller, Xia, & Hastings, 2019). The following section, therefore, explores how the framework of cognitive load can elucidate the top-down control.

Cognitive Load and Affective Processing

To understand how limits on our cognitive processing power regulate social behaviors like mimicry, the load theory of attention and cognitive control (Lavie et al., 2004) offers a foundational framework. According to the theory, information processing involves two distinct capacity limits: perceptual capacity and cognitive control. A high perceptual load consumes resources needed to perceive a distractor (Lavie, 1995). Conversely, heavy demands on working memory deplete the top-down executive resources necessary to suppress irrelevant distractors (de Fockert et al., 2001; Lavie, 2005). As a result, when working memory is heavily burdened by a primary task, goal-directed cognitive control fails. Without top-down regulation, task-irrelevant distractors 'break through' and are processed more deeply than in low cognitive load conditions.

In the context of affective processing, emotional faces are perhaps the most salient distractors human beings encounter. Because facial expressions convey critical survival and social information, they are biologically prioritised for processing (Vuilleumier, 2005). During a goal-directed task, actively ignoring distractors like a smiling or frowning face requires active top-down suppression (Etkin et al., 2015; Pessoa, 2005). According to Load Theory, if an observer's working memory is heavily burdened, the cognitive control necessary to inhibit the emotional distractor is compromised (Lavie, 2005).

Further, Tavares et al. (2016) demonstrated that high perceptual load reduces the impact of emotional distractors, indicating a perceptual bottleneck. On the other hand, the study also illustrated that an elevated working memory load creates the

opposite effect by drastically increasing emotional distraction, which reflects a bottleneck in top-down cognitive control. A critical premise of the control bottleneck hypothesis is the case of mimicry being subjected to active inhibitory suppression under normal task conditions. Evidence for control bottleneck comes from multiple sources. First, neuroimaging studies demonstrate that prefrontal regions associated with executive control are reliably activated during observation of emotional faces during goal-directed tasks, suggesting that inhibition of affective motor responses is an active and ongoing process (Etkin et al., 2015). Second, behavioural studies show that participants in competitive or achievement-oriented contexts exhibit significantly reduced mimicry compared to affiliative contexts, implying that situational goals recruit inhibitory resources to suppress default mimicry (Bourgeois & Hess, 2008). Third, deliberate instructions to suppress facial reactions increase self-reported cognitive effort and are associated with physiological markers of regulatory engagement (Korb et al., 2012). Taken together, these results indicate that during goal-oriented tasks, mimicry does not merely fail to trigger; rather, it is actively suppressed by executive control.

Recent studies have used cognitive load paradigms to examine the limits of automaticity in general affective processing. However, the findings in the literature are mixed. Some studies report that high cognitive load dampens empathic neural responses and affective priming (e.g., Gu & Han, 2007; Morelli & Lieberman, 2013). In contrast, other studies indicate that cognitive load actually increases interference from emotional distractors, facilitating affective responses by impairing top-down inhibition (e.g., de Fockert et al., 2001; Tavares et al., 2016). While these results are well-documented in general affective processing, the specific influence of cognitive load on facial mimicry remains underexplored.

These mixed findings may stem from how previous research has operationalised cognitive load, often treating working memory as a single, uniform resource rather than a multicomponent system (Baddeley, 2012). By manipulating overall task difficulty without isolating the underlying cognitive subsystems, different types of mental resources are conflated (Konstantinou & Lavie, 2013). Studies employing tasks that primarily burden executive control, such as digit sequence retention, tend to report facilitation of affective processing (de Fockert et al., 2001; Tavares et al., 2016), whereas studies employing visuospatial or spatial tracking tasks tend to report attenuation (Gu & Han, 2007; Konstantinou et al., 2014). Taken together, the direction of cognitive load effects on affective processing could depend systematically on which working memory subsystem is engaged. Specifically, working memory involves both the limited executive resources required for top-down control and the finite storage capacity required to maintain sensory information, such as visual data (Baddeley, 2012). According to Load Theory, distractors 'break through' when resources for executive control are depleted (Lavie et al., 2004). However, if a task primarily burdens the capacity to hold a visual image in mind, the effect on processing a distracting facial expression, and consequently facial mimicry, may be entirely different (e.g., Konstantinou et al., 2014). Therefore, to clarify how cognitive load influences affective processing or particularly emotional mimicry, it is necessary to deconstruct working memory into its specific functional components.

Deconstructing Working Memory

Understanding the influence of cognitive load on emotional mimicry requires moving beyond a unitary view of working memory to a multi-component perspective. In this regard, Baddeley's model (Hitch & Baddeley, 1976; Baddeley, 2003; 2012) is instrumental, as it partitions working memory into a central executive responsible for cognitive control, alongside domain-specific storage systems for verbal (phonological loop) and visuospatial (visuospatial sketchpad) data. Applying functional dissociation to the processing of emotional faces may clarify the specific mechanisms that regulate facial mimicry.

The visuospatial sketchpad has a limited capacity for maintaining visual and spatial representations (Baddeley, 2012). It should be noted that the visuospatial sketchpad primarily maintains visual representations after initial perceptual encoding, rather than supporting early sensory processing. However, the sensorimotor simulation underlying mimicry is not thought to depend solely on initial feedforward processing. Rather, it requires the sustained maintenance of a detailed facial representation sufficient to drive motor mimicry (Hofelich & Preston, 2012). When visuospatial storage capacity is heavily occupied by a concurrent retention task, the constancy with which the face can be maintained and processed is reduced, thereby attenuating the motor response even if primary level detection of the face remains intact. Although Dimberg et al. (2000) found that facial mimicry can be triggered by stimuli presented below the threshold of awareness, their methodology relied on briefly masked faces presented in isolation, entirely free from competing attentional tasks. If faces are presented during a resource-demanding visual task which can create a competition for visual attention, the availability of residual visuospatial capacity becomes critical (e.g., Carmel et al., 2012). While initial detection may occur automatically, sustained perceptual encoding appears contingent upon these remaining cognitive resources. Further, Wood et al. (2016) demonstrated that sensorimotor simulation of expressions depends on the quality of perceptual encoding rather than mere detection, suggesting that under high visuospatial load, facial mimicry is predicted to decrease.

In contrast, the central executive is responsible for top-down cognitive control, goal maintenance, and the active suppression of task-irrelevant stimuli (Baddeley, 2012). When a primary task heavily burdens the central executive system, such as retaining sequences of numbers, inhibitory control is severely depleted. As established in the literature, a depleted central executive fails to inhibit salient distractors like emotional faces, allowing the expressions to be better processed (e.g., de Fockert et al., 2001; Tavares et al., 2016). Building upon this, the uninhibited processing of facial expressions should directly facilitate facial mimicry. Therefore, under high central executive load, facial mimicry response should increase.

Synthesising the visuospatial and executive function mechanisms reveals that facial mimicry could be governed by a dual-bottleneck architecture. Rather than a purely automatic reflex, the mimicry response is proposed to be a resource-dependent process subject to two distinct cognitive constraints. First, it is hypothesized to require available visuospatial capacity for bottom-up perceptual encoding (a perceptual bottleneck; Konstantinou & Lavie, 2013). Second, once perceived, the response is proposed to rely on central executive capacity for top-down control (a control bottleneck; Lavie et al.,

2004). Dual-dependency suggests that the modulation of facial mimicry under cognitive load, specifically, whether it decreases or increases, depends on which functional subsystem is currently burdened.

The dual-bottleneck hypothesis generates specific and falsifiable predictions. One, that while simultaneously processing task irrelevant faces, high visuospatial load will produce significantly reduced zygomaticus activity compared to low load conditions. If high visuospatial load instead produces increased or equivalent mimicry, the results would contradict the perceptual bottleneck hypothesis and suggest that facial mimicry is sufficiently robust to survive visuospatial resource depletion, consistent with more strongly automatic accounts. Two, that while simultaneously processing task irrelevant faces, high central executive load will produce significantly reduced zygomaticus activity compared to low load conditions. If high central executive load instead produces reduced or equivalent mimicry, the results would contradict the control bottleneck hypothesis and suggest either that baseline mimicry does not involve active suppression or that executive depletion impairs the processing of emotional faces more broadly. Additionally, if both manipulations produced null effects, the results would suggest that the emotional mimicry response, as measured by facial EMG in a dual-task paradigm, is insensitive to working memory load manipulations, which would itself be a theoretically informative finding consistent with strict automaticity accounts.

Empirical Investigation

To test the dual-bottleneck hypothesis, a dual-task paradigm was employed combining a visual search task with a working memory manipulation while recording continuous facial electromyography (EMG). Emotional mimicry was indexed via activity of the zygomaticus major (ZM) muscle in response to task-irrelevant happy and neutral faces presented during the search display. ZM EMG is a well-established physiological measure of spontaneous positive facial mimicry (Dimberg & Thunberg, 1998; Fridlund & Cacioppo, 1986; Cannon et al., 2009).

By manipulating working memory load (High vs. Low) in both experiments, the regulatory mechanisms that gate emotional mimicry were examined. Load manipulation builds on load theory's proposal that working memory resources support the top-down control of task-irrelevant distractor processing (Lavie et al., 2004; de Fockert et al., 2001). Rather than treating working memory as a uniform resource, a functional dissociation of its components was employed by varying the stimuli used for the working memory task.

The visuospatial sketchpad was targeted in Experiment 1 using non-verbal Brussels Artificial Character Set (BACs) stimuli to test the perceptual bottleneck, as BACs characters are commonly used to impose visuospatial working memory demands while minimising verbal encoding (Vanderplas & Garvin, 1959; Tavares et al., 2016). In experiment 2 the central executive was targeted using numerical stimuli to test the control bottleneck. While numbers can initially be encoded visuospatially, maintaining a multi-digit sequence across a delay relies heavily on active subvocal rehearsal (Baddeley, 2012). Crucially, coordinating the continuous rehearsal while simultaneously executing a primary visual search task heavily taxes the central executive, depleting the resources typically available for top-down distractor inhibition (Engle, 2002; Kane

& Engle, 2003). The dissociation of visuospatial processing or executive control allowed us to investigate whether limitations in visuospatial processing or executive control differentially constrain the emergence of emotional mimicry under cognitive load.

Experiment 1 - Isolating the Perceptual Bottleneck: Visuospatial Capacity and Spontaneous Mimicry

In Experiment 1, visuospatial working memory demands were manipulated using BACs characters (Vidal, Content, & Chetail, 2017) in working memory task. BACs characters are highly complex, unfamiliar geometric configurations that cannot be easily verbalised, thereby imposing demand of visuospatial resources while minimising verbal encoding. The working memory load manipulation followed the procedure established by Tavares et al. (2016), in which memory set presentation was temporally separated from the search display to minimise direct visuospatial competition during face processing.

Hypothesis 1: There is a significant visuospatial Load × Emotion interaction, such that zygomaticus major (ZM) reactivity to happy faces (relative to neutral baselines) is significantly higher under high visuospatial load compared to low visuospatial load.

Methods

Participants

Following a pilot study with 12 participants, an a priori power analysis (power = 0.95, $\alpha = 0.05$) based on the smallest observed effect size (main effect of Emotion, $\eta_p^2 = 0.123$) indicated a required sample size of 18. However, in line with previous studies examining EMG responses to passively presented facial expressions, we oversampled to account for potential data loss.

Thirty-six participants were recruited for Experiment 1. To significantly exceed the 50% chance level on a 120-trial, two-alternative forced-choice (2AFC) task, a minimum accuracy of 58.33% (at least 70 correct responses) is required based on the binomial distribution. Three participants failed to exceed the 58.33% accuracy threshold and were excluded. All remaining participants surpassed the threshold (see Appendix A). A further two participants were excluded during EMG data screening, as their mean values exceeded ±3 standard deviations from the group mean. The final sample comprised 31 participants (all female, mean age = 25.64, $SD = 3.03$). All participants had normal or corrected-to-normal vision and reported no neurological or psychiatric conditions.

Stimuli

Facial Stimuli - To ensure the emotional specificity of the stimuli, 200 facial images (100 happy and 100 neutral, generated from 50 male and 50 female individuals) were revalidated from the IIM-Indore Emotional Face Database (Tewari, Mehta, & Srinivasan, 2023). These images were rated by 10 independent participants (5 male, 5

female) who did not take part in the main experiment. Participants evaluated each face on a 7-point Likert scale, where '1' indicated "very happy" and '7' indicated "very angry." Based on these ratings, 120 images were selected for the main study, comprising 30 images in each category: happy-female, happy-male, neutral-female, and neutral-male. The mean ratings for these categories were 1.98 (happy-female), 2.06 (happy-male), 4 (neutral-female), and 4 (neutral-male). During the experiment, the faces were presented against a grey background at a visual angle of $6.33° \times 6.67°$.

Working Memory Load Task Stimuli - Characters drawn from the Brussels Artificial Character Sets (BACs; Vidal, Content, & Chetail, 2017). In the high-load condition, a set of five BACS characters was presented for retention. In the low-load condition, a single BACs character was presented.

Visual Search Task Stimuli - The letter search array comprised a target letter ('X' or 'N') presented among five distractors, each subtending $0.477° \times 0.605°$ of visual angle, arranged equidistantly in a circular array with a radius of 2.75°. Two of the five distractor positions were occupied by letters randomly drawn from the set {'K', 'M', 'H', 'Z', 'W'}, while the remaining three distractor positions contained the letter 'O'. The target letter and the two heterogeneous distractors were assigned to positions within the array at random on each trial.

Procedure

The study was approved by the institutional ethics committee. Participants were recruited via convenience sampling and were monetarily compensated for their time. Researchers obtained informed consent from all individuals before participation.

The behavioral load paradigm was adapted from previous studies manipulating working memory load during attentional selection tasks (e.g., Lavie et al., 2004; Tavares et al., 2016). Specifically, the working memory task from experiment 1 of Tavares et al. (2016), but in deviating from their use of emotional scene images as distractors, emotional facial expressions were employed. Stimuli were presented on HP monitors connected to Dell i5 desktop computers and behavioral responses recorded using PsychoPy (version 2025.1.1; Peirce et al., 2019). The display had a resolution of 1366×768 pixels and a refresh rate of 60 Hz.

Working Memory - Visual Search Task structure is presented in Figure 1. Each trial began with the presentation of either one (low-load) or five (high-load) BACs characters. The memory set was displayed for 500 ms in the low-load condition and 2000 ms in the high-load condition. This was followed by a masking screen presented for 750 ms (low-load) or 2500 ms (high-load), and a fixation cross displayed for 500 ms. Subsequently, a face displaying either a happy or neutral expression appeared at the centre of the screen. Superimposed around the face was a circular array of six letters, comprising a target letter ('X' or 'N'), two heterogeneous distractors randomly drawn from the set {'K', 'M', 'H', 'Z', 'W'}, and three identical distractor letters ('O'). Participants were instructed to identify the target letter as quickly and accurately as possible by pressing the corresponding key ('X' or 'N') on the keyboard. Following the search display, a probe BACS character was presented, and participants indicated whether it matched any of the characters in the previously presented memory set by

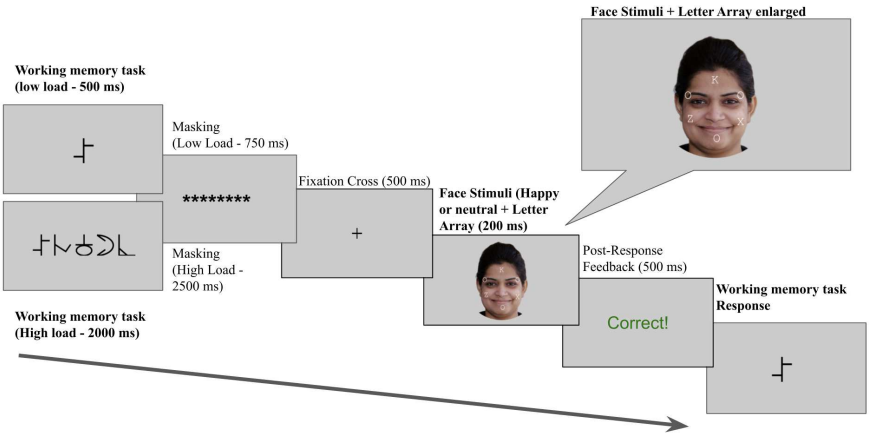


Fig. 1 Trial structure of Experiment 1 in both low-load and high-load conditions

pressing the "up" arrow key for a match or the "down" arrow key for a non-match. The probe character matched the memory set on randomly distributed 50% of trials.

The experiment began with two practice blocks, one for the low-load condition and one for the high-load condition. The practice phase was terminated once participants achieved at least 60% accuracy across the most recent 10 trials at any point. Following the practice phase, the main experiment consisted of 12 blocks (6 low-load and 6 high-load), with 20 trials per block, yielding a total of 240 trials per task. Blocks were presented in an interleaved order, and happy and neutral stimuli were randomised within each block.

Electromyography data acquisition

Facial mimicry while processing the emotional face was measured through electromyography (EMG), which was recorded from the zygomaticus major (cheek) for smile, using pairs of $Ag/AgCl$ bipolar electrodes on the left side of the face (for consistency), following previous literature (Fridlund & Cacioppo, 1986; Cannon, Hayes & Tipper, 2009). EMG activity was recorded using the extracranial channels of Biosemi ActivTwo EEG acquisition device. Data was sampled at a frequency of 2048 Hz. NuPrep gel and isopropyl alcohol were used in skin preparation for EMG.

Data Analysis

EMG Data Preprocessing EMG data were exported to Brainstorm (Tadel et al., 2011) for preprocessing and analysis. The raw signals were band-pass filtered using a 20 Hz high-pass filter and a 500 Hz low-pass filter. A notch filter was additionally applied at 50 Hz and its harmonics (100, 150, 200,..., 500 Hz), based on inspection of the power spectral density plots. DC offset correction and linear detrending were performed to remove abrupt and slow drifts in the continuous signal. Consistent with previous

research (Cannon, Hayes, & Tipper, 2009), analyses focused on the 300-1000 ms post-stimulus onset time window. For each trial, muscle activity was recorded relative to a baseline period from -1000 to -300 ms prior to facial stimulus onset. The mean baseline amplitude was subtracted from the activity in the 300-1000 ms window to perform baseline correction. Subsequently, data were standardized by converting values to z-scores across for ZM muscle activity for each trial within each condition. The mean absolute value (MAV) of the z-scores was then calculated and averaged across trials within each condition for each participant. The processed data were exported for offline statistical analysis in R (R Core Team, 2024).

EMG Data Analysis To clean the data, data points deviating from the average more or less than three standard deviations $Mn > (\overline{M} \pm 3SD)$ were discarded. Linear interpolation was applied to impute missing values using the formula:

$$Y = Y_1 + \frac{x - X_1}{x_2 - x_1} \times (Y_2 - Y_1) \tag{1}$$

Where Y_1 and Y_2 are adjacent known values, and X_1 and X_2 are their respective positions. X is the position of the missing value Y. The interpolation method fills gaps where values were missing by estimating intermediate values along the same numeric variable, ensuring continuity and minimising data loss.

Mean amplitude values were computed for each participant in each condition and submitted to perform a 2×2 repeated-measures analysis of variance (ANOVA) using the ez package (Lawrence, 2016) in R, examining the main effects of Emotion (Happy vs. Neutral) and Load (High vs. Low), and their two-way interaction (Emotion $\times$ Load). Partial eta-squared (η_p^2) was reported as a measure of effect size. To examine the temporal dynamics of facial mimicry and how they are modulated by cognitive load, a cluster-based permutation ANOVA was conducted using the permuco package (Frossard & Renaud, 2021) in R. The 300-1000ms post-stimulus time course was segmented into 14 consecutive 50ms time windows (300-350ms through 950-1000ms), and mean EMG amplitude was computed per participant per condition within each window. A repeated-measures cluster-mass ANOVA was applied across the full time series with 10,000 permutations, modelling the main effects of Emotion and Load and their interaction, with participant treated as a random factor. To correct for multiple comparisons across time bins, the family-wise error rate was controlled using a cluster-mass correction. Clusters were defined as contiguous time bins in which the per-bin F-statistic exceeded the critical threshold ($p < .05$ per bin), and a cluster was considered statistically significant if its cluster-mass permutation p-value was below .05. Per-bin F-statistics and uncorrected permutation p-values are reported descriptively; all inferential conclusions are based exclusively on cluster-corrected p-values.

Behavioral Data Analysis Behavioral analyses were conducted to evaluate the effectiveness of the working memory load manipulation. Accuracy (%) and reaction times (RTs) from the working memory probe task were analyzed separately for low-load and high-load conditions. For each participant, mean accuracy was calculated for low- and high-load trials. A paired-samples t-test was conducted to compare accuracy between load conditions. Reaction time analyses were performed on correct working memory probe trials only. For each participant and load condition, mean RTs were

computed and log-transformed to correct for positive skew and to improve normality. Paired-samples t-tests were then conducted on the log-transformed RTs to compare performance under low-load and high-load conditions. All tests were two-tailed with α set at .05. These analyses were intended to confirm that the high-load condition resulted in significantly lower accuracy and/or slower reaction times relative to the low-load condition, thereby validating the cognitive load manipulation.

Results

Behavioural Results

To validate the visuospatial cognitive load manipulation, accuracy and log-transformed reaction times on the working memory probe task were compared across low-load and high-load conditions using paired-samples t-tests.

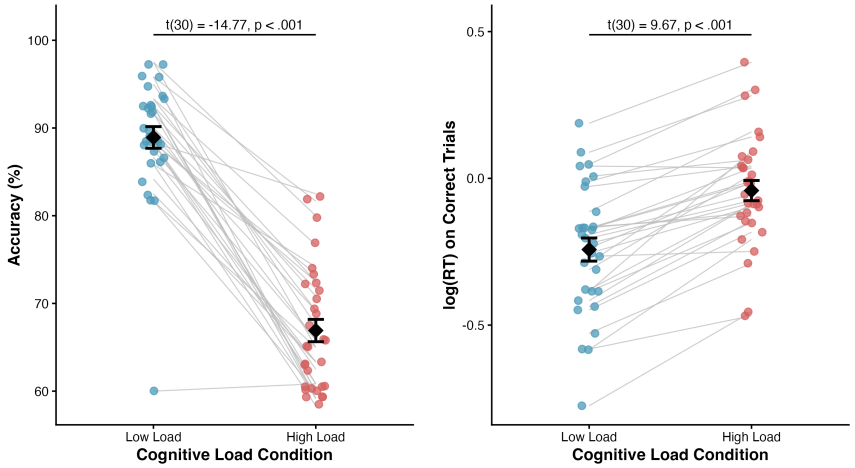


Fig. 2 Working memory task performance across low-load and high-load conditions ($N = 31$). Left panel shows accuracy (%) and Right panel shows log-transformed reaction times on correct trials. Diamonds represent group means ± standard error; connecting lines indicate paired observations

Participants performed significantly poorer in the high-load condition ($M = 66.91\%$, $SD = 7.09\%$) relative to the low-load condition ($M = 88.93\%$, $SD = 6.88\%$), $t(30) = -14.77$, $p < .001$, $d = -2.65$. In terms of reaction time, participants were significantly slower to respond to the memory probe in the high-load condition ($M = -0.04$, $SD = 0.20$) than in the low-load condition ($M = -0.25$, $SD = 0.22$), $t(30) = 10.17$, $p < .001$, $d = 1.83$. Given that the high-load condition produced both significantly lower accuracy and slower reaction times relative to the low-load condition, visuospatial working memory load manipulation was effective (see Figure 2).

EMG results

ANOVA - A repeated-measures ANOVA was conducted on mean ZM amplitude across the 300-1000 ms post-stimulus window. The main effect of emotion was statistically significant $[F(1, 30) = 5.042, p = .032, \eta_p^2 = .144]$, indicating that happy facial expressions elicited greater overall activity than neutral expressions.

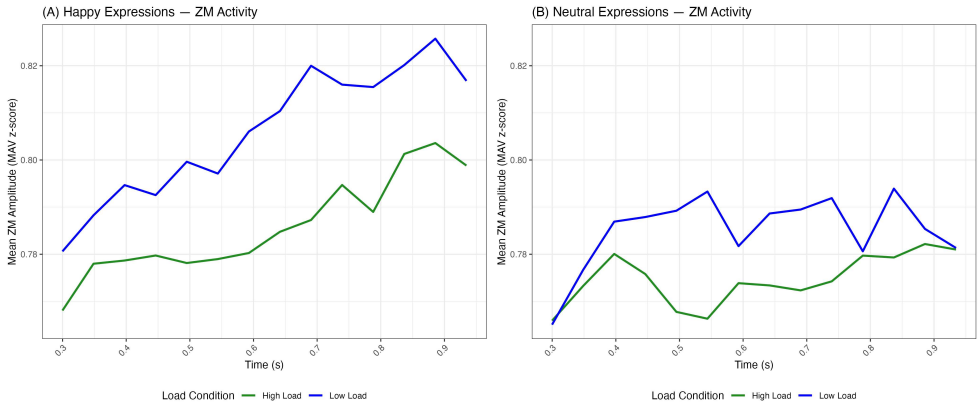


Fig. 3 Mean zygomaticus major (ZM) amplitude (MAV of z-scores) across the 300-1000ms post-stimulus window for (A) Happy and (B) Neutral facial expressions under low-load (blue) and high-load (green) conditions

Though the main effect of visuospatial working memory Load did not reach statistical significance $[F(1, 30) = 3.309, p = .079, \eta_p^2 = .099]$, a numerical trend was observed suggesting lower ZM amplitude under high-load relative to low-load conditions. Critically, the Load × Emotion interaction was also not statistically significant $[F(1, 30) = 0.309, p = .583, \eta_p^2 = .010]$, indicating that cognitive load did not differentially modulate ZM activity as a function of emotional expression. As illustrated in Figure 3, inspection of condition means revealed a broadly consistent pattern across both emotional expressions: ZM activity under low-load was numerically higher than under high-load for both happy (Panel A) and neutral (Panel B) expressions across the post-stimulus window, suggesting a general rather than emotion-specific suppression of ZM activity under high visuospatial load.

Temporal Analysis - To examine the temporal dynamics of ZM activity, a cluster-based permutation ANOVA was conducted across fourteen 50 ms time windows spanning the 300-1000 ms post-stimulus period (see Figure 4). The main effect of Load did not produce any clusters surviving correction; above-threshold F-values were observed at isolated time windows at 500-550 ms $[F(1, 30) = 4.514, p_{uncorr-bin} = .040]$, 550-600 ms $[F(1, 30) = 4.549, p_{uncorr-bin} = .039]$, and 700-750 ms $[F(1, 30) = 5.755, p_{uncorr-bin} = .018]$, but none of these bins formed a cluster that survived cluster-mass correction (cluster $p = .107, .107$, and .140 respectively).

The Load × Emotion interaction produced no above-threshold F-values at any time window (all per-bin $p > .05$). Critically, the main effect of Emotion produced a significant cluster spanning 700-1000 ms [peak $F(1, 30) = 12.573$ at 850-900 ms, $p_{uncorr-bin} = .001$, cluster $p = .013$], indicating that happy expressions elicited reliably greater ZM activity than neutral expressions during the late post-stimulus window. The emotion-specific effect was consistent across both load conditions, as reflected by the absence of a significant Load × Emotion interaction at any time point. Mean ZM amplitude across all conditions and time windows is presented in Appendix C (Figure 11) for reference.

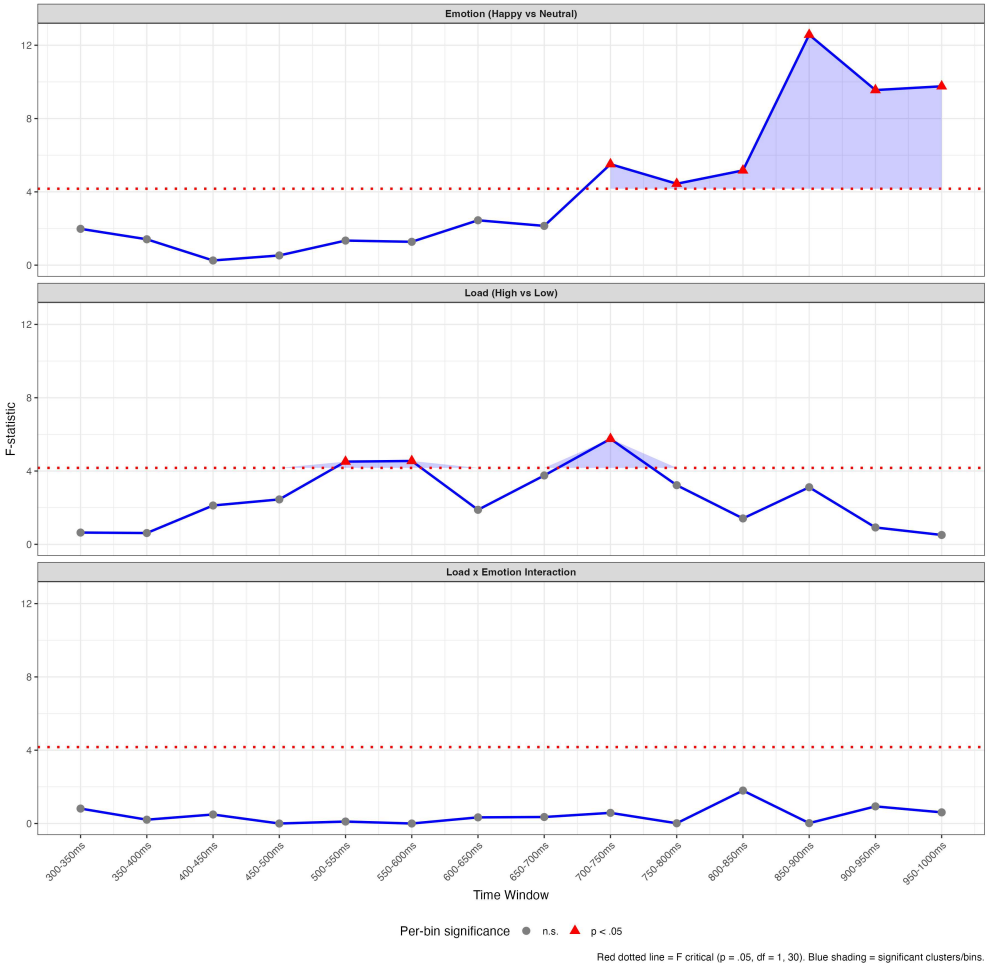


Fig. 4 F-statistics across fourteen 50 ms time windows (300-1000 ms) for the Emotion main effect (upper panel), Load main effect (middle panel), and Load × Emotion interaction (lower panel), derived from the cluster-based permutation ANOVA

Bayesian Analysis of the Interaction - To quantify the evidence for the null hypothesis regarding the non-significant Load × Emotion interaction, a Bayesian repeated-measures ANOVA was conducted using default Cauchy priors. Analysis of effects revealed a Bayes Factor for exclusion (BF_{excl}) of 3.699 for the interaction term. Bayes Factor indicates that the data are approximately 3.7 times more likely to occur under a model that excludes the interaction than one that includes it, suggesting evidence for the null hypothesis. This confirms that while visuospatial working memory load may exert a generalized influence on facial motor activity, it does not selectively attenuate the mimicry response to happy expressions.

Experiment 2 - Isolating the Cognitive Bottleneck: Executive Depletion and the Regulation of Mimicry

In subsequent investigation (Experiment 2), cognitive load was manipulated using a numerical working memory task. Retaining sequences of numbers engages verbal storage processes and taxes the central executive's capacity for cognitive control. Because participants are instructed to focus on a primary visual search while ignoring the emotional face distractors, success requires active top-down suppression. While maintaining any high-load representation inevitably recruits some executive capacity, numerical stimuli was selected for Experiment 2 specifically to maximize the demand on the central executive. Maintaining a random, multi-digit sequence requires continuous, serial subvocal rehearsal. Particularly, while simultaneously executing a primary visuospatial task (visual search) requires intense cross-domain coordination. According to multicomponent models of working memory, coordinating two distinct subsidiary systems, like the phonological loop and the visuospatial sketchpad is a primary function of the central executive, thereby reliably taxing its capacity for top-down inhibitory control (Baddeley, 2012; Emerson & Miyake, 2003).

Hypothesis 2: There is a significant Load × Emotion interaction, such that zygomaticus major (ZM) reactivity to happy faces (relative to neutral baselines) is significantly higher under high cognitive load compared to low cognitive load.

Methods

Participants

A total of 35 participants were initially recruited. This target sample size was chosen to match that of Experiment 1, as both experiments examine facial mimicry when faces are processed in a task-irrelevant manner. Two participants failed to reach the 60% accuracy criterion during the practice phase and were discontinued. The remaining 33 participants successfully completed the main experiment. Applying the same criterion as Experiment 1, all recruited participants surpassed the threshold of 58.33% accuracy in the working memory tasks (see Appendix D for per-participant accuracy). During subsequent EMG data screening, data from an additional four participants were excluded because their mean values exceeded ±3 standard deviations from the group mean. Therefore, the final analyses were conducted on a sample of 29 female participants (mean age = 25.4, SD = 3.4). All participants had normal

or corrected-to-normal vision and reported the absence of neurological or psychiatric conditions.

Stimuli

Facial Stimuli - Facial stimuli were identical to those used in Experiment 1, comprising the same 120 validated images (30 happy-female, 30 happy-male, 30 neutral-female, 30 neutral-male) selected from the IIM-Indore Emotional Face Database (Tewari, Mehta, & Srinivasan, 2023). Faces were presented against a grey background at the same visual angle as Experiment 1 ($6.33° \times 6.67°$).

Visual Search Task Stimuli - The visual search display consisted of a single white target letter ('X' or 'N') presented alongside five identical distractor letters ('0'). Each letter subtended $0.477° \times 0.605°$ of visual angle, and all six letters were arranged equidistantly in a circular array with a radius of 2.75°.

Procedure

Ethical approval, recruitment protocols, and consent procedures were identical to those described in Experiment 1. The general procedure was identical to that of Experiment 1, with the exceptions that the working memory stimuli were replaced with numbers instead of BACs characters and all the distractors in the visual search task were '0'. Stimuli were presented and behavioural responses recorded using PsychoPy (version 2025.1.1; Peirce et al., 2019) on HP monitors connected to Dell i5 desktop computers. The display had a resolution of 1366×768 pixels and a refresh rate of 60 Hz.

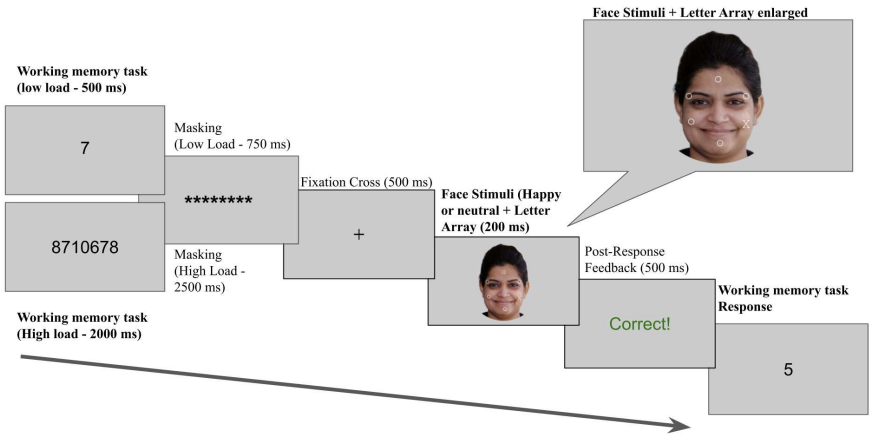


Fig. 5 Trial structure of Experiment 2 in both low-load and high-load conditions

Working Memory - Visual Search Task structure is presented in Figure 5. Each trial began with the presentation of a number string consisting of either one digit (low

load) or six digits (high load). The memory set was displayed for 500 ms in the low-load condition and 2000 ms in the high-load condition. To account for proportional rehearsal times, memory set display was followed by a masking screen presented for 750 ms (low load) or 2500 ms (high load), and a fixation cross displayed for 500 ms. Subsequently, a face displaying either a happy or neutral expression appeared at the center of the screen. Superimposed around the face was a circular array of six letters. In the visual search condition, the target letter (X or N) appeared among five identical distractors ('0'). Participants were instructed to identify the target letter as quickly and accurately as possible by pressing the corresponding key ('X' or 'N') on the keyboard. After a brief interval, a probe digit was presented, and participants indicated whether it matched any of the previously presented numbers. Participants pressed the "up" arrow key if the digit matched and the "down" arrow key if it did not match. The probe digit matched the memory set on 50% of the trials.

The experiment began with two practice blocks, one for the low-load condition and one for the high-load condition. The practice phase was terminated once participants achieved at least 60% accuracy across the most recent 10 trials at any point. If a participant failed to reach this criterion within 50 trials, the session was discontinued. Following the block design established by Tavares et al. (2016), the main experiment consisted of 12 interleaved blocks (6 low-load and 6 high-load) of 20 trials each, yielding a total of 240 trials. Within each block, the presentation of neutral and happy stimuli was completely randomised. EMG data acquisition was the same as Experiment 1.

Data Analysis

Data analysis procedures were identical to those described in Experiment 1. Briefly, behavioural analyses examined accuracy and log-transformed reaction times (only for correct trails) on the working memory probe task across low and high-load conditions using paired-samples t-tests (two-tailed, $\alpha = .05$), to confirm the effectiveness of the visuospatial load manipulation. EMG data processing, outlier exclusion, linear interpolation, and statistical analyses followed the same procedures as Experiment 1, including a repeated-measures ANOVA examining the main effects of Emotion (Happy vs. Neutral) and Load (High vs. Low) and their interaction, followed by a cluster-based permutation ANOVA across the 300-1000 ms post-stimulus time course using the permuco package (Frossard & Renaud, 2021) in R.

Results

Behavioural results

To validate the cognitive load manipulation, accuracy and log-transformed reaction times on the working memory probe task were compared across low-load and high-load conditions using paired-samples t-tests. Participants performed significantly poorer in the high-load condition ($M = 89.37\%$, $SD = 7.01\%$) relative to the low-load condition ($M = 92.79\%$, $SD = 6.10\%$), $t(28) = -3.54, p = .001, d = -0.52$. In terms of reaction time, participants were significantly slower to respond to the memory probe in the high-load condition ($M = -0.01$, $SD = 0.21$) than in the low-load condition ($M = -0.27$, $SD = 0.21$), $t(28) = 9.63, p < .001, d = 1.22$. As expected, the high-load

condition produced both significantly lower accuracy and significantly slower reaction times relative to the low-load condition. Therefore, the working memory load manipulation was effective (see Figure 6).

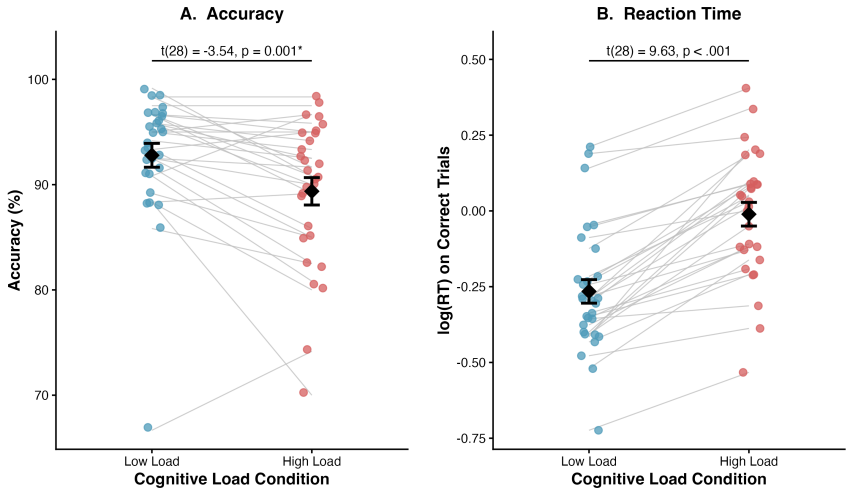


Fig. 6 Working memory task performance across low-load and high-load conditions ($N = 29$). Panel A shows accuracy (%) and Panel B shows log-transformed reaction times on correct trials. Diamonds represent group means ± standard error; connecting lines indicate paired observations

EMG results

ANOVA - A repeated-measures ANOVA was conducted on mean ZM amplitude across the 300-1000ms post-stimulus window. Neither the main effect of Emotion $[F(1, 28) = 0.135, p = .717, \eta_p^2 = .005]$ nor the main effect of Load $[F(1, 28) = 0.926, p = .344, \eta_p^2 = .032]$ reached statistical significance. However, a significant Load × Emotion interaction emerged $[F(1, 28) = 4.502, p = .043, \eta_p^2 = .139]$.

As illustrated in Figure 7, inspection of condition means revealed a divergent pattern across the two emotional expressions: for happy expressions (Panel A), ZM activity under low-load was consistently lower than under high-load across the post-stimulus window, whereas for neutral expressions (Panel B), the two load conditions showed a more overlapping and less systematic pattern across the same time period. This suggests that the availability of cognitive resources modulated ZM activity in an emotion-specific manner.

To understand this interaction further, conditional post-hoc comparisons were conducted using Holm correction. Conditional on load level, comparisons between emotional expressions revealed that under high-load, ZM amplitude was higher for happy relative to neutral expressions, although this difference did not reach statistical significance $[t(28) = 1.658, p_{Holm} = .109, d = 0.308, \text{mean difference} = 0.010, SE = 0.006]$. Similarly, under low-load, ZM amplitude did not differ significantly between happy

and neutral expressions $[t(28) = -1.355, p_{Holm} = .186, d = -0.252, \text{mean difference} = -0.007, SE = 0.005]$. However, the direction of the effect reversed between load conditions: under high-load, happy expressions were associated with greater ZM activity than neutral expressions, whereas under low-load, this pattern was reversed, with neutral expressions showing higher ZM activity than happy expressions.

Conditional on emotional expression, comparisons between load conditions revealed a numerical increase in ZM amplitude for happy expressions under high-load relative to low-load, though this difference was not statistically significant $[t(28) = 1.876, p_{Holm} = .071, d = 0.348, \text{mean difference} = 0.016, SE = 0.008]$. For neutral expressions, no meaningful difference between load conditions was observed $[t(28) = -0.221, p_{Holm} = .827, d = -0.041, \text{mean difference} = -0.002, SE = 0.008]$. As illustrated in Figure 7, this pattern suggests that cognitive load selectively influenced ZM activity during the processing of happy facial expressions, with high-load associated with greater ZM amplitude relative to low-load for happy but not neutral expressions, consistent with an emotion-specific modulation of facial mimicry by attentional resources.

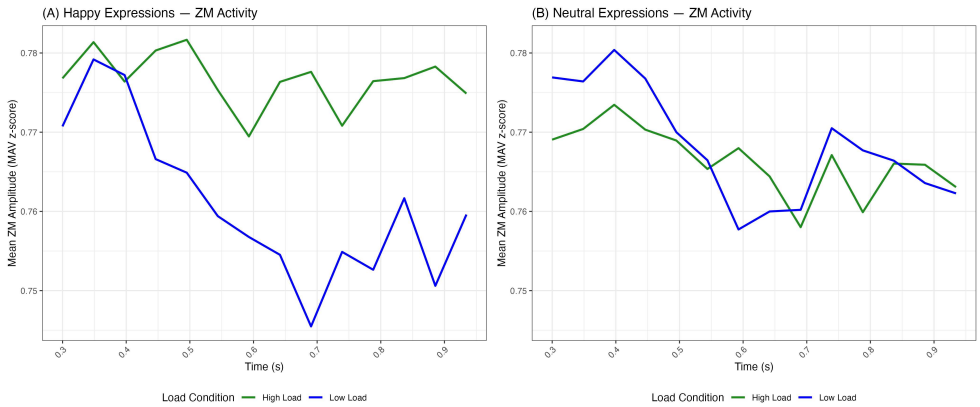


Fig. 7 Mean zygomaticus major (ZM) amplitude (MAV of z-scores) across the 300-1000ms post-stimulus window for (A) Happy and (B) Neutral facial expressions under low-load (blue) and high-load (green) conditions

Temporal Analysis - To examine the temporal dynamics of this interaction, a cluster-based permutation ANOVA was conducted across fourteen 50ms time windows spanning the 300-1000ms post-stimulus period (see Figure 8). Neither the main effect of Emotion nor the main effect of Load produced F-values exceeding the critical threshold at any time window (all per-bin $p > .05$). With respect to the Load $\times$ Emotion interaction, above-threshold F-values were observed in two distinct time windows: a single bin at 450-500ms $[F(1, 28) = 7.402, p_{uncorr} = .010, \text{cluster } p = .113]$ and a cluster spanning 700-800ms [peak $F(1, 28) = 6.249$ at 700-750ms, $p_{uncorr} = .017, \text{cluster } p = .083$]. However, neither cluster survived the cluster-mass correction threshold ($p < .05$), indicating that although the overall interaction was statistically

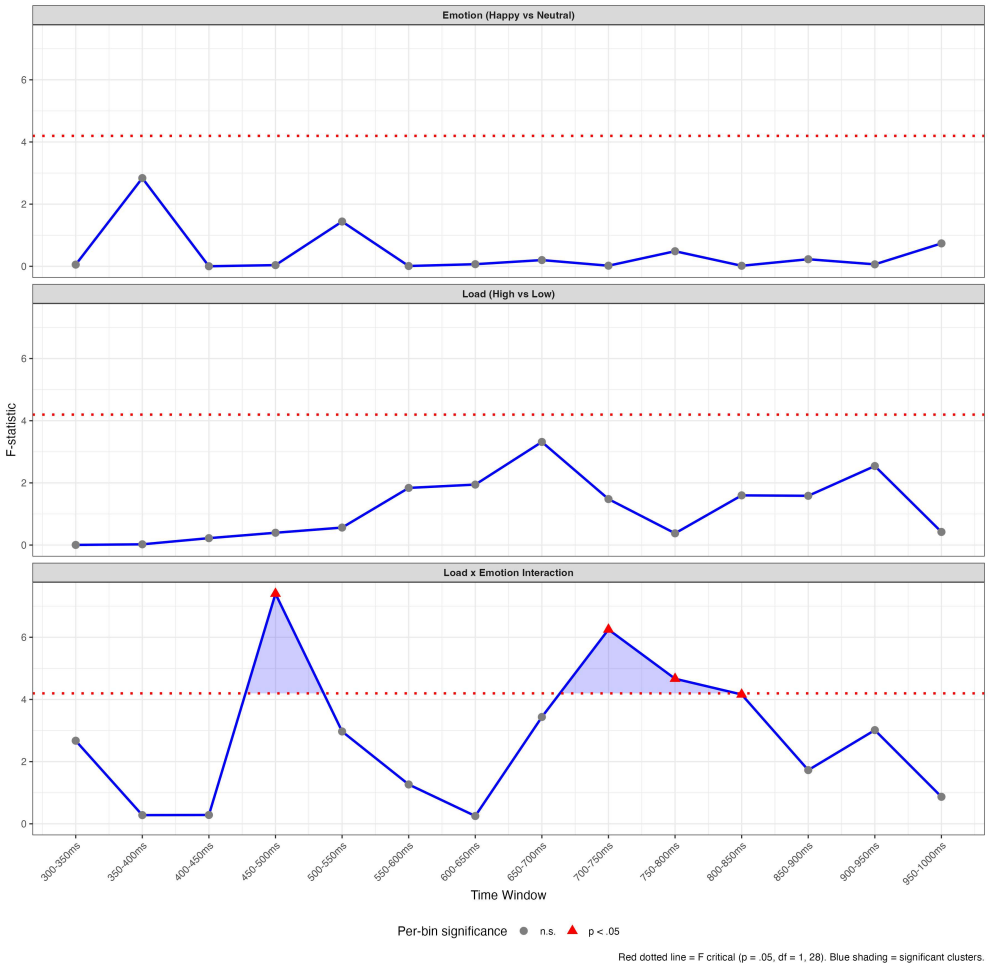


Fig. 8 F-statistics across fourteen 50ms time windows (300-1000ms) for the Emotion main effect (upper panel), Load main effect (middle panel), and Load × Emotion interaction (lower panel), derived from the cluster-based permutation ANOVA

significant, the effect could not be reliably localised to a specific post-stimulus time window after correction for multiple comparisons across the time course. Mean ZM amplitude across all conditions and time windows is presented in Appendix F (Figure 14) for reference.

Discussion

The present study investigated whether emotional mimicry is regulated by working memory resources. Based on Load Theory and multicomponent models of working memory (Hitch & Baddeley, 1976; Baddeley, 2012; Lavie et al., 2004), a dual-bottleneck

framework was tested. Across two experiments using continuous facial electromyography (EMG), the results indicate that, contrary to hypothesis 1, taxing visuospatial working memory did not show an attenuation of mimicry based on the emotional expression. But aligning with hypothesis 2, executive working memory load actively modulates emotional mimicry. Specifically, when central executive resources were depleted, a selective increase in zygomaticus major (ZM) activity in response to happy facial expressions relative to neutral ones was observed. Ultimately, the results suggest that mimicry is not entirely resource-free, and its modulation relies more on top-down executive control processes rather than visuospatial storage capacity.

Experiment 1 results did not support the prediction that taxing visuospatial working memory attenuates emotional mimicry. The basic mimicry effect was replicated where happy expressions elicited greater overall ZM activity than neutral ones (Dimberg, 1982; Dimberg & Thunberg, 1998; Lundqvist & Dimberg, 1995), visuospatial load did not interact with this emotion-driven response. Bayesian analyses further supported the absence of this interaction (Rouder et al., 2009; Wagenmakers et al., 2018). This challenges the strict 'perceptual bottleneck' hypothesis, which assumes that mimicry critically relies on available visuospatial storage resources (Konstantinou & Lavie, 2013; Konstantinou et al., 2014). However, this null finding does not falsify the broader idea that mimicry is resource-dependent (Hatfield et al., 1993; Wang & Hamilton, 2012); rather, it refines the understanding of when those resources matter.

The absence of interaction between Load and Emotion in Experiment 1 suggests that perceptual encoding of centrally presented happy faces was either resilient to concurrent maintenance demands or not directly challenged by the visuospatial load manipulation (Vuilleumier, 2005; Pessoa & Adolphs, 2010). This interpretation is consistent with evidence that emotionally salient stimuli gain prioritized access to perceptual processing even under attentional competition (Fox et al., 2000; Öhman et al., 2001). The results also suggest the possibility that mimicry depends on rapid feedforward encoding that occurs before capacity-limited visuospatial storage is fully engaged (Baddeley, 2012; Salway & Logie, 1995; Rossion & Boremanse, 2011; Bullier, 2001; Thorpe et al., 1996; Brosch et al., 2011; Eastwood et al., 2001).

In experiment 2, although the omnibus interaction reached significance, the individual post-hoc contrasts did not survive correction, and temporal cluster analyses did not localize the effect to a specific time window. These findings should therefore be interpreted as preliminary evidence of executive modulation rather than definitive proof. When participants performed a central executive task that taxed the central executive (Engle, 2002; Kane & Engle, 2003), ZM activity increased under high load relative to low load specifically for happy, but not neutral, faces (Vuilleumier, 2005; Fox et al., 2000). This pattern matches with load theory accounts proposing that working memory resources support the top-down suppression of salient distractors (Lavie et al., 2004; de Fockert et al., 2001). When executive control is burdened, the regulation of task-irrelevant affective responses weakens, allowing emotional motor resonance to emerge more strongly (Dimberg, 1982; Niedenthal, 2007; Korb et al., 2012; Lavie, 2005; Pessoa, 2005; Tavares et al., 2016; van Dillen & Koole, 2007).

The findings of experiment 2 also offer a cognitive explanation for how motivational and contextual factors shape mimicry, as outlined by the Emotional Mimicry in Context (EMIC) model (Hess & Fischer, 2013; 2014). The EMIC framework suggests that mimicry is an affiliative signal actively modulated by social appraisals and relational goals (Fischer & Hess, 2017; Seibt et al., 2015). Top-down executive control could be the underlying mechanism driving this modulation (Etkin et al., 2015; Miller et al., 2019). Navigating complex social contexts, whether that means maintaining focus on a primary task, inhibiting a socially inappropriate reaction (Bourgeois & Hess, 2008; Likowski et al., 2008), or adjusting the behavior to fit situational demands (Celeghin et al., 2017; Kaltwasser et al., 2019), relies on the central executive (Baddeley, 2012; Engle, 2002). When these cognitive resources are strained, individuals' capacity to actively align their emotional responses with their current goals diminishes (Kane & Engle, 2003; Schmeichel, 2007). This depletion allows the default mirroring of positive expressions to manifest more strongly (Blocker & McIntosh, 2016; Wróbel & Imbir, 2019), consistent with the view that mimicry represents a default affiliative tendency that is held in check by regulatory resources under normal conditions (Wang & Hamilton, 2012; Hess & Fischer, 2014). Ultimately, executive control acts as a top-down filter, actively managing and calibrating the physical display of affiliative mimicry to match immediate motivational priorities.

This regulatory role of the central executive mirrors broader findings on self-regulation, where finite executive resources are known to govern the degree to which behaviour remains aligned with current goals across a range of domains (Muraven & Baumeister, 2000; Inzlicht et al., 2014). Just as self-regulatory depletion compromises goal-directed behaviour more generally, depleting executive resources in the paradigm appears to have loosened the cognitive constraints on affiliative motor output, allowing default mimicry tendencies to surface more strongly.

Taken together, the two experiments support a hierarchical model of emotional mimicry consistent with two-stage accounts of affective processing (LeDoux, 1996; Pessoa, 2005). On this view, the initial encoding of emotional expressions is relatively robust and automatic (Dimberg et al., 2000; Whalen et al., 1998), whereas the central executive functions as a regulatory gate that determines whether sensorimotor mimicry is amplified or suppressed during goal-directed behaviour. The lack of an emotion-specific effect of visuospatial load suggests that centrally presented happy faces access early perceptual processing efficiently (Öhman et al., 2001; Fox et al., 2000), whereas the selective effect of executive load indicates that limitations at the regulatory stage alter the magnitude of motor expression (de Fockert et al., 2001; Tavares et al., 2016). This account preserves the broader claim that mimicry is resource-dependent while specifying executive control as the more critical bottleneck for its behavioural expression (Wróbel & Imbir, 2019; Wang & Hamilton, 2012; Engle, 2002; Baddeley, 2012). Conceptually, this account parallels two-stage models of emotion regulation and empathy, which distinguish between bottom-up affective activation and subsequent top-down modulation (Gross, 1998; Ochsner & Gross, 2005; Singer & Lamm, 2009).

Importantly, these findings do not contradict evidence that emotional mimicry can be initiated rapidly and automatically (Chartrand & Bargh, 1999; Hatfield et al., 1993; Dimberg et al., 2000; Lundqvist & Dimberg, 1995). Rather, they suggest

that automatic affective activation and the overt expression of mimicry should be distinguished: the former may arise with minimal intent or awareness (Dimberg & Thunberg, 1998; Niedenthal, 2007; Whalen et al., 1998; LeDoux, 1996), whereas the latter appears to remain sensitive to top-down executive control (Wróbel & Imbir, 2019; Wang & Hamilton, 2012; Etkin et al., 2015; Ochsner & Gross, 2005). In this sense, the current study's results support a sequential two-stage account rather than a strict automatic-versus-controlled dichotomy (Bargh, 1994; Moors & De Houwer, 2006; Strack & Deutsch, 2004; Smith & DeCoster, 2000), helping bridge early perception-action models (Prinz, 1997) with newer accounts that emphasize social context and cognitive regulation (Wang & Hamilton, 2012; Fischer & Hess, 2017; Hess & Fischer, 2013).

Despite theoretical implications, several methodological constraints must be considered when interpreting the present findings. Although Experiment 2 suggested a significant Load × Emotion interaction, the effect size was moderate, and temporal cluster analyses did not identify a specific time window after correction for multiple comparisons, so the evidence for executive modulation should be considered preliminary. In Experiment 1, the high visuospatial load substantially reduced working memory accuracy (see Appendix A), suggesting that the task may have approached participants' cognitive capacity limits, which could have obscured emotion-specific effects. In addition, because faces were presented centrally and clearly, the paradigm may not have created enough direct perceptual competition to disrupt early face processing, limiting generalization to more visually demanding conditions. Generalizability is also constrained by the use of female-only samples. Finally, only happy expressions and zygomaticus major activity were examined, so it remains unclear whether similar effects would emerge for negative expressions, particularly given that corrugator activity is also sensitive to cognitive load.

Conclusion

In sum, the findings suggest that emotional mimicry is an adaptable social behavior shaped by cognitive constraints and motivational goals (Hess & Fischer, 2013, 2014; Wang & Hamilton, 2012; Fischer & Hess, 2017). Specifically, taxing the central executive may amplify mimicry, whereas taxing the visuospatial sketchpad does not appear to selectively attenuate it, pointing to a refined resource-dependent account in which overt mimicry reflects a balance between rapid affective activation and top-down executive regulation (Etkin et al., 2015; Wróbel & Imbir, 2019; Niedenthal, 2007; Gross, 1998; Ochsner & Gross, 2005).

Declarations

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Appendix A: Per-Participant Accuracy Across All Conditions (Experiment 1)

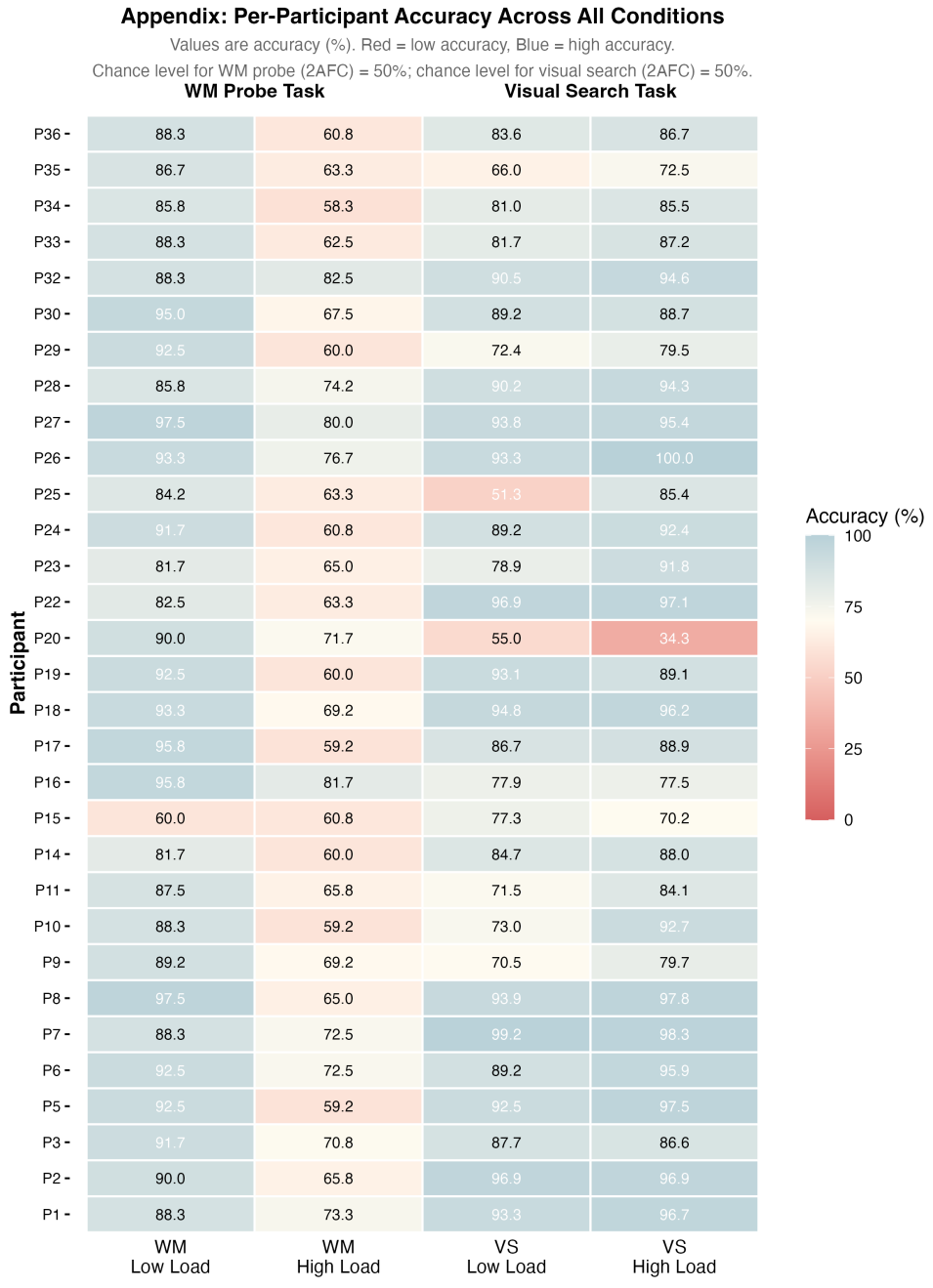


Fig. 9 Per-participant accuracy (%) across all conditions in Experiment 1, displayed as a colour-coded heatmap. Each row represents an individual participant. The left panel displays working memory (WM) probe task accuracy and the right panel displays visual search (VS) task accuracy, each split by low-load and high-load conditions. Chance level for both tasks is 50%

Appendix B: Visual Search Task Performance by Load Condition (Experiment 1)

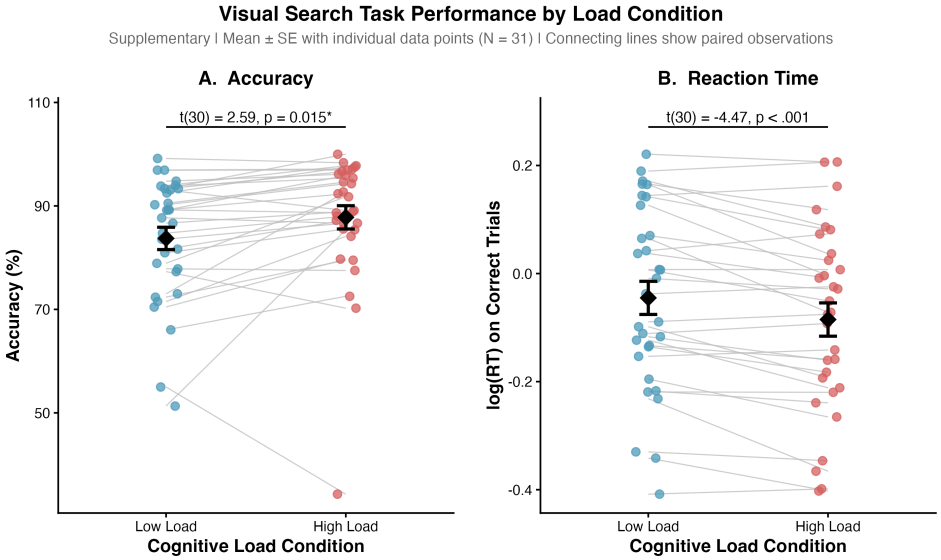


Fig. 10 Visual search task performance across low-load and high-load conditions in Experiment 1 ($N = 31$). Panel A shows accuracy (%) and Panel B shows log-transformed reaction times on correct trials

Appendix C: Condition Means Across Time Bins (ZM Muscle) - Experiment 1

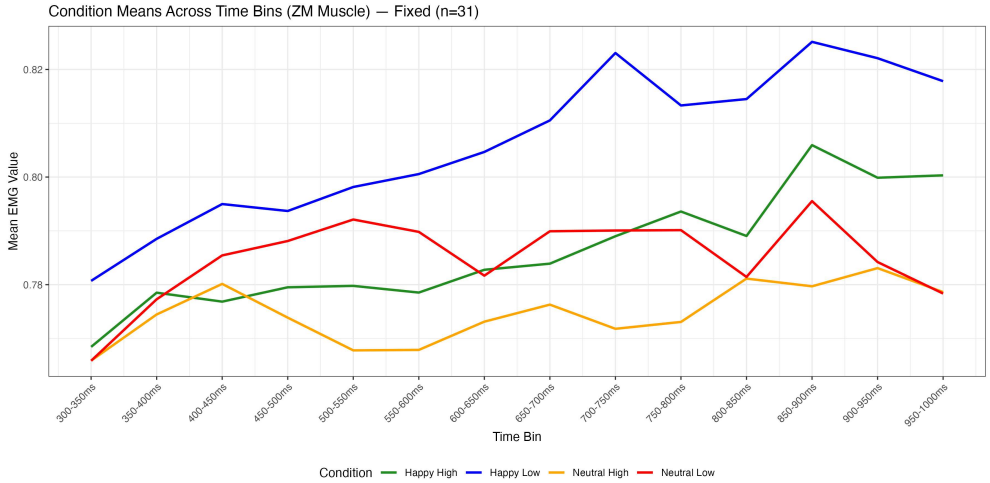


Fig. 11 Mean zygomaticus major (ZM) amplitude (MAV of z-scores) across fourteen 50ms time windows spanning the 300-1000ms post-stimulus period for all four conditions in Experiment 1

Appendix D: Per-Participant Accuracy Across All Conditions (Experiment 2)

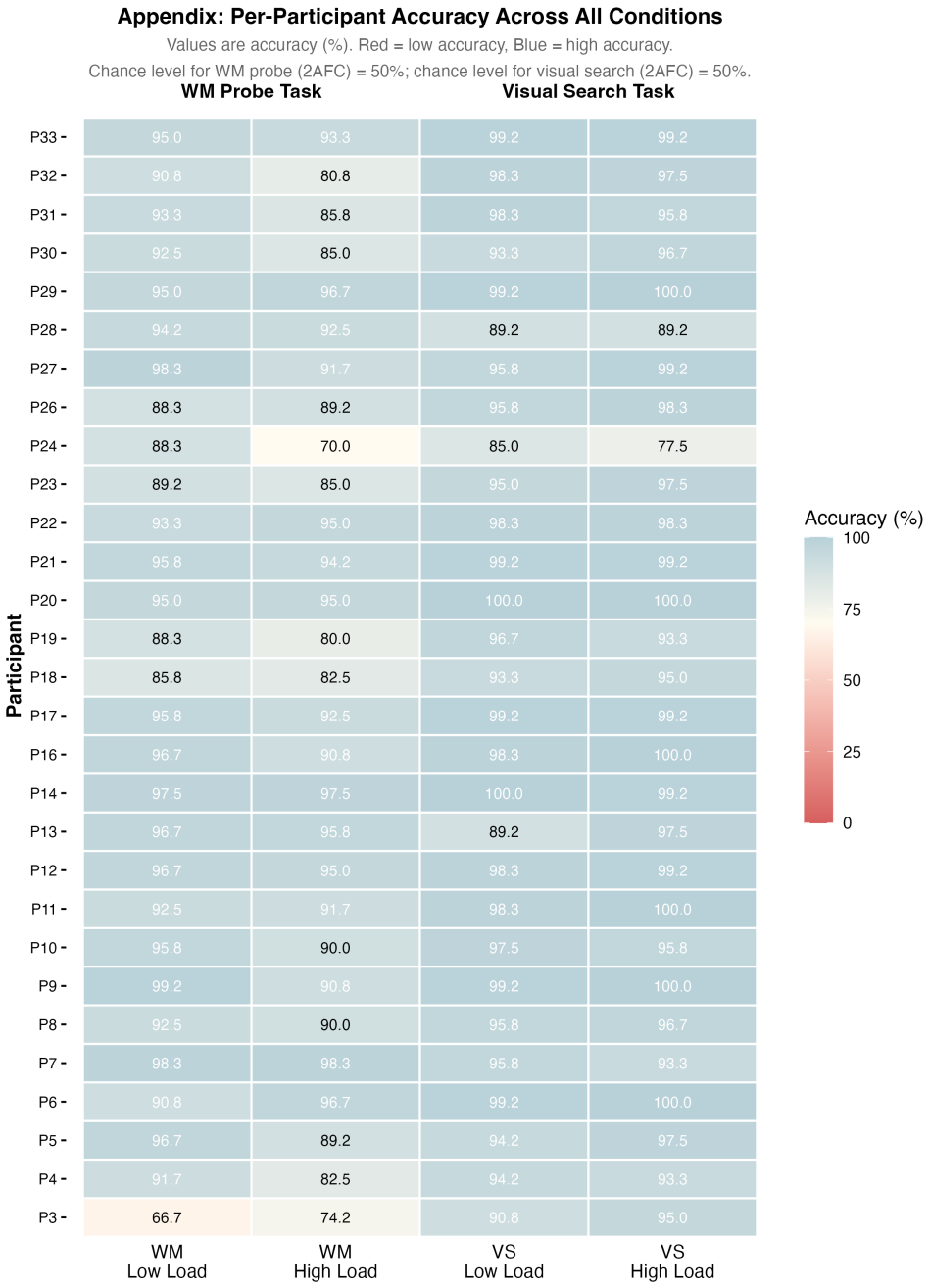


Fig. 12 Per-participant accuracy (%) across all conditions in Experiment 2, displayed as a colour-coded heatmap

Appendix E: Visual Search Task Performance by Load Condition (Experiment 2)

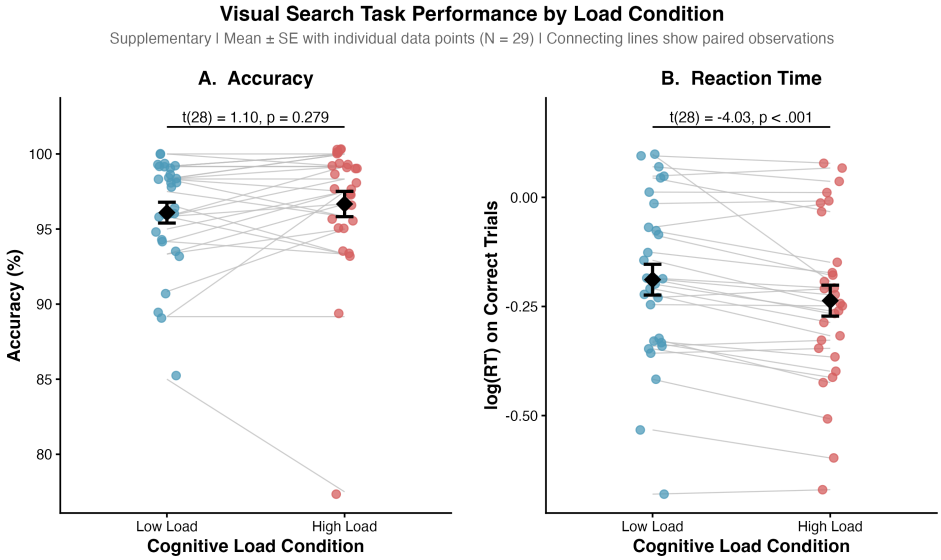


Fig. 13 Visual search task performance across low-load and high-load conditions in Experiment 2 ($N = 29$)

Appendix F: Condition Means Across Time Bins (ZM Muscle) - Experiment 2

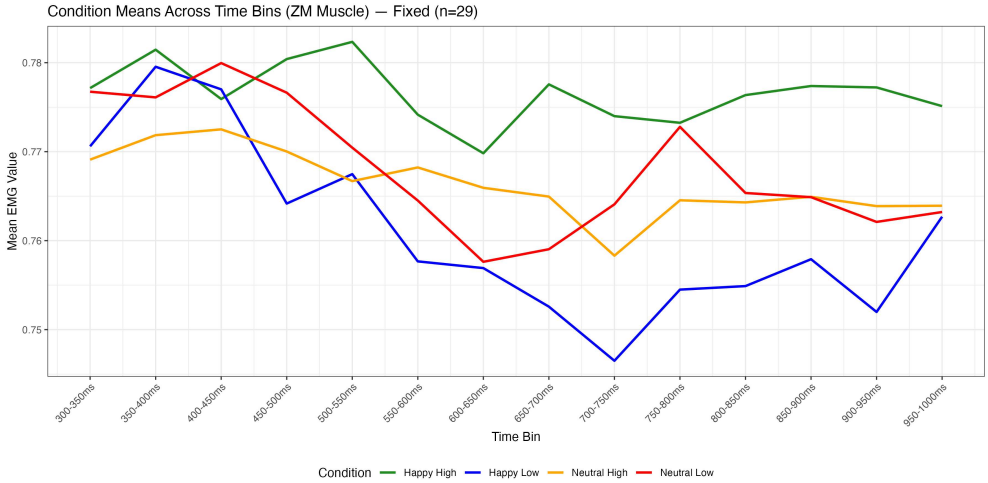


Fig. 14 Mean zygomaticus major (ZM) amplitude (MAV of z-scores) across fourteen 50ms time windows spanning the 300-1000ms post-stimulus period for all four conditions in Experiment 2