Temporal Dilation for Emotionally Salient Stimuli in Peri-hand Space

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Abstract

Emotion timing literature has consistently shown temporal dilation for emotionally salient stimuli compared to neutral stimuli. Such stimuli have also shown preferential processing near the graspable space of the hands, known as peri-hand space (PHS). However, none of the studies have systematically examined the interplay of emotion, time perception, and peri-hand space in a unified framework. Therefore, the present study investigated the temporal factors underlying the processing of emotionally salient stimuli in PHS. Participants completed the temporal bisection task in Near-hand and Far-hand conditions. The stimuli were high-arousal emotional and low-arousal neutral images. Results showed temporal dilation for highly arousing emotional stimuli compared to low-arousal neutral stimuli in PHS, perhaps to facilitate in-depth cognitive evaluation of emotional salience. No such temporal processing differences between emotional and neutral stimuli were obtained in the far-hand condition. Temporal dilation is primarily attributed to early anticipatory mechanisms associated with PHS.

Keywords: Time Perception; Emotion; Peri-hand Space; Anticipatory mechanism

Introduction

The efficient perception of both positive and negative emotionally salient objects is fundamental to adapting to the surrounding environment and crucial for our survival. For instance, seeing a smiling face can help reduce social anxiety and increase the likelihood of social interaction. Similarly, perceiving threatening stimuli- snake, barking dog, etc. enables us to immediately prepare for defensive actions. Several studies have shown that emotionally salient visual stimuli (de Haan et al., 2016; Ellena et al., 2021; Ruggiero et al., 2017) and auditory stimuli (Bahadori & Cesari, 2021; Ferri et al., 2015; Taffou & Viaud-Delmon, 2014) are prioritized in the immediate space surrounding the body, known as peri-personal space (PPS). Processing of such stimuli has also shown facilitation near the graspable palm region of the hands, known as the peri-hand space (PHS; de Haan et al., 2016; Du et al., 2017). For instance, Du et al. (2017) investigated the processing of emotionally salient stimuli in peri-hand space compared to far-hand space. Participants completed a pictorial Emotional Stroop Task, in which they were presented with an emotional or neutral picture surrounded by a red or blue border. Participants needed to distinguish the border color while ignoring the picture's contents. Results showed longer reaction times to unpleasant emotional pictures than to neutral pictures, demonstrating the Emotional Stroop effect. Importantly, longer RT was shown for unpleasant emotional pictures in peri-hand space relative to the far-hand space, suggesting an enhanced Emotional Stroop effect in PHS. No such RT differences in hand conditions were observed for positive or neutral pictures. ERP results showed a larger Late Positive Potential amplitude for unpleasant emotional pictures compared to neutral pictures in PHS. They concluded that hand proximity plays a crucial role in assessing potentially threatening stimuli.

Another such study by de Haan et al. (2016) investigated the impact of approaching a threatening stimulus on visuo-tactile processing in PHS. In their study, participants put their right hand on the flat, horizontal monitor and were shown an animation of a crawling spider (emotional) or a flying butterfly (neutral), which moved towards or away from the participant's hand. Participants completed a 'tactile detection task' in which they had to detect the tactile stimulus presented to their right hand at different time points during the animation, and they responded by pressing the foot pedal. Results showed steeper slopes for 'approaching' stimuli compared to 'receding stimuli', suggesting that the distance between the observer's hand and the visual stimulus played a crucial role in tactile processing for approaching stimuli. Notably, steeper slopes were observed when the approaching stimuli were perceived as 'threatening' than when they were perceived as 'neutral'. In case of stimuli receding from the stimulated hand, there was no difference between emotional and neutral stimuli. The study highlights the prioritization of emotional stimuli over neutral stimuli in visuo-tactile processing in PHS.

Previous literature has also investigated temporal processing differences between emotional and neutral stimuli. Typically, researchers in the time perception domain who have explored temporal processing for emotional stimuli focus on – Arousal (Angrilli et al., 1997; Gil et al., 2007; Mella et al., 2011; Noulhiane et al., 2007; Smith et al.,

In G. Boleda, I. Dautriche, M. Maldonado, C. Saldana and T. Torrent (Eds.), *Proceedings of the 48th Annual Conference of the Cognitive Science Society*

2011; Zhou et al., 2021), Valence (Droit-Volet et al., 2004, 2016; Eberhardt et al., 2020; Grommet et al., 2011; Lui et al., 2011) and Motivation (Gable et al., 2016, 2022; Gable & Poole, 2012; Gupta, 2022; L. Zhang et al., 2024) dimensions of emotional stimuli. Arousal refers to the extent of the physiological activation, such as skin conductance or heart rate, varying from calm to the excited state (Bradley et al., 2001; Lang et al., 1998). Valence is defined as the extent to which an individual feels an emotional stimulus as pleasant or unpleasant (Bradley et al., 2001). It has three levels-positive, negative, and neutral. Lastly, motivation is defined as the tendency to 'approach' or 'avoid' an emotional stimulus, and its intensity varies from low to high. In the current study, we will emphasize well-established valence and arousal dimensions rather than the motivation dimension, since most emotional stimulus databases classify stimulus properties on the basis of valence and arousal. Another reason for excluding motivation is the findings from a recent study by Campbell et al. (2021), which directly investigated the relationship between motivational intensity and valence. The results showed that motivational intensity is highly correlated with valence, thus challenging the distinct nature of these two emotional dimensions and suggesting that, unlike valence and arousal, the motivational intensity dimension alone is not the core emotional stimulus property. In terms of types of emotional stimuli, studies have looked at words (Johnson & MacKay, 2019; Tipples, 2010), facial expressions (Bar-Haim et al., 2010; Fayolle & Droit-Volet, 2014; Li & Yuen, 2015; Tipples, 2011; S. Zhang et al., 2014), images (Gable et al., 2016; Grondin et al., 2014; Tian et al., 2018; Tipples, 2019)and videos (Droit-Volet et al., 2011; Özgör et al., 2018; Wöllner et al., 2018) taken from standardized emotional databases like International Affective Pictures System (IAPS; Lang et al., 1999, 2005), International Affective Digitized Sounds system (IADS; Bradley & Lang, 1999), etc. in visual (Droit-Volet et al., 2004; Micillo et al., 2024; Séguin, 2013) as well as auditory modality (Droit-Volet et al., 2010; Noulhiane et al., 2007; Wackermann et al., 2014).

A vast amount of literature has shown temporal dilation for 'high-arousal' emotional stimuli relative to neutral stimuli (Cui et al., 2023; Droit-Volet et al., 2004, 2016; Grommet et al., 2011; Jones et al., 2017; Lake et al., 2016; Smith et al., 2011; Thayer & Schiff, 1975). For instance, Droit-Volet et al. (2004) studied the temporal judgements for high arousal emotional facial expressions- anger, happiness, and sadness relative to the neutral stimuli. In their study, participants performed a temporal bisection task using short (400ms) and long (1600ms) anchor durations. The results showed temporal dilation for all three facial expressions relative to the neutral stimuli. Another study by Grommet et al. (2011) investigated temporal judgement for high-arousal fear-related stimuli relative to neutral stimuli using the temporal bisection paradigm across short (250–1000ms) and long (400–1600ms) duration ranges. The results showed temporal dilation to fearful stimuli relative to neutral stimuli across short and long duration ranges.

Such studies, in which arousal levels are manipulated, explain emotional effects on time perception using the Pacemaker-Accumulator (PA) model of time perception (Gibbon et al., 1984; Lake et al., 2016; Treisman, 1963; Van Rijn et al., 2014). Such models posit that making temporal judgements relies primarily on three stages: clock (pacemaker, attentional gate, switch, and accumulator components), memory (working memory and long-term memory components), and decision making. All these models assume that any manipulation of arousal level will be reflected in changes in the pacemaker rate, such that an increase or decrease in arousal will increase or decrease the pacemaker rate, respectively. For instance, if the arousal level is high, the pacemaker component will emit a greater number of pulses, which are then accumulated by the accumulator via the switch during the timing of a specific event. For the current timed event, the greater number of pulses is then subsequently stored in the working memory. Further, a comparison is made between the number of pulses stored in working memory and the number of pulses previously stored in long-term memory. Since the number of pulses stored in the working memory is greater than long-term memory, it will lead to the temporal dilation of the perceived interval. Therefore, in the time perception literature, studies have shown that increased arousal levels increase the pacemaker speed, leading to temporal dilation of the perceived interval.

Along with arousal-based explanation, researchers in the emotional timing domain have also provided attentional explanation of the effects of emotion on time perception. In the emotion timing literature, attention is conceptualized as the allocation of attentional resources to timing processes (e.g., emotion) or to non-timing processes, and is mediated by an open or closed state of the attentional gate and/or switch component that connects the pacemaker to the accumulator. Pacemaker-Accumulator models also make assumptions about attention, assuming that, under normal conditions, full attentional resources are dedicated to temporal processes. In this condition, the switch can either be closed early in time or open late, thereby allowing a greater flow of pulses from the pacemaker to the accumulator and subsequently leading to temporal dilation. However, if attentional resources are distracted from the timing processes or distributed between timing and non-timing processes, it will cause the switch to remain open or 'flicker' between open and closed states, respectively (Droit-Volet et al., 2007; Lui et al., 2011; Lustig & Meck, 2011; Penney et al., 1998), thereby leading to temporal contraction or underestimation of the perceived duration. In sum, the attentional mechanism predicts that emotional stimuli capture attention easily and distracts from processing temporal information, thereby leading to temporal underestimation.

Taken together, the literature that has investigated emotional effects on time perception has shown well-established temporal dilation effects for emotionally arousing stimuli relative to neutral stimuli. In parallel, studies in the peri-hand space literature have also shown preferential processing of emotional stimuli in PHS. However, such extensive literature has largely been investigated in isolation. To the best of our knowledge, none of the studies have systematically examined the interplay of emotion, time perception, and peri-hand space in a single framework. Such a unified approach is critical for understanding the temporal encoding of emotionally relevant stimuli, particularly in the peri-hand space, where the likelihood of interaction with such stimuli is high. To address this gap in the literature, the present study investigated the temporal factors underlying the processing of emotionally salient stimuli in peri-hand space. We hypothesize a general temporal dilation effect for high-arousal emotional stimuli relative to low-arousal neutral stimuli. We also hypothesize that the temporal dilation effect will be specific to peri-hand space and will not extend beyond this space.

Methods

Participants

A priori, G*Power analysis was conducted with an estimate of $\eta p^2 = 0.30$ (Qi et al., 2019; Thomas & Sunny, 2017; Yin et al., 2021) to detect an effect of the experimental condition, at a power of 0.80 ($\alpha = 0.05$). Thirty-four undergraduate students (28 males, 6 females), recruited from the Indian Institute of Technology Roorkee, aged 18-25 years (M = 19.42, SD = 2.13), participated in the experiment. The study was conducted after taking ethical approval.

Apparatus and Materials

The experimental stimuli were shown on a 24-inch LED monitor (1920 x 1080 resolution; 100 Hz refresh rate). Experimental codes were written in MATLAB, and stimuli were displayed on screen through Psychtoolbox. The stimuli consisted of a vertically-oriented filled gray oval (6.5cm height x 5.5cm width) in the training phase and 210 color photographs (20cm height x 28cm width) taken from International Affective Picture Systems (IAPS; Lang et al., 2005) in the experimental phase of the experiment, subtending a visual angle of 6.02° x 5.20° and 18.92° x 26.26°, respectively, at a distance of 60 cm (approx.) from the monitor. All the experimental stimuli were presented on a black background. The stimulus set in the experimental phase consisted of equal numbers of highly arousing negative images (70), highly arousing positive images (70), and neutral images (70).). This classification was based on the valence and arousal ratings provided with the IAPS image database (see Table 1).

Table 1: IAPS Valence and Arousal Ratings for the Three Stimulus Types

Stimulus type	Mean Valence Rating	Mean Arousal Rating
High-Arousal Negative	2.233	6.758
High-Arousal Positive	6.798	6.513
Low-Arousal Neutral	4.991	2.693

Procedure and Design

Participants completed a Temporal Bisection Task (Allan & Gibbon, 1991), which consists of a Training phase and an Experimental phase. Before the training phase, participants were shown a gray oval stimulus for short (200ms) and long (800ms) standard durations. Participants had to just see and learn the oval durations without making any explicit response.

In the training phase, participants had to respond whether the presented oval was “SHORT or LONG?” by clicking the mouse attached to the ‘right’ side of the screen; left- and right-clicks for short and long ovals, respectively (counterbalanced across participants). Feedback for correct and incorrect responses was provided. The training phase consists of 20 trials.

The trial structure (Fig. 1) in the experimental phase was similar to the training phase except that instead of ovals, the colored IAPS images were presented randomly for either of the seven durations- ‘200ms, 300ms, 400ms, 500ms, 600ms, 700ms, or 800ms’, and the participants had to respond whether the presented image was “Closer to Shorter or Longer duration?”. No feedback was provided in this phase. Participants were familiarized with the experimental phase before it began.

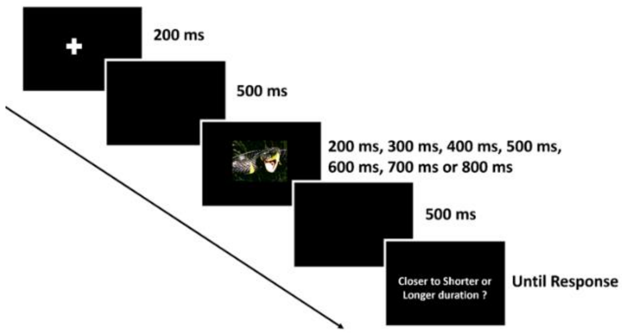

Figure 1: Trial structure of the Experimental phase.

The temporal judgements in the experimental phase were made in two different hand conditions. The first condition required participants to place their left and right palms on the left and right sides of the monitor, respectively, so that the stimuli appeared within the peri-hand space; this condition is therefore referred to as the 'Near-hand condition' (Fig. 2a).

In the second condition, participants placed both of their hands on the cardboards placed on their laps, thus making the stimuli appear far away from peri-hand space, and this condition is referred to as the 'Far-hand condition'(Fig. 2b). In the Near-hand and Far-hand conditions, the participant responded by clicking the mouse attached to the 'right' side of the screen and the cardboard, respectively. In both conditions, the mouse attached to the left side of the screen, and the cardboard was not used for responses. The order of hand postures and mouse button-click responses was counterbalanced across participants. The experimental setup is similar to the Maurya et al. (2024) study.

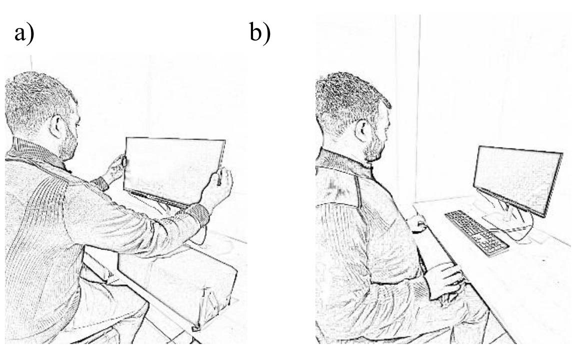

Figure 2: Near-hand condition (2a) and Far-hand condition (2b). Reproduced from Maurya et al. (2024) study.

The experimental phase was performed in each of the Near-hand & Far-hand conditions, yielding 210 trials (each of the 7 durations was presented 10 times, making 70 trials for each of the three image categories) in each condition and 420 trials across the experiment. The present experiment employs a fully factorial design, with Arousal (high-arousal and low-arousal images) and Duration (200ms, 300ms, 400ms, 500ms, 600ms, 700ms, and 800ms) as independent variables, and temporal judgments of the stimuli (reflected by PSE) as dependent variables.

Data Analysis

The 'mean proportion of the long responses' for each of the three categories of images was first sorted into the 'Near-hand' and 'Far-hand' conditions. Further, the mean proportion of the long responses for the high arousal positive and high arousal negative images was combined ('High-Arousal'). The mean proportion of the long responses for high-arousal and low-arousal (neutral images) was fitted with a logistic function in the Psignifit toolbox (Wichmann & Hill, 2001) for MATLAB. Point of Subjective Equality (PSE) was derived from a psychometric function fitted on the mean proportion of long responses given for the actual duration, for both high-arousal and low-arousal stimuli in the near-hand and far-hand conditions. A comparison was made between the psychometric function for the 'High-Arousal' and 'Low-Arousal' visual stimuli, separately in Near-hand and Far-hand conditions.

Results

A Repeated Measures ANOVA was performed on the mean proportion of long responses for the Near-hand condition, with Arousal (High & Low) and Durations (200ms, 300ms, 400ms, 500ms, 600ms, 700ms or 800ms) as the within-subject factors. Greenhouse-Geisser correction was applied wherever the assumption of sphericity was violated. A significant main effect was obtained for Arousal [$F(1,33) = 11.47$, $p = .002$, $\eta p^2 = .25$]. The main effect of Durations was also found to be significant, [$F(2.50, 82.49) = 527.87$, $p < .001$, $\eta p^2 = .94$]. Additionally, a significant interaction was obtained between Arousal and Duration [$F(4.11, 135.69) = 5.32$, $p < .001$, $\eta p^2 = .13$], suggesting differences in the mean proportion of long responses for high and low arousal stimuli across durations.

To look at the results in greater detail, a paired sample t-test run on PSE revealed significantly lower PSE for high arousal stimuli (M = 486.21, SD = 55.41) relative to the low arousal stimuli (M = 508.66, SD = 60.11), [$t(33) = -3.53$, $p = 0.001$], indicating a leftward shift in the psychophysical curve (Fig. 3), suggesting temporal dilation for high arousal stimuli presented in peri-hand space. No significant difference in PSE was obtained between high arousal negative (M = 483.82, SD = 58.89) and high arousal positive (M = 488.59, SD = 59.40) stimuli in the Near-hand condition, [$t(33) = -.673$, $p = .506$].

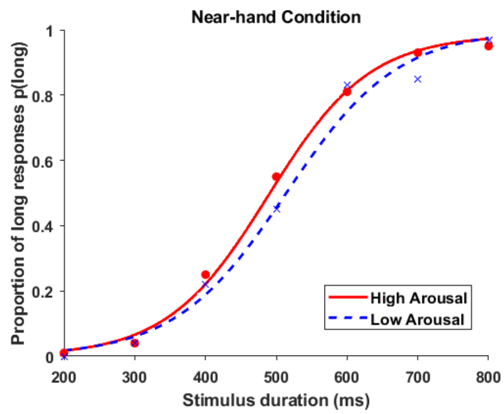

Figure 3: Psychophysical curve for the High-Arousal and the Low-Arousal stimuli in the 'Near-hand condition'.

Another Repeated Measures ANOVA was performed on the mean proportion of long responses for the Far-hand condition, with similar within-subject factors. Greenhouse-Geisser correction was applied wherever the assumption of sphericity was violated. The results (Fig. 4) showed a non-significant main effect of Arousal [$F(1, 33) = 3.15$, $p = .08$, $\eta p^2 = .087$]. No significant difference in PSE was obtained between high arousal negative ($M = 488.44$, $SD = 66.12$) and high arousal positive ($M = 483.96$, $SD = 63.51$) stimuli in the Far-hand condition, [$t (33) = .482$, $p = .633$]. However, the main effect of Durations was found to be significant, [$F(2.92, 96.64) = 537.09$, $p < .001$, $\eta p^2 = .94$]. The interaction between Arousal and Duration [$F(4,15, 137.22) = .607$, $p = .66$, $\eta p^2 = .018$] was non-significant.

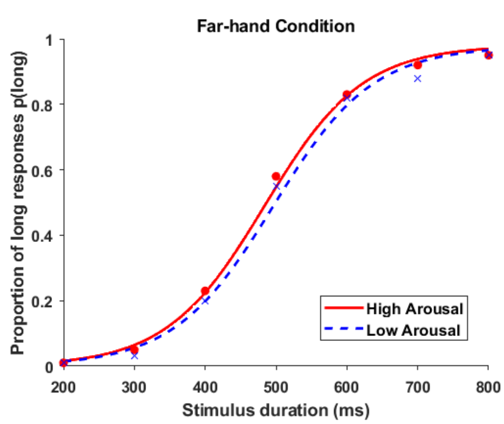

Figure 4: Psychophysical curve for the High-Arousal and the Low-Arousal stimuli in the 'Far-hand condition'.

Discussion

The present study investigated the temporal mechanisms underlying the processing of emotionally salient objects in peri-hand space. Results from the experiment were consistent with our hypothesis and showed temporal dilation for highly arousing emotional stimuli relative to low-arousal neutral stimuli in the near-hand condition, suggesting that processing of high-arousal emotional stimuli lasts longer than their actual duration in PHS. No such temporal processing differences between emotional and neutral stimuli were observed in far-hand space, suggesting that the emotional salience of the objects is not prioritized in far-hand space. Overall, the experimental findings suggest that the subjective slowing down of time for processing emotional stimuli is not uniform across space and is specifically modulated by the space near the graspable palm regions of the hands. Temporal dilation is primarily attributed to early 'anticipatory mechanisms' associated with PHS.

Such an early anticipatory mechanism associated with peri-hand space makes relatively more time available to the motor system, i.e., motor resources are activated earlier, which in turn prepares the body to receive emotional object-related information sooner, thus enabling planning for an immediate action. High-arousing emotional objects typically signify either a critical threat (negative stimuli) or a significant reward (positive stimuli); thus, our brain "temporally" prioritizes emotional events over neutral events to better adapt to threatening environmental situations or to maximize high-value opportunities. Interestingly, this extra availability of subjective time to process emotionally salient information is specifically tied to the peri-hand space. This finding seems ecologically valid: our brain continuously assesses the 'ecological relevance' of emotionally salient stimuli, since such arousing stimuli need to be cognitively and behaviorally prioritized in time, particularly when they are in spatial proximity to the hands, where the likelihood of interaction with the objects is high. Notably, the same emotionally arousing stimuli were not temporally prioritized in the far-hand space, due to the less possibility of interaction with objects placed away from the hands, i.e., the far-hand space lies outside of the immediate action zone, and therefore no such 'temporal urgency' is required for processing emotionally salient stimuli.

Our experimental findings align with the emotion timing literature, which shows temporal dilation of emotional stimuli relative to neutral stimuli (Cui et al., 2023; Droit-Volet et al., 2004; Grommet et al., 2011; Smith et al., 2011). However, such studies have largely ignored the role of near-hand and far-hand space in the subjective distortion of time and have implicitly assumed that the temporal dilation effect is generalized across space. Our current finding of temporal dilation specific to peri-hand space, but not in far-hand space, directly challenges this assumption and possibly suggests dissociated timing mechanisms in the brain for processing emotionally salient information in peri-hand space and far-hand space. Specifically, since peri-hand space is an 'action-relevant space' and far-hand space is a 'perception-oriented space' (Gozli et al., 2012; Kelly & Brockmole, 2014; Taylor et al., 2015), it possibly suggests the engagement of 'motor-timing mechanism' and 'perceptual-timing mechanism', respectively.

In addition, the temporal dilation effect for emotionally salient stimuli is primarily interpreted in terms of the 'Arousal' hypothesis of pacemaker-accumulator models of time perception (Gibbon et al., 1984; Treisman, 1963; Zakay & Block, 1995). Such models assume that increased arousal levels increase the pacemaker's speed, thereby leading to temporal dilation. Therefore, our current findings of temporal dilation for 'high-arousal' emotional stimuli relative to the low-arousal neutral stimuli are consistent with an 'Arousal' based explanation of emotional effects on time perception.

Our findings can also be explained within the framework of the Striatal Beat Frequency (SBF) model, which is a neurobiological model of time perception (Matell & Meck, 2000, 2004). The SBF model consists of three components: Cortical oscillators, Medium spiny neurons (MSNs), and Dopaminergic modulation. The model predicts that higher dopamine levels increase the firing rates of different cortical oscillators, which, in turn, result in earlier coincidence detection by the MSNs and thereby lead to temporal dilation, and vice versa. Previous studies have shown the release of dopamine during the processing of emotionally salient stimuli (Frick et al., 2022; Jo et al., 2018; Schultz, 1998; Takikawa et al., 2004) as well as in motor-related cortical as well as subcortical brain regions (Cole et al., 2013; Cousineau et al., 2022; Tritsch & Sabatini, 2012). Such brain regions, forming a cortico-striatal loop, have shown activations for objects in peri-hand space, thus suggesting the indirect link between dopamine and peri-hand space. In the context of the current experiment, high-arousing emotional stimuli in PHS increase emotional arousal and action relevance, which, in turn, activate the same cortico-striatal circuitry, leading to stronger dopaminergic modulation and, consequently, temporal dilation of emotional stimuli in PHS. Conversely, in far-hand space, only emotionally salient stimuli modulate dopamine levels, not action relevance. Consequently, the dopaminergic modulation is not strong enough to produce a temporal dilation for emotional stimuli in far-hand space.

Our results are also consistent with the studies that have shown prioritization of emotional stimuli in PHS (de Haan et al., 2016; Du et al., 2017; Taffou & Viaud-Delmon, 2014). For instance, although Du et al., (2017) study was not related to time perception, both behavioral and electrophysiological findings showed enhanced processing of high-arousal emotional stimuli relative to neutral stimuli in PHS. Other studies have shown an expansion of peri-hand boundaries when approaching unpleasant stimuli, suggesting preferential processing of emotional stimuli in PHS (Taffou & Viaud-Delmon, 2014). Studies have also shown that processing of emotional stimuli is facilitated via the magnocellular pathway (Bocanegra & Zeelenberg, 2009, 2011), which is an action-oriented pathway and shows greater contribution to process stimuli in PHS. Therefore, such facilitation of emotionally salient stimuli in PHS may involve interacting with objects near the hands or avoiding threatening situations.

Our current finding also challenges the viewpoint that emotional temporal distortions are 'stimulus-driven' and support temporal distortions as an embodied phenomenon (Chambon et al., 2008; Droit-Volet et al., 2013; Effron et al., 2006; Jia et al., 2015; Wittmann & Van Wassenhove, 2009). If the emotional saliency of the stimuli is sufficient enough for distorting subjective time, then the temporal dilation effect should be observed in both the near-hand and far-hand space. Given the current findings, this is not the case. Thus, the present finding indicates that emotional arousal of the stimuli alone is not sufficient to dilate subjective time; rather, temporal dilation depends critically on spatial proximity to the hands. This implies the role of bodily space in shaping our time.

It is noteworthy to mention that our findings do not arise due to the vision of hands in the near-hand condition, but rather are the result of hand-proximity. Neurophysiological studies have shown that the mere presence of objects in PHS automatically activates the bimodal neurons (respond to visual as well as tactile stimulations) present in cortical and subcortical brain regions responsible for performing voluntary actions (Graziano & Cooke, 2006; Rizzolatti et al., 1997). Other studies have showed that hand proximity effects persisted when the participant's hands were occluded while performing the task in the hand-proximal condition (Abrams et al., 2008) and even when they only imagined their hands near the presented stimuli (Davoli & Abrams, 2009). Such studies shows that brain takes proprioceptive information into account that leads to hand-proximity effect.

Conclusion

In sum, our current findings suggest temporal dilation for the emotionally salient objects in peri-hand space and not the space beyond, i.e., slowed down perception of 'high-arousal' stimuli, perhaps to give temporal allowance for in-depth evaluation of emotional salience for better planning and execution of defensive actions, as well as to maximize reward opportunities. Our findings also suggest that emotional salience has spatial characteristics: arousing emotional stimuli are prioritized only in PHS, and not in the far-hand space. Temporal dilation is most likely driven by the anticipatory mechanism associated with PHS.

Acknowledgments

AI tools were sparingly used to improve language clarity and flow, and to create a summary of a few studies. However, such summaries were created for my own understanding of the studies and are not incorporated into the current paper. The current research was supported by the University Grants Commission of India through Senior Research Fellowship to Ankit Maurya.

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