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Emotional modulation of attention affects time perception: Evidence from event-related potentials

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ABSTRACT

Emotional effects on human time perception are generally attributed to arousal speeding up or slowing down the internal clock. The aim of the present study is to investigate the less frequently considered role of attention as an alternative mediator of these effects with the help of event-related potentials (ERPs). Participants produced short intervals (0.9, 1.5, 2.7, and 3.3 s) while viewing high arousal images with pleasant and unpleasant contents in comparison to neutral images. Behavioral results revealed that durations were overproduced for the 0.9 s interval whereas, for 2.7 and 3.3 s intervals, underproduction was observed. The effect of affective valence was present for the shorter durations and decreased as the target intervals became longer. More specifically, the durations for unpleasant images were less overproduced in the 0.9 s intervals, and for the 1.5 s trials, durations for unpleasant images were slightly underproduced, compared to pleasant images, which were overproduced. The analysis of different ERP components suggests possible attention processes related to the timing of affective images in addition to changes in pacemaker speed. Early Posterior Negativity (EPN) was larger for positive than for negative images, indicating valence-specific differences in activation of early attention mechanisms. Within the early P1 and the Late Positive Potential (LPP) components, both pleasant and unpleasant stimuli exhibited equal affective modulation. Contingent Negative Variation (CNV) remained independent of both timing performance and affective modulation. This pattern suggests that both pleasant and unpleasant stimuli enhanced arousal and captured attention, but the latter effect was more pronounced for pleasant stimuli. The valence-specificity of affective attention revealed by ERPs combined with behavioral timing results suggests that attention processes indeed contribute to emotion-induced temporal distortions, especially for longer target intervals.

1. Introduction

Our sense of time can be altered by context, being particularly dependent on emotional states. The capacity to estimate time is assumed to rely on an internal clock-like mechanism (Buhusi & Meck, 2005; Gibbon, Church, & Meck, 1984; Treisman, 1963). This conceptual clock consists of a pacemaker transmitting pulses to an accumulator through a switch. Temporal decisions observed in laboratory timing tasks further require comparing the content of the accumulator with previously stored target durations in working memory. In principle, independent influences on any part of this clock-like mechanism – pacemaker, switch, accumulator, and memory – may generate distortions in subjective time. Affective temporal distortions are mostly explained by the effects of emotional arousal on an internal clock. However, theoretical arguments as well as empirical findings suggest that an interference between affective attention and a switch component of an internal clock-like mechanism may also be involved. The present study uses ERP components associated with emotional arousal, affective attention, and time perception to disentangle arousal and attention contributions to timing illusions.

One phenomenon capable of influencing time is emotion (for reviews see Droit-Volet & Gil, 2009; Droit-Volet & Meck, 2007; Wittmann & Paulus, 2008). As a general rule, durations of emotional stimuli tend to be judged as longer than neutral stimuli. This effect has been observed with emotional faces (Droit-Volet, Brunot, & Niedenthal, 2004; Gil & Droit-Volet, 2011; Lee, Seelam, & O'Brien, 2011) and images (Angrilli, Cherubini, Pavese, & Manfredini, 1997), as well as with emotional sounds (Noulhiane, Mella, Samson, Ragot, & Pouthas, 2007). Moreover, highly arousing negative stimuli (i.e., angry faces, negative sounds) are judged as significantly longer than low arousal stimuli of negative or positive valence (e.g., fearful, sad, and happy faces; positive sounds) (Noulhiane et al., 2007; Tipples, 2008). However, emotional lengthening of time is typically demonstrated for intervals shorter than 1 s and is rarely observed for durations longer than 2–3 s (e.g., Droit-Volet et al., 2004). Angrilli et al. (1997) even showed, in a temporal reproduction task, that the relative overestimation of time for 2 s intervals shifted

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to underestimation at longer intervals (4 and 6 s). Emotions, therefore, seem to have complex effects on time perception.

Emotional lengthening of subjective time can first of all be attributed to arousal, which is known to increase the rate at which pulses are emitted from the internal pacemaker. For instance, subjective time is modulated when arousal is directly manipulated by body temperature (Wearden & Penton-Voak, 1995) or drug administration (Maricq, Roberts, & Church, 1981). Therefore, increases in physiological arousal induced by emotional events (Cacioppo & Gardner, 1999) should similarly enhance the speed of the pacemaker. In fact, temperature effects on time may be mediated by the higher levels of emotional discomfort and arousal accompanying increased body temperature (Tamm et al., 2014).

Alternatively, shifts in timing performance can also be induced by attention processes. According to the internal-clock model, attention can influence sense of time by determining the fraction of pulses that reach the accumulator (Pouthas & Perbal, 2004; Zakay, 1998; Zakay & Block, 1996). Affective stimuli are known to be natural targets for selective attention — a phenomenon known as motivated attention (for a review, see Vuilleumier, 2005). Conceivably, emotional stimuli may therefore alter the switch component of the timing mechanism via their effects on attention. However, the direction of these effects seems to depend on whether affective stimuli are distractors or targets for the timing task (Schirmer, 2011). In the former case, given that selective attention is resource-limited, emotional stimuli may draw attention away from interval timing. This in turn leads to fewer temporal units being processed and consequently results in temporal underestimations (Penney, 2003; Zakay, 1998; Zakay & Block, 1996). When emotional stimuli are to be timed, however, the additional attention captured by emotional stimuli could facilitate the perceiving of the temporal aspects of those stimuli (e.g., carefully counting all the ticks), resulting in relative overestimation of durations (Schirmer, 2011).

Emotional effects on attention also provide some of the evidence that is not congruent with the arousal–pacemaker explanation of emotional time distortion (Droit-Volet & Gil, 2009). For example, Gable and Poole (2012) propose that the attentional capture caused by high approach motivation can explain why pleasant stimuli shorten time while equally arousing negative stimuli do not. Differences in emotional processing as a function of interval length also suggest the involvement of several separate timing mechanisms (Angrilli et al., 1997; Gil & Droit-Volet, 2011). Temporal distortions in emotional stimuli within shorter durations should reflect arousal-based effects and the activation of automatic processes, whereas timing of longer durations requires more cognitive resources, such as attention. In combination, the theoretical and empirical arguments suggest that the interplay between arousal and attention mechanisms may result in the affective modulation of time perception.

While arousal and attention could both conceivably underlie emotional influences on subjective time, their contributions are often difficult to disentangle at the behavior level. One potential solution is to search for the neural correlates of the different underlying processes, such as event-related potentials (ERP). To date, the quest to find the electrophysiological correlates of time perception has mostly concentrated on Contingent Negative Variation (CNV). CNV is a slow frontal ERP component occurring during the anticipation stage of a required action or relevant feedback (van Rijn, Kononowicz, Meck, Ng, & Penney, 2011) and it has also been related to timing performance in general (for reviews see Macar & Vidal, 2004, 2009; van Rijn et al., 2011) and emotional time modulations in particular (Eimer & Holmes, 2007; Gan, Wang, Zhang, Li, & Luo, 2009). However, the specific functional correlates of CNV in the context of timing remain unclear (cf. Macar & Vidal, 2009; van Rijn et al., 2011). According to one bold proposal, a gradually increasing CNV amplitude directly reflects the accumulation of pulses, probably in the Supplementary Motor Area (Macar & Vidal, 2009). This account can explain the correlations between CNV amplitudes and time production errors (Bendixen, Grimm, & Schröger, 2005; Macar & Vidal, 2002; Macar, Vidal, & Casini, 1999). However, failures to replicate such correlations as well as other findings contradict this idea (Kononowicz & van Rijn, 2011). Alternatively, CNV may simply reflect peripheral aspects of timing performance, such as motor preparation and decision processes (van Rijn et al., 2011). Understanding the relationship between timing and CNV thus requires further research. To this end, the present study investigates the sensitivities of CNV amplitudes to timing performance with and without emotional influences.

The usefulness of ERPs in timing research need not be confined to CNV dynamics. That is, ERPs may also reveal aspects of emotional arousal and attention experienced by participants during timing performance. In particular, emotional stimuli are known to enhance the amplitudes of several posterior components such as P1, Early Posterior Negativity (EPN), and Late Positive Potential (LPP) (Hajcak, MacNamara, & Olvet, 2010; Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp, Flaisch, Stockburger, & Junghöfer, 2006; Schupp et al., 2004). These components, particularly LPP, can first of all be used to obtain direct and fairly objective measures of the overall emotional arousal induced by certain stimuli in specific participants. This is an important advantage over those studies where arousal levels were only assumed from normative stimulus ratings or indirectly assessed from subjective self-ratings. Moreover, some affective ERP components can also be linked to more distinct underlying mechanisms. EPN and LPP have been associated with two consecutive stages of affective attention (Schupp et al., 2006; Uusberg et al., 2013). At the first and largely automatic stage, motivationally significant stimuli are selected for further prioritized processing, which occurs at the second stage. We thus assume that EPN can be considered a more selective measure of the extent to which affective stimuli automatically capture attention, compared to LPP, which reflects more controlled processes, as well as P1, which probably corresponds to pre-attentive perceptual encoding. This partial dissociation will be used to differentiate the contributions of attention and arousal phenomena on time perception. If EPN predicts behavior better than LPP, distortions should be attributed, at least partially, to attention-related mechanisms. Meanwhile, if LPP is a better match to performance data, the underlying mechanism is more likely to involve affective arousal.

2. Method

2.1. Participants

The sample consists of 62 university students (42 females) aged 19–51 years. All participants were healthy, had normal or corrected-to-normal vision, and spoke fluent Estonian. All participants provided informed consent and the study was approved by the Ethics Review Committee of Human Research at the University of Tartu, Estonia.

2.2. Stimuli

Images from the International Affective Picture System (IAPS) were selected based on published normative ratings (Lang, Bradley, & Cuthbert, 2005). Unpleasant and pleasant image sets were constructed with similarly high arousal ratings, accompanied by a minimally arousing neutral category. Separate positive stimuli were selected for males and females, as the latter are known to report less arousal as well as reduced valence in response to some erotic images. As a result, negative images depicting mutilated human bodies (IAPS images 3051, 3060, 3170; mean normative valence $M = 1.9$, $SD = 1.5$; arousal $M = 6.7$, $SD = 2.2$), neutral images of everyday objects (7000, 7004, 7009; valence $M = 5.0$, $SD = 0.8$; arousal $M = 2.5$, $SD = 1.8$) and positive images of opposite sex nudes or erotic couples (4645, 4676, 4677 for females; valence $M = 6.7$, $SD = 1.7$; arousal $M = 6.0$, $SD = 2.2$; and 4652, 4664, 4670 for males; valence $M = 7.9$, $SD = 1.1$; arousal $M = 7.4$, $SD = 1.7$) were used in the study. All images contained a few