

The Effects of Valence and Arousal on the Emotional Modulation of Time Perception: Evidence for Multiple Stages of Processing

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Previous research has demonstrated that both emotional valence and arousal can influence the subjective experience of time. The current research extends this work by (1) identifying how quickly this emotional modulation of time perception can occur and (2) examining whether valence and arousal have different effects at different stages of perception. These questions were addressed using a temporal bisection task. In each block of this task, participants are trained to distinguish between two different exposure durations. Participants are then shown stimuli presented at a number of durations that fall between the two learned times, and are asked to indicate whether the test stimulus was closer in duration to the shorter or longer learned item. In the current study, participants completed blocks of trials in which the durations were “Short” (100–300 ms) or “Long” (400–1600 ms). Stimuli consisted of neutral photographs as well as four categories of emotional images: high-arousal negative, high-arousal positive, low-arousal negative, and low-arousal positive. In Short blocks, arousing and nonarousing negative images were judged to have been shown for shorter durations than they actually were (i.e., the duration was underestimated); this effect occurred at durations as brief as 133 ms. In Long blocks, the display time for highly arousing negative items was overestimated, whereas durations were underestimated for highly arousing positive items and less arousing negative items. These data suggest that arousal and valence have different effects at different stages of perception, possibly due to the different neural structures involved at each stage of the emotional modulation of time perception.

Keywords: time perception, temporal bisection, valence, arousal, emotion, attention

Emotion alters the subjective experience of time (Campbell & Bryant, 2007; Droit-Volet & Meck, 2007; Tse, Intriligator, Rivest, & Cavanagh, 2004; Wittmann & van Wassenhove, 2009). Events that are perceived as enjoyable and engaging often lead to the experience of “time flying by.” In contrast, events that are emotionally distressing generally lead to the experience of “time dragging” or, in more extreme situations, “time standing still.” These effects have been demonstrated in several previous studies with both adults and children (Droit-Volet, Brunot, & Niedenthal, 2004; Droit-Volet & Rattat, 2007; Droit-Volet, Tourret, & Wearden, 2004; Droit-Volet & Wearden, 2002; Gil & Droit-Volet, 2011a, 2011b; Gil, Niedenthal, & Droit-Volet, 2007; Grommet et al., 2011) as well as in individuals with negative emotionality (Tipples, 2008, 2011) and depression (Gil & Droit-Volet, 2009). However, less is known about the time course of this “emotional modulation of time perception.” Event-related potential studies have demonstrated that emotion influences attention-related components of perception during the first 300 ms of encoding, but then influences a combination of attention- and memory-related com-

ponents after 300 ms (see Olofsson, Nordin, Sequeira, & Polich, 2008, for a review). Given that different neural mechanisms are processing the stimuli at brief (<300 ms) and longer (>300 ms) durations, it is possible that the influence of emotion on the subjective experience of time differs at brief and long durations as well. In order to test this hypothesis, the current research examined how different categories of emotional stimuli—varying on dimensions of valence and arousal—influence time judgments at short (100–300 ms) and longer (400–1600 ms) durations.

The ability of emotion to influence the subjective experience of time has most often been conceptualized using the scalar expectancy theory (Gibbon, 1977; Wearden & Penton-Voak, 1995; see Macar & Vidal, 2009 and Karmarkar & Buonomano, 2007, for descriptions of alternative models). According to this model, our internal clock consists of (1) a pacemaker, (2) a switch, and (3) an accumulator. The pacemaker is a constant biological rhythm; however, as people rarely consciously measure time, its activity goes largely unnoticed. The switch is controlled by attentional processes. When people are judging the duration of an event, the switch closes and allows the accumulator to begin collecting the pulses emitted by the pacemaker. The more pulses to accumulate, the greater the amount of time the perceiver will feel has passed. The switch reopens when the event being timed has ended, thus allowing the pulses to once again flow freely through the accumulator and preventing further accumulation of pulses.

A number of different variables can increase or decrease the speed at which pulses accumulate, thereby altering the subjective experience of time. Several studies have demonstrated that reducing the amount of attention directed toward time perception results

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in an underestimation of exposure durations (e.g., Casini & Macar, 1997; Gautier & Droit-Volet, 2002). Emotional valence (positive vs. negative stimuli) can also influence temporal judgments. Angry faces have been found to produce overestimations in time perception as compared to other facial expressions (Droit-Volet, Brunot et al., 2004; Fecica & Stolz, 2008; Gil et al., 2007; Gil & Droit-Volet, 2011b; Thayer & Schiff, 1975), particularly when the gaze of the face is directed toward the observer (Doi & Shinohara, 2009). These results suggest that perceived threat leads to differential experiences of time. Finally, physiological arousal also modulates time perception. Increasing arousal due to increased body temperature (Wearden & Penton-Voak, 1995) or the administration of dopaminergic drugs (e.g., MacDonald & Meck, 2005) leads to an overestimation of time (i.e., time appears to “last longer”); this effect is likely due to physiological arousal increasing the speed of the internal clock, thereby creating more pulses per unit of time (see Droit-Volet & Gil, 2009, for a review). Thus, there is substantial evidence that different physiological and cognitive factors can have specific influences on how time is experienced.

More striking, however, is the work by Angrilli and colleagues (Angrilli, Cherubini, Pavese, & Mafredini, 1997), who examined the effects of both emotional valence and arousal on time judgments. Using photographs from the International Affective Picture System (see Lang, Bradley, & Cuthbert, 2005), Angrilli and colleagues selected stimuli that were high-arousal positive, low-arousal positive, high-arousal negative, low-arousal negative, and neutral. Thus, it was possible to examine the effects of both valence and arousal in the same participants. Angrilli and colleagues found that low-arousal negative items were judged to have been presented for shorter durations than low-arousal positive items. In contrast, at high levels of arousal, the duration of negative slides was judged to have been longer than positive slides. It is important to note that no comparisons were made with neutral items. Based on these results, Angrilli and colleagues hypothesized that there were two different systems influencing time perception. The perception of low-arousal material was influenced by attentional factors. Specifically, more attentional resources were allocated to positive than to negative stimuli. In contrast, the perception of high-arousal material was influenced by arousal-based emotional factors. However, the durations used in this study—2 to 6 seconds—make it difficult to determine if the attentional and emotional systems operate at different time scales. As noted above, event-related potential studies typically show emotional influences on perception occurring less than 300 ms after stimulus onset (see Olofsson, Nordin, Sequeira, & Polich, 2008, for a review). This initial influence appears to begin in temporal and parietal areas before modulating occipital and frontal regions (Krolak-Salmon, Hénaff, Vighetto, Bertrand, & Mauguière, 2004; Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005). Therefore, based on neuroimaging data, it appears likely that emotion would have different effects on the subjective experience of a stimulus if it were presented rapidly (<300 ms) than it would at longer durations, when multiple neural systems could interact.

The current research will address this question by examining how valence and arousal influence time perception at short (100–300 ms) and long (400–1600 ms) durations using a temporal bisection task (Allan & Gibbon, 1991; Wearden, 1991). In the temporal bisection task, participants are trained to distinguish

between two different exposure durations (in several papers by Droit-Volet and colleagues, these durations were 400 ms and 1600 ms). Participants are then shown stimuli that are presented at a number of different durations that fall between the two learned times (e.g., 400, 600, 800, 1000, 1200, 1400, and 1600 ms) and are asked to indicate if that stimulus was presented for a time period that was closer to the “short” or the “long” exposure duration from the training period. In the current study, participants will complete blocks of trials involving short (“Short blocks”: 100–300 ms) or longer (“Long blocks”: 400–1600 ms) durations. For the Long blocks, we hope to replicate the valence \times arousal interaction reported by Angrilli and colleagues (1997); namely, an overestimation of high-arousal negative and low-arousal positive stimuli, and an underestimation of low-arousal negative and high-arousal positive stimuli. However, we do not expect this pattern of results in the Short blocks. Because rapid responses to emotional stimuli generally involve the amygdala (Zald, 2003), we predict that highly arousing stimuli, particularly negative items, will selectively modulate the subjective experience of time.

Method

Participants

Seventy-five undergraduate students (56 female, 19 male) from the University of Winnipeg participated in this experiment in exchange for partial credit in an introductory psychology class. All participants provided written informed consent before participating, as per ethics regulations of the University of Winnipeg’s Senate Committee on Ethics in Human Research and Scholarship (SCEHRS).

Materials

The stimuli consisted of 50 10 cm \times 7.5 cm color photographs taken from the International Affective Picture Systems (IAPS; Lang et al., 2005).

The stimulus set consisted of equal numbers of (1) highly arousing positive images, (2) highly arousing negative images, (3) less arousing positive images, (4) less arousing negative images, and (5) neutral images. This classification was based on valence and arousal ratings provided with the IAPS image database (Lang et al., 2005). The relevant characteristics of the resulting categories of images are depicted in Table 1.

All stimuli were presented on a 15 color 75-Hz CRT monitor attached to a 2.0 GHz Pentium 4 Dell microcomputer, and were viewed from a distance of approximately 60 cm. All experiments

Table 1
IAPS Arousal and Valence Ratings for the Five Stimulus Types

Stimulus type	Arousal rating	Valence rating
<i>High-Arousal Negative</i>	6.764	2.016
<i>Low-Arousal Negative</i>	4.025	2.820
<i>High-Arousal Positive</i>	6.762	7.235
<i>Low-Arousal Positive</i>	4.194	7.452
<i>Neutral</i>	3.788	5.155

were programmed using E-Prime 2.0 software (Psychology Software Tools, Inc.).

Design and Procedure

The temporal bisection task consisted of 10 blocks of 70 trials. Five of these blocks involved relatively short exposure durations ranging from 100–300 ms (“Short Blocks”); the remaining five blocks involved relatively long exposure durations ranging from 400–1600 ms (“Long Blocks”). The order of these 10 blocks was randomized for each participant.

Each block began with a training phase consisting of 20 practice trials in which the stimulus was a 10 cm × 7.5 cm blue rectangle (see Figure 1). In the training phase, the participants learned to distinguish between the longest and the shortest possible exposure durations for that block type (i.e., they learned to discriminate between 100 ms and 300 ms in Short blocks and between 400 ms and 1600 ms in Long blocks). The order of the 20 practice trials—10 for each of the two durations—was randomized for each block. Feedback was provided following each trial to facilitate the participants’ learning of the exposure durations. Participants were then prompted to begin the 70 test trials for that block.

Each test trial began with a fixation cross displayed for 1000 ms that alerted the participant to the commencement of a new trial. The fixation cross was followed by a blank screen presented for durations ranging from 250 ms to 2000 ms; the duration of this blank screen was varied in order to reduce the temporal information available to the participants (i.e., to prevent participants from being able to predict the onset of the target image). After this brief delay, a stimulus image was presented at the center of the screen for a variable duration. In the Short blocks, the duration was 100, 133, 167, 200, 233, 267, or 300 ms; in the Long blocks, the duration was 400, 600, 800, 1000, 1200, 1400, or 1600 ms. Following the offset of this image, participants were prompted to indicate whether the image was shown for a duration that was closer to the shorter trained duration (100 ms in the Short blocks;

400 ms in the Long blocks) or to the longer trained duration (300 ms in the Short blocks; 1600 ms in the Long blocks). Responses were made via key press on the computer keyboard (*s* for short and *l* for long). As the response keys (which mapped on to the linguistic labels for those durations) were not counterbalanced, reaction time data were not analyzed. Therefore, the key dependent variable was the proportion of trials labeled as being “short” or “long” at each exposure duration.

Data Analysis

The proportion of trials on which participants responded with the answer “long” was calculated for each stimulus type at each exposure duration. Using the “long” responses as opposed to the “short” responses for these calculations is arbitrary; we therefore followed the precedent of previous research (e.g., Droit-Volet, Meck, & Penney, 2007; Gil, Rousset, Droit-Volet, 2009). Thus, a larger number would reflect a greater tendency to respond “long” on those trial types. These data were initially analyzed using a 2 (Short vs. Long Block) × 5 (Stimulus Type) × 7 (Duration) repeated-measures analysis of variance. Subsequent ANOVAs were conducted separately for the Short and Long blocks of trials. Tukey’s post hoc tests were conducted for specific post hoc comparisons; this method corrected for multiple comparisons, thereby reducing the likelihood of a Type I error.

To further elucidate the effects of arousal and valence on the subjective experience of time, two additional indices of time perception were calculated: the bisection point (BP) and the Weber ratio (WR). The bisection point is the time interval of subjective equality (i.e., the duration at which the probability of responding “long” was 0.5). The BP was calculated using the regression intercept and slope for each participant’s responses. Weber ratios are a measure of temporal sensitivity. These values were calculated by subtracting the stimulus duration that would lead to a $p(\text{long})$ of 0.25 from the duration that would lead to a $p(\text{long})$ of 0.75, dividing the difference by 2, and then dividing that quotient by the

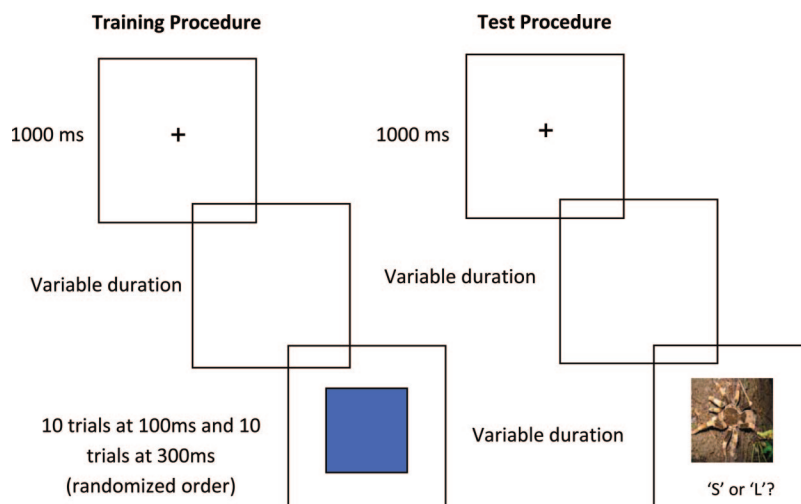


Figure 1. A depiction of the training and test procedures in the temporal bisection task. In the Short blocks, stimuli were presented for 100, 133, 167, 200, 233, 267, and 300 ms. In the Long blocks, stimuli were presented for 400, 600, 800, 1000, 1200, 1400, and 1600 ms.

bisection point. Higher Weber ratios reflect an inferior sensitivity to time (see Droit-Volet & Wearden, 2002, for a complete description of the scalar properties of these temporal calculations). Separate BPs and WRs were calculated for each emotion type for each participant, with separate calculations conducted for Short and Long blocks of trials. Therefore, each participant produced 10 BPs and 10 WRs.

Results

Omnibus Analysis

A 2 (Block Type: Long vs. Short) \times 7 (Duration) \times 5 (Stimulus Type) repeated-measures ANOVA was conducted to examine whether emotion differently affected time perception in Short and Long blocks. The main effect of Block Type was highly significant: $F(1, 74) = 138.88$, $MSE = 0.019$, $p < .0001$. Block Type also interacted with Duration ($F(6, 444) = 66.38$, $MSE = 0.028$, $p < .001$) and Stimulus Type, $F(4, 296) = 4.98$, $MSE = 0.017$, $p < .001$. The three-way interaction was marginally significant: $F(24, 1776) = 1.49$, $MSE = 0.032$, $p = .06$. These results suggest that emotion influenced time perception differently when the images were easy (Long blocks) or difficult (Short blocks) to perceive. Possible neuroanatomical explanations for this difference are discussed below.

Short Blocks

The analysis of the Short blocks produced a highly significant main effect of Duration, indicating that as the exposure duration increased, participants were more likely to respond “long”: $F(6, 444) = 485.75$, $MSE = 25.98$, $p < .001$. This effect, although not surprising, verifies that the participants were able to distinguish between the different exposure durations even though they varied by only 33 ms; however, it should be noted that there was an overall tendency to underestimate the duration of the stimuli (i.e., to respond “short”). Of greater interest is the main effect of Stimulus Type, which was also statistically significant: $F(4, 296) = 4.10$, $MSE = 0.079$, $p < .003$. As is evident from Figure 2, the high-arousal negative items were generally judged to have been presented more quickly than the other types of stimuli. However, the differences in responses to the five stimulus types varied across the different exposure durations, thus leading to a significant Duration \times Stimulus Type interaction: $F(24, 1776) = 2.15$, $MSE = 0.03$, $p < .001$. This result demonstrates that the tendency for negative stimuli to be underestimated does not occur across all exposure durations.

Planned comparisons demonstrated that at the middle duration—200 ms—high-arousal negative items were significantly underestimated relative to other types of stimuli. This effect will be discussed in more detail during our presentation of the bisection-point analyses. Post hoc comparisons noted one important significant result. At 133 ms, high-arousal negative items were underestimated compared to all other stimulus types. However, only the comparisons with neutral and high-arousal positive stimuli were significant when a conservative threshold ($q = 2.81$) was used to correct to multiple comparisons. (When no correction was made, there was a significant difference with low-arousal positive stimuli, $t(74) = 2.00$, $p < .05$ and a marginally significant difference

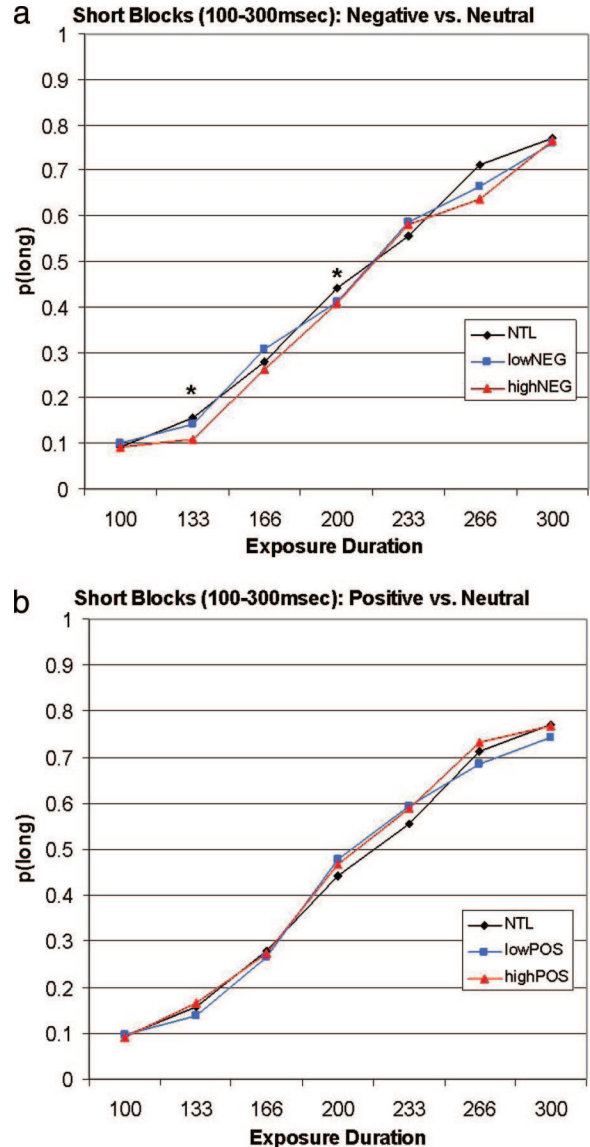


Figure 2. The probability that participants responded “long” on trials for each stimulus duration in Short blocks. For the purposes of clarity, the results are separated into separate figures depicting negative (Figure 2a) and positive (Figure 2b) stimuli compared to neutral items. Note that negative items, particularly high-arousal negative items, lead to fewer “long” responses than other stimulus types, particularly at 133 and 200 ms. Asterisks indicate time intervals at which responses to high-arousal negative stimuli significantly differ from responses to neutral stimuli.

with low-arousal negative stimuli, $t(74) = 1.84$, $p < .07$). This result suggests that although negative items affect time perception at brief durations, this effect occurs at an earlier stage of processing for highly arousing items.

Long Blocks

The Long blocks were also subjected to a 5 (Stimulus Type) \times 7 (Duration) repeated-measures ANOVA (see Figure 3 for a description of the Long Block data). As with the Short blocks there

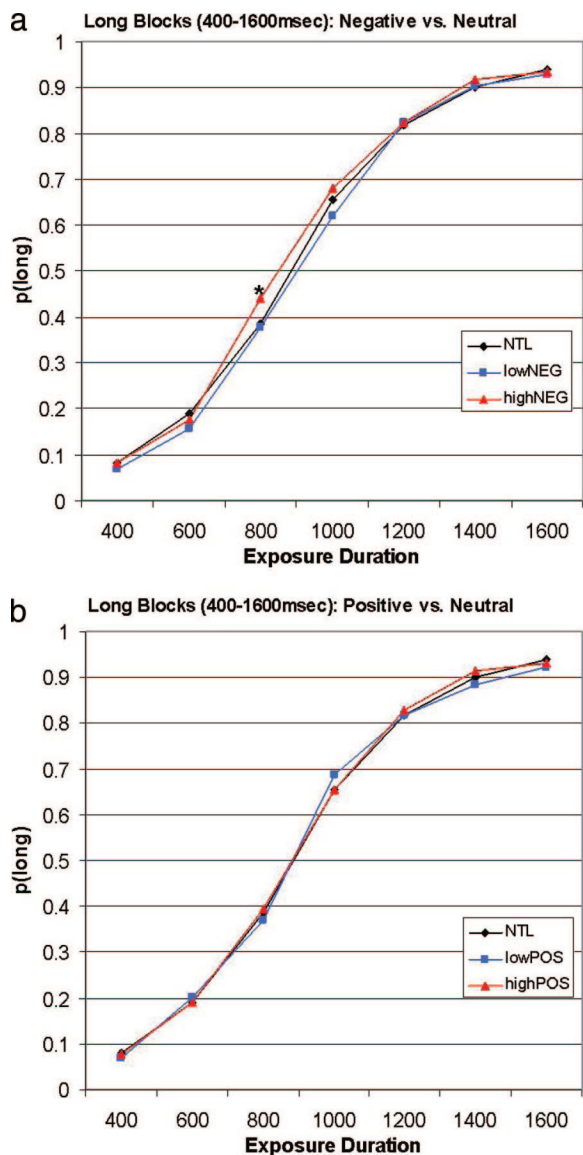


Figure 3. The probability that participants responded “long” on trials for each stimulus duration in Long blocks. For the purposes of clarity, the results are separated into separate figures depicting negative (Figure 2a) and positive (Figure 2b) stimuli compared to neutral items. Note that high-arousal negative items lead to significantly more “long” responses, particularly at 800 ms (indicated by an asterisk).

was a robust main effect of Duration, demonstrating that participants were able to distinguish between the different stimulus durations: $F(6, 444) = 796.60$, $MSE = 46.15$, $p < .0001$. The main effect of Stimulus Type was also significant, indicating an overall difference in how the different stimulus types were perceived: $F(4, 296) = 3.56$, $MSE = 0.045$, $p < .01$. This effect appears to be due primarily to an overestimation of the duration of high-arousal negative items, the same items that were underestimated in the Short blocks. The results also included a significant Duration \times Stimulus Type interaction ($F(24, 1776) = 1.61$, $MSE = 0.012$, $p < .03$), suggesting that the effect of different emotions on time perception varied across exposure durations.

Planned comparisons demonstrated that at the middle duration—1000 ms— low-arousal negative items were significantly underestimated relative to low-arousal positive, $t(74) = 2.91$, $p < .01$ and high-arousal negative images, $t(74) = 2.61$, $p < .02$, but were only marginally different from neutral items: $t(74) = 1.76$, $p = .08$. None of the other planned comparisons were statistically significant (all t -values < 1.60). These effects will be discussed during our presentation of the bisection-point analyses. Post hoc comparisons revealed that the duration of high-arousal negative items was overestimated (i.e., “time stood still”) compared to all other stimulus types at 800 ms (all q values > 2.70 , all p values < 0.05) with the exception of high-arousal positive stimuli, which were marginally significant ($q = 2.42$, $p < .10$).

Analyses of Bisection Points and Weber Ratios

Summaries of the bisection points and Weber ratios for each trial type are presented in Table 2. An analysis of variance conducted on the BP data in the Short blocks yielded a significant effect of emotion type: $F(4, 296) = 3.319$, $MSE = 316.43$, $p < .02$. Planned comparisons indicated that high arousal negative items had a significantly higher BP than neutral, $t(74) = 2.16$, $p < .04$ and high arousal positive items, $t(74) = 3.14$, $p < .005$. Additionally, comparisons with low arousal negative, $t(74) = 1.70$, $p = .09$ and low arousal positive, $t(74) = 1.62$, $p = .11$ were marginally significant in the predicted direction. A significant difference was also found between the BPs for low and high arousal positive items, $t(74) = 2.49$, $p < .02$, with the BP for highly arousing stimuli being lower than that for less arousing items. More striking were the results for the WRs in the Short blocks. As in the BP calculations, there was a significant effect of emotion type: $F(4, 296) = 3.059$, $MSE = 0.011$, $p < .02$. Planned comparisons demonstrated that only high arousal negative items led to significantly lower levels of temporal sensitivity (all t values > 2.00 , all p values < 0.05); no other significant results were obtained.

Similar calculations were conducted for data from Long blocks. An analysis of variance examining BP data for these blocks again showed a main effect of emotion type: $F(4, 296) = 2.882$, $MSE = 3729.78$, $p < .03$. However, the planned comparisons were less conclusive than those conducted on data from Short blocks. The BP for low arousal negative stimuli was found to be significantly higher than that for neutral, $t(74) = 2.12$, $p < .04$, high arousal negative, $t(74) = 3.32$, $p < .001$, or low arousal positive stimuli, $t(74) = 2.38$, $p < .02$. Thus, the BP was smaller (overestimation) for the high than for the low-arousal stimuli. No other comparisons approached significance. Low arousal negative items also produced WRs that were significantly lower than those for neutral, $t(74) = 2.06$, $p < .05$ and high arousal positive items, $t(74) = 2.19$, $p < .04$. The comparison between low and high arousal negative items approached significance as well: $t(74) = 1.96$, $p = .053$.

The WR data for Short and Long blocks were combined into a 2 (Block Type: Long vs. Short \times 5 (Stimulus Type) repeated-measures ANOVA. The results demonstrate that there was a main effect of Block Type ($F(1, 74) = 5.34$, $MSE = 0.619$, $p < .03$) and a Block Type \times Stimulus Type interaction ($F(4, 296) = 3.12$, $MSE = 0.005$, $p < .02$). It should be noted that the Weber ratios in the current study, particularly in the Long blocks, were higher than

Table 2
Bisection Points and Weber Ratios for Short and Long Blocks

Stimulus type	Short Blocks (100–300 ms)		Long Blocks (400–1600 ms)	
	BP (SD)	WR (SD)	BP (SD)	WR (SD)
<i>High-Arousal Negative</i>	228.32 (51.89)	0.28 (0.18)	926.05 (179.21)	0.37 (0.28)
<i>Low-Arousal Negative</i>	222.26 (45.85)	0.30 (0.20)	958.41 (160.26)	0.34 (0.21)
<i>High-Arousal Positive</i>	218.25 (44.12)	0.31 (0.20)	934.06 (162.49)	0.38 (0.40)
<i>Low-Arousal Positive</i>	223.03 (44.59)	0.31 (0.20)	943.16 (157.09)	0.35 (0.24)
<i>Neutral</i>	220.36 (35.42)	0.30 (0.17)	938.47 (155.89)	0.35 (0.22)

those found in several other studies using the temporal bisection task. This difference was unexpected, as our method of calculating Weber ratios were identical to that used by previous researchers. We suspect that our divergent results may be due to the large number of stimuli used in the current study as well as to different personality traits influencing the perception of emotional images. These possibilities will be discussed below.

Discussion

The results of the current study demonstrate that valence and arousal influence time perception differently at short durations (<300 ms) than at longer durations (>400 ms). In the Short blocks of trials, the exposure duration of negative stimuli was generally underestimated. This effect was most salient for highly arousing negative stimuli; indeed, this effect emerged for exposure durations as brief as 133 ms. In the Long blocks of trials, the predicted valence \times arousal interaction originally reported by Angrilli and colleagues (1997) was found. It is interesting that the same highly arousing negative stimuli that were underestimated in Short blocks were overestimated (i.e., “time stood still”) in Long blocks. The overestimation of the duration for arousing negative stimuli has clear evolutionary benefits. These images are often perceived as threatening; therefore, if the perception of these stimuli appears to “slow down,” it will allow the perceiver more time to generate a protective response. Indeed, a neuroimaging study of time perception using similar exposure durations have detected activity in a caudate-presupplementary motor area circuit (Pouthas et al., 2005), suggesting that time perception is linked to an overt motoric response (see Meck, 2006, for a review of animal-based studies describing similar neural circuitry).

The finding that such images are underestimated when shown for very brief durations is less intuitive and initially appears to contradict previous research. Grommet and colleagues (2011) presented fear-inducing or neutral stimuli to participants across two different temporal ranges: 250–1000 ms and 400–1600 ms. In both duration ranges, fearful stimuli were judged to have been presented longer than neutral stimuli. A possible explanation for the difference between the shorter blocks of trials in the current study and that of Grommet and colleagues is that the current study used temporal ranges that were based on theoretical time courses for specific neuroanatomical networks. Olofsson and colleagues (2008) found that for presentations less than 300 ms, ERP components related to attention were modulated by emotional stimuli; for presentations longer than 300 ms, ERP components related to attention and memory were affected. Therefore, the temporal ranges used in the current research likely involved attentional

networks whereas the slightly longer time spans of Grommet and colleagues likely involved neuroanatomical networks related to attention, memory, and decision-making; this difference in durations (100–300 ms vs. 250–1000 ms) may explain the divergent results between the two studies.

The time period in which the underestimation of arousing negative images occurred (133–267 ms) coincides with the time frame in which emotional images begin to influence attentional processing in the extrastriate cortex (Gan, Wang, Zhang, Li, & Luo, 2009; Pizzagalli et al., 2002), likely via connections with the amygdala (Morris et al., 1998; Surguladze et al., 2003). It is possible that stimuli that activate the amygdala during this initial perceptual stage are immediately identified as a threat and rapidly activate other brain systems. In contrast, less threatening items which do not activate the amygdala would require longer processing in order to determine the appropriate response. The result of this difference in neural responses would be that threatening stimuli would initially seem to have been presented more quickly than other stimuli. Although this explanation is speculative and requires further research, there are existing data demonstrating that the amygdala influences attention at specific time scales. Using ERP, Rotschtein and colleagues (2010) found that damage to the amygdala diminished P1 components (approximately 100–150 ms) and later components of attention (approximately 500–600 ms); however, no effect was found for components in the 150–250 ms range. These data suggest that the amygdala is therefore involved with early stages of emotional perception when stimuli are not optimally perceived (as in the case of the Short blocks in the current study). Whether these patients would also show an attenuation of the emotional modulation of time perception has yet to be investigated.

A concern related to the Short block data is that the stimuli in this block were more difficult to perceive than were those in the Long blocks. Therefore, differences in time perception independent of emotion might explain some aspects of the current results. Indeed, our omnibus analyses indicated that the average bisection point was longer than the arithmetic mean (200 ms) in the Short blocks and was shorter than the arithmetic mean (1000 ms) in the Long blocks. While stimulus discriminability does explain the difference in average bisection points, it is important to note that in the Short blocks, highly arousing negative stimuli—which the amygdala is specialized to process—led to different temporal judgments than other stimulus types. This specificity of effects is consistent with numerous studies demonstrating that the amygdala is exceptionally sensitive to emotional stimuli that are degraded or unconsciously perceived (see Costafreda, Brammer, David, & Fu,

2008, for a meta-analysis). Therefore, the current results complement existing neuroimaging data.

As noted in the Results section above, the Weber ratios in the current study were larger and more variable than found in previous research. This variability may be due to the influence of having five different stimulus types (10 images per type) in the same blocks of trials. Most previous research utilized less than 10 total images (e.g., Grommet et al., 2011, included three fear-evoking and three neutral images). A small number of stimuli allows the participant to pay more attention to the timing of the item and less attention to the identity of the item, as frequent presentations of the stimulus leads to less effortful processing. However, in the current study, over 50 different images were used. Therefore, it was more difficult for participants to ignore the identity of the stimulus. If we were to reduce the number of individual images in the current study, we predict that the WRs would decrease as well.

Another factor that likely influenced the results is the role of individual differences in emotional processing. Substantial data indicate that individuals who exhibit high levels of neuroticism show larger (Larsen & Ketelaar, 1991) and longer-lasting (Norris, Larsen, & Cacioppo, 2007) physiological responses to emotional stimuli. It is important that Tipples (2008) noted that at relatively long durations roughly corresponding to the Long blocks in the current study, individuals high in negative emotionality showed a larger tendency to overestimate the duration of angry faces than did less negative individuals. Similar results were found for individuals high in fearfulness (Tipples, 2011). The length of the current study precluded the acquisition of personality data. Individual differences are, therefore, a potential source of “noise” in the current data. We are currently conducting studies to examine whether different personality traits—particularly neuroticism and conscientiousness—differentially influence the emotional modulation of time perception during Short and Long blocks.

An important caveat to the current study, as well as to many studies in this area, is that time perception was not measured while perception was occurring. Instead, participants’ responses occurred after the stimulus had disappeared. This delay, while brief (generally 500–1500 ms), does suggest that there is a working memory component to the temporal bisection task. Indeed, in their seminal work on models of time perception, Gibbon, Church, and Meck (1984) noted that the scalar properties associated with the scalar expectancy theory need not be isolated to encoding and may include other stages of processing. It is important to note that although the working memory effect should be consistent across all stimulus types, there is evidence that emotional items elicit additional activity in some brain structures. Using schematic faces, Beneventi, Barndon, Erslund, and Hugdahl (2007) noted emotion-dependent activity in the right inferior frontal gyrus during the performance of a working memory task. Therefore, corroboration of the current results using alternative paradigms is necessary in order to rule out the possibility that emotions are influencing working memory rather than time perception.

The current study suggests that there are multiple stages at which emotion influences time perception. This idea is consistent with recent neuroimaging studies that have noted different patterns of brain activity during the perception of neutral stimuli presented at different time scales (Gutyrchik et al., 2010). However, it is important to note that we are not suggesting that these multiple systems are necessarily distinct. Given the density of reciprocal

connections between structures involved with emotional perception (LeDoux, 2000), it seems logical to assume that these systems are overlapping or complementary. Indeed, recent animal-based work by Meck and MacDonald (2007) noted that damage to the amygdala reduced the effect of emotion on time judgments for periods lasting several seconds, thereby demonstrating that this structure could influence time perception for periods lasting much longer than a few hundred milliseconds. However, the existence of multiple stages of time perception will hopefully serve as a catalyst for future studies investigating these phenomena in neurological and psychiatric populations. Such studies, as well as neuroimaging investigations, would provide stringent tests of the multiple-stage hypothesis and would further delineate the neural architecture underlying the emotional modulation of time perception.

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Appendix A IAPS Images Used in the Current Study

High arousal negative: 3102, 3000, 3266, 3110, 3140, 3500,
3150, 6230, 6300, 6370

Low arousal negative: 2205, 9220, 9000, 2750, 2900, 9280,
9290, 2722, 9008, 9190

High arousal positive: 5950, 5629, 8400, 8180, 8490, 8030,
8200, 5621, 8185, 8501

Low arousal positive: 5220, 1604, 7280, 1721, 5820, 1600,
2311, 2170, 1920, 1460

Neutral: 2220, 6150, 7170, 7207, 7182, 2514, 5532, 2385, 2487,
1616

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Call for Nominations: *Psychology and Decision Making*

The Publications and Communications (P&C) Board of the American Psychological Association has opened nominations for the editorship of *Psychology and Decision Making*. The editorial search is co-chaired by Valerie Reyna, PhD, and David Dunning, PhD.

Psychology and Decision Making, to begin publishing in 2014, is a multidisciplinary research journal focused on understanding the psychological and cognitive processes involved in decision making. The journal will publish empirical research that advances knowledge and theory regarding all aspects of decision making processes. Specifically, the goal of the journal is to provide for an interdisciplinary discussion of contrasting perspectives on decision making.

Submissions from all domains of decision making research are encouraged, including (but not limited to) research in the areas of individual decision making, group decision making, management decision making, consumer behavior, reasoning, risk tasking behavior, risk management, clinical and medical decision making, organizational decision making, choice behavior, decision support systems, strategic decision making, interpersonal influence, persuasive communication, and attitude change.

Editorial candidates should be members of APA and should be available to start receiving manuscripts in January 2013 to prepare for issues published in 2014. Please note that the P&C Board encourages participation by members of underrepresented groups in the publication process and would particularly welcome such nominees. Self-nominations are also encouraged.

Candidates should be nominated by accessing APA's EditorQuest site on the Web. Using your Web browser, go to <http://editorquest.apa.org>. On the Home menu on the left, find "Guests." Next, click on the link "Submit a Nomination," enter your nominee's information, and click "Submit."

Prepared statements of one page or less in support of a nominee can also be submitted by e-mail to Sarah Wiederkehr, P&C Board Search Liaison, at swiederkehr@apa.org.

Deadline for accepting nominations is January 10, 2012, when reviews will begin.