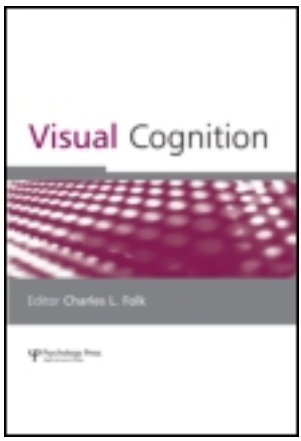

Visual Cognition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pvis20

Time and number under the influence of emotion

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Version of record first published: 08 Nov 2012.

To cite this article: Laura N. Young & Sara Cordes (2012): Time and number under the influence of emotion, Visual Cognition, 20:9, 1048-1051

To link to this article: http://dx.doi.org/10.1080/13506285.2012.726504

Time and number under the influence of emotion

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As humans keep track of temporal and numeric quantities, often with serious ramifications for survival, it is always possible that strong emotions will be stirred. What happens to our perception of time and number under the influence of emotion? Whereas adults judge negative stimuli as lasting longer (e.g., Droit-Volet, Brunot, & Niedenthal, 2004), it is entirely unknown how emotions impact numerical estimations. An important distinction underlying this investigation is whether, at their most fundamental levels, time and number are truly separable domains. It has been claimed that they are part of a common magnitude system (Meck & Church, 1983), and if this is so, numerical estimates, like temporal ones, should also be increased under the influence of emotion. However, opposing evidence also exists (e.g., Agrillo, Ranpura, & Butterworth, 2010; Dormal, Seron, & Pesenti, 2006) suggesting that temporal and numeric processing are separable at a fundamental level; therefore, it is possible that emotion affects them in qualitatively different ways.

In this study, we tested the effects of emotional stimuli on temporal and numeric processing within the same individuals; and, using a baseline condition without face stimuli, compared processing of time and number within subjects. This study serves as the first investigation of the impact of emotional stimuli on numerical processing while also shedding light on the concept of a shared common magnitude system for time and number.

METHOD

Participants were 38 undergraduate psychology students (M age = 19.2; 14 males) who completed both a temporal and numeric computerized bisection

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http://dx.doi.org/10.1080/13506285.2012.726504

task (based on, e.g., Droit-Volet et al., 2004; Gil & Droit-Volet, 2011), with the task order counterbalanced. Both tasks involved learning a small and large temporal and numeric standard (small: 400 ms presentation of an oval/4 dots, large: 1600 ms/16 dots), and then choosing whether the durations or numerosities presented subsequently in test trials (consisting of five, new logarithmically spaced values situated between the standards; time: 1270, 1008, 800, 635, 504; number: 13, 10, 8, 6, 5) were closer to the small or the large standard.

Following a training period of eight trials, participants initially completed a block of 42 trials in which the values were randomly presented six times each without emotional stimuli (baseline condition). Following this block, each of the remaining 126 trials included an emotional face stimulus (neutral, happy, and angry faces from the NimStim set: Tottenham et al., 2009) presented for 400 ms before the oval/dots presentations. The 54 faces presented were chosen as the most similarly rated from 96 face stimuli judged by nine raters on intensity, attractiveness, arousal, and valence. Importantly, the raters judged the angry faces as more arousing than the happy faces, and the happy faces as more arousing than the neutral faces, $F(2, 51) = 911.80$, $p < .001$.

Data analyses

The proportion of long/large responses at each of the seven values was calculated for each participant for each of the four conditions (baseline, angry faces, happy faces, and neutral faces; as per Droit-Volet et al., 2004). Using the slope and intercept of regressions of the probability of long/large responses on duration/numerosity, the point of subjective equality (PSE; the value at which 50% of responses were long/large) was determined for each participant, for each condition within each task.

RESULTS

Baseline (no faces)

No correlation was observed between the PSE for time and the PSE for number, $r = .090$, $p = .590$. Using normalized PSEs, the PSE for time was observed to be significantly higher than the PSE for number, $t(37) = 5.48$, $p < .001$. These results suggest that temporal and numeric judgements function independently within individuals.

Time

As in previous research (Droit-Volet et al., 2004), durations presented after angry emotional faces were estimated as lasting longer compared to

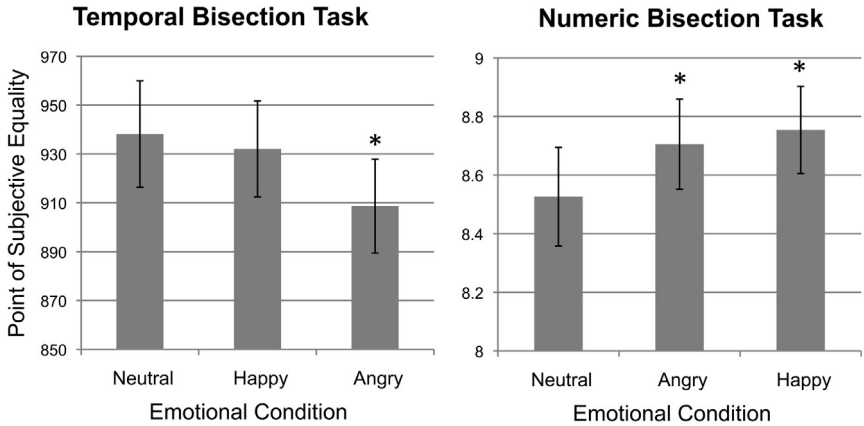

Figure 1. Temporal and numeric bisection tasks. $N = 38$. Error bars indicate standard error. Asterisks indicate a significant difference from neutral. Angry PSE was significantly lower than neutral for time, whereas angry and happy PSEs were significantly higher than neutral for number (all $ps < .05$).

durations presented after neutral faces, as evidenced by a lower PSE (see Figure 1). Relative to the neutral faces PSE ($M = 938.16$, $SD = 134.41$), the angry face PSE ($M = 908.63$, $SD = 118.29$) was significantly lower, $F(1, 37) = 5.94$, $p = .020$, and the happy face PSE ($M = 932.05$, $SD = 121.02$) fell between the angry (contrast of happy and angry), *ns,* and neutral face PSEs (contrast of happy and neutral), *ns.*

Number

Contrasting with the results of the temporal task, both emotional stimuli (angry *and* happy face stimuli) led to *underestimation* relative to the neutral face condition in the number bisection task (see Figure 1): Contrast of angry PSE ($M = 8.71$, $SD = 0.95$) and neutral PSE ($M = 8.53$, $SD = 1.04$), $F(1, 37) = 4.38$, $p = .043$; contrast of happy PSE ($M = 8.75$, $SD = 0.92$) and neutral PSE, $F(1, 37) = 4.87$, $p = .034$. There was no difference in the PSE between the happy and angry conditions.

DISCUSSION

Results of the temporal bisection task are consistent with several studies using similar tasks that have found overestimation of durations under emotional conditions (e.g., Droit-Volet et al., 2004; Gil & Droit-Volet, 2011). Our results provide additional support for claims of a direct, arousal-modulated effect on temporal processing by emotion (Droit-Volet et al.,

2004), as overestimation of durations aligned with the arousal ratings of faces.

In contrast, an entirely different and opposite pattern was observed in the numerical bisection task, with underestimation of quantity following emotional faces relative to the neutral face condition. Unlike the temporal task, numerical underestimation did *not* track with arousal ratings of the faces: Both happy faces and angry faces produced a similar underestimation of number relative to neutral. The numerical bisection results suggest that number is processed by a different system than time, which is differentially affected by emotion.

Although the arousing effects of emotion appear to drive the observed shifts in temporal judgements, emotional effects on visual attention likely underlie the changes in numerical processing. The importance of visual attention for numerical processing is supported by neural evidence: Numeric processing draws heavily upon regions of the brain implicated in maintaining control of visual attention (IPS; e.g., Corbetta & Shulman, 2002; Piazza, Mechelli, Price, & Butterworth, 2006), and changes in perceptual ability as a result of effects on attention from emotion have been observed (Phelps, Ling, & Carrasco, 2006). Future research will aim to uncover the mechanism driving the observed dissociation, but the results of this study strongly suggest nonoverlapping processes for tracking of time and number, each affected differently by incoming emotional information.

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