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Short Report

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Fewer Things, Lasting Longer: The Effects of Emotion on Quantity Judgments

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Although emotion and timing interactions have been extensively examined, the effects of emotion on another important quantitative tracking process, numerical processing, have been unstudied. Temporal-processing tasks involving tracking the durations of visual stimuli have revealed that emotion information leads to a subjective dilation or overestimation of duration relative to neutral information (e.g., Angrilli, Cherubini, Pavese, & Manfredini, 1997; Bar-Haim, Kerem, Lamy, & Zakay, 2010; Droit-Volet, Brunot, & Niedenthal, 2004). Yet it is entirely unknown how emotions affect numerical estimations in similar conditions. 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-tracking system (Meck & Church, 1983; Walsh, 2003), which would suggest that numerical estimates, like temporal ones, should also be increased under the influence of emotion. However, evidence against shared systems (e.g., Agrillo, Ranpura, & Butterworth, 2010; Dormal, Seron, & Pesenti, 2006) suggests that temporal and numeric processing are separable at a fundamental level. Therefore, it is certainly possible that temporal and numeric processing are each affected by emotion in qualitatively different ways.

The aim of this study was to test the effects of emotional stimuli on temporal and numeric processing within the same individuals and, using a baseline condition without emotion stimuli, to compare processing of time and number within subjects. In doing this, the present study not only serves as the first investigation of the impact of emotional stimuli on numerical processing, but it also offers new data to consider in relation to theories of a shared common magnitude system for time and number.

Method

Participants and procedure

Thirty-eight undergraduates (14 males, 24 females; mean age = 19.2 years) completed both a temporal and a numeric bisection task on a computer. Task order was counterbalanced (tasks were based on those used in Droit-Volet et al., 2004, and Gil & Droit-Volet, 2011). Each task began with 8 training trials, in which participants learned to press one key following a small standard value (400-ms presentation of an oval in the temporal task or 4 dots in the numeric task) and another key following a large standard value (1,600-ms presentation of an oval in the temporal task or 16 dots in the numeric task). Arrays of dots were always presented for 400 ms. Participants then completed 42 baseline trials for each task. On these trials, in addition to identifying the small and large standard values, participants indicated whether intermediate oval durations (1,270 ms, 1,008 ms, 800 ms, 635 ms, and 504 ms) or numbers of dots (13, 10, 8, 6, and 5), respectively, were closer to the small or the large standard (values for both tasks were logarithmically spaced).

Following baseline, participants completed 126 emotion trials, which were identical to baseline trials except that the ovals or dots were preceded by an emotional face stimulus (neutral, happy, and angry faces from the NimStim set; Tottenham et al., 2009), which was presented for 400 ms. The 54 faces used were chosen as the most similar within emotion category from 96 face stimuli judged by nine raters on intensity, attractiveness, arousal, and valence. Angry faces were judged as more arousing than happy faces, which were judged as more arousing than neutral faces, $F(2, 51) = 911.80$, $p < .001$.

Data analyses

Following Droit-Volet et al. (2004), we calculated each participant's proportion of "large" responses (i.e., responses indicating that durations or numbers were closer to the large than to the small standard) for each of the seven tested values in each of the four conditions (baseline, angry, happy, and neutral). Using regressions

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of the probability of "large" responses on duration or numerosity, respectively, we determined the point of subjective equality (PSE; the value at which 50% of responses were "large") for each participant and each condition within each task.

Results

Baseline (no faces)

Normalized PSEs for the temporal task were significantly higher than those for the numerical task, $t(37) = 5.48$, $p < .001$, and there was no correlation across tasks, $r = .090$, $p = .590$, which suggests that temporal and numeric judgments functioned independently within individual participants.

Time

Consistent with previous findings (Droit-Volet et al., 2004), results of the temporal task showed that participants overestimated durations presented after angry faces compared with durations presented after neutral faces, as evidenced by a lower PSE for the former (see Fig. 1). Relative to the PSE for neutral-face trials ($M = 938.16$ ms, $SD = 134.41$ ms), the PSE for angry-face trials ($M = 908.63$ ms, $SD = 118.29$ ms) was significantly lower, $F(1, 37) = 5.94$, $p = .020$, with the PSE for happy-face trials falling in between these values ($M = 932.05$ ms, $SD = 121.02$ ms; contrasts of happy- and neutral-face trials, and happy- and angry-face trials were nonsignificant, ps $> .08$). PSEs for trials with neutral faces and baseline trials (no faces) were not significantly different ($p > .08$).

Number

In contrast to the temporal task, both emotion stimuli (angry and happy faces) in the numerical task led to underestimation relative to neutral faces (see Fig. 1). The PSE for angry-face trials ($M = 8.71$ dots, $SD = 0.95$) was greater than the PSE for neutral-face trials ($M = 8.53$ dots, $SD = 1.04$), $F(1, 37) = 4.38$, $p = .043$, and the PSE for happy-face trials ($M = 8.75$ dots, $SD = 0.92$) was also greater than the PSE for neutral-face trials, $F(1, 37) = 4.87$, $p = .034$ (the contrast of happy- and angry-face trials was nonsignificant, $p > .6$). PSEs for neutral-face trials and baseline trials did not differ significantly ($p > .6$).

Discussion

Entirely different and opposing patterns of results were observed in the temporal and numeric tasks. Consistent with previous studies (e.g., Gil & Droit-Volet, 2011), our findings revealed that durations were overestimated under the influence of negative emotion (angry faces). In contrast, number was underestimated following presentation of angry and happy faces. These opposing shifts in numeric and temporal judgments under the influence of emotion, the significantly higher PSEs for time than for number, and the finding of no correlation across modalities suggest that separate cognitive systems are responsible for tracking time and number. Moreover, the difference

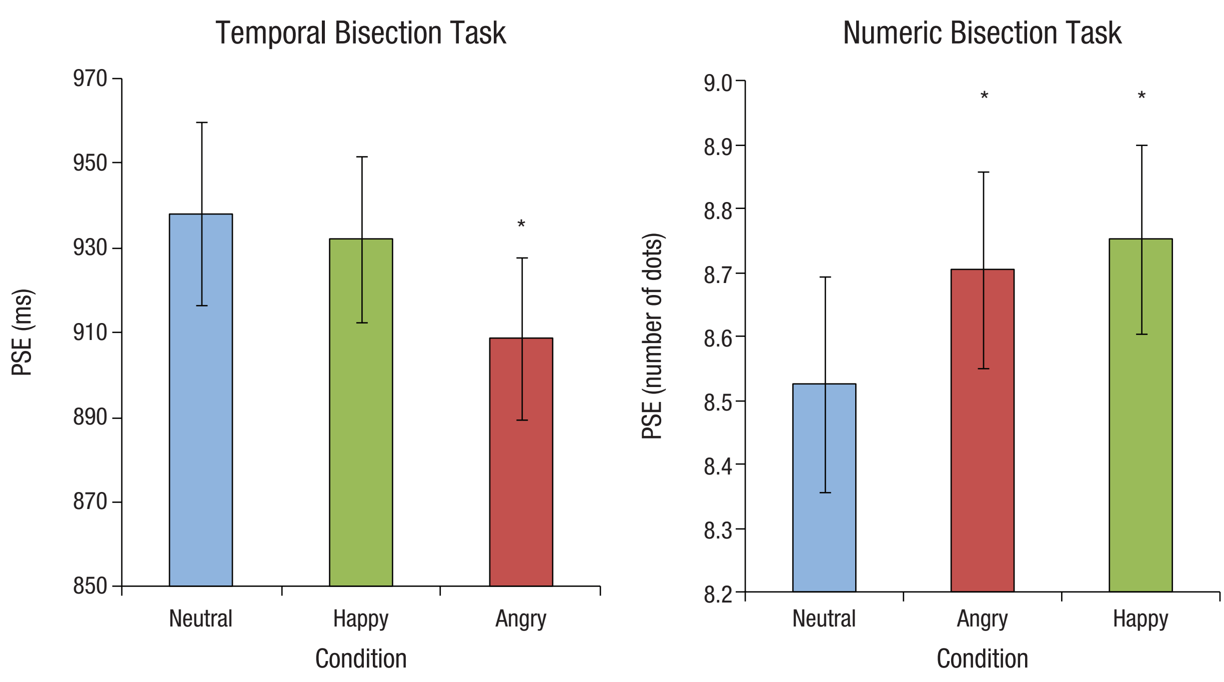

Fig. 1. Point of subjective equality (PSE) as a function of emotion condition for the temporal bisection task (left panel) and the numeric bisection task (right panel). Error bars indicate standard errors. Asterisks indicate a significant difference from the neutral condition. $N = 38$.

in the strength of the effects across emotion categories implies that the mechanism behind the shifts may differ as well: The largest effects were found after presentation of emotion faces with the highest arousal ratings (angry faces) for time, and no significant difference was found between the effects of happy or angry faces for number. The pattern of duration overestimation aligned well with arousal ratings of faces in our task, which provides further support for claims of arousal-modulated temporal overestimation (Droit-Volet et al., 2004).

However, the mechanism driving the novel finding of underestimation of numerosities under the influence of emotion is unclear. One possibility is that numeric perception was affected by emotion via effects on attentional focusing. Supporting this hypothesis is evidence that numeric processing draws heavily on regions of the brain implicated in maintaining control of visual attention (such as the intraparietal sulcus; e.g., Corbetta & Shulman, 2002; Piazza, Mechelli, Price, & Butterworth, 2006) and findings of changes in perceptual ability as a result of effects on attention from emotion (Phelps, Ling, & Carrasco, 2006). This possibility, along with the question of why emotion-based effects on attention would lead to seeing fewer things, is ripe for investigation.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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