The impact of emotion on numerical estimation

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Abstract

Research has demonstrated that both attention and emotion influence temporal perception. Even though behavioral findings support a common system for temporal and numerical estimations, no research has investigated the impact of emotion on numerical estimation or the role that attention plays in that process. Using a numerical bisection task, the current research investigated enumeration of emotional events (Study 1) as well as the influence of attentional distraction (Study 2). Overall, (1) the number of emotional faces is underestimated compared to the number of neutrally valenced faces, and (2) when attention is divided, the number of negatively valenced faces is underestimated. Emotional stimuli may capture attention more rapidly, and as such, increase enumeration accuracy.

Introduction

Emotions play a critical role in human functioning and have been considered by some as the primary motivational system in humans, involved in organizing cognition, perception, and action (e.g., Izard, 1977; Tomkins, 1962, 1963). Because of the important role emotions have been hypothesized to serve in assisting individuals with successfully navigating their physical and social environments, certain researchers have addressed how emotions affect perception. It is known that time and number share common behavioral signatures in humans and non-humans and may perhaps rely on a common mechanism (e.g., Bueti and Walsh, 2009; Cantlon et al., 2009; Meck and Church, 1983; Walsh, 2003). Despite this burgeoning body of work documenting the similarities between numerical and temporal processing, a distinct gap in our knowledge of number representation remains: What is the effect of emotion on numerical representations?

Common Representation of Number and Time

Different magnitudes may be represented similarly in both behavioral and neural systems by humans and non-human animals, such as brightness, size, time, length, and number, with Weber's Law underlying the format of all such nonverbal representations. (e.g., Cantlon et al., 2009; Hubbard et al., 2005). One possibility for a mechanism that organisms use to represent both time and numerical stimuli is the mode-control model, a serial process that represents continuous magnitudes directly analogous to the quantities they represent (Meck and Church, 1983; Meck, Church, and Gibbon, 1985). Comprising this model are a pacemaker, an accumulator, a working memory buffer, reference memory, comparator, and a mode switch that allows the model to either time or count. First, pulses are gated into the accumulator at stimulus onset by one of three different modes, depending on the nature of the stimulus: (1) In the run mode, the initial stimulus starts an accumulation process that continues until the end of the signal or trial (allowing the organisms to estimate duration); (2) in the stop mode, the process occurs whenever the stimulus is physically present (allowing the organism to estimate duration); (3) in the event mode, each onset of the stimulus produces a relatively fixed duration of the process regardless of stimulus duration (allowing the organism to represent number). All three of these different modes illustrate how the mode control model is used for both temporal perception and enumeration of stimuli. Next, the accumulator value is transferred to working memory or reference memory. Finally, the organism subsequently compares the current value in the accumulator with the value(s) in reference memory to determine what type of response- either temporal or numerical- is appropriate.

Evidence that the same mechanism, the mode control model, could be used for both time and number can be found across a variety of animal species (e.g. Fetterman, 1993; Meck &Church, 1983; Meck, Church & Gibbon, 1985; Roberts, Coughlin, & Roberts, 2000; Santi & Hope, 2001). Meck and Church (1983) showed that rats encode both time and number when the two dimensions are confounded. Rats were trained on a duration bisection task that confounded the number of cycles of each stimuli with the duration of each stimuli in seconds. During test, (1) the duration of the stimuli was held constant while the number of cycles varied or (2) number of cycles was held constant while duration. Rats' behavior in either scenario was modulated by whichever stimulus dimension varied, showing that they had encoded both duration and quantity of the stimuli.

In the mode control model, an attentional system—which can allocate differential resources to incoming stimuli—is added to the mode switch, helping explain erroneous estimations of time and number. For example, research suggests that attentional distraction can either delay the mode switch closing or prematurely open it, resulting in a net loss of pacemaker pulses. Buhusi and Meck (2005, 2006, 2009) reported that when reallocation of attention occurs- through the use of distracters and/or gaps- timing is delayed.
This loss of pulses in the accumulator results in a consistent underestimation of time (Buhusi & Meck, 2006, 2009; Coull, et al., 2004; Meck & MacDonald, 2007). Overall, these results support a common system of timing and number- the mode control model- that is influenced by attention distraction through the mode switch, causing underestimation of duration.

Effects of emotion on attention and temporal processing

Emotional salience can significantly impact attentional priority, with highly emotional stimuli directing both conscious and unconscious attention away from neutral stimuli (Taylor & Fragopanagos, 2005). Emotional stimuli have been shown to: (a) be more accurately and rapidly detected than neutral stimuli, regardless of the number of neutral distracters (Ohman, Flykt, & Esteves, 2001), (b) remain more detectable within an attentional blink paradigm, even persisting past the point at which neutral stimuli become minimally detected (Anderson & Phelps, 2001), and (c) capture automatic attention earlier than neutral stimuli when measured by event-related potentials (Carretie et al., 2004). Overall, previous findings demonstrate how both detected and undetected emotional stimuli impact cognitive and neural processes involved with attention.

Recent findings have provided substantial evidence that emotions also impact temporal processing by causing overestimation of the duration of emotional: (a) events (Meck, 1983; Stetson, Fiesta, & Eagleman, 2007), (b) faces (Droit-Volet, Brunot, & Niedenthal, 2004, Gil, Niedenthal, & Droit-Volet, 2007), and (c) other stimuli (Angrilli, et al., 1997). When experiencing stressful events, such as foot shocks (Meck, 1983), and forcing eye contact with an angry face (Schiff & Thayer, 1970), higher arousal level is hypothesized to increase the pacemaker's speed, thereby impacting the number of pulses acquired in the accumulator. Droit-Volet and colleagues (2004, 2007) have investigated how perception of emotion (anger, happiness, or sadness) in human facial expression impacts temporal perception in a duration bisection task. Participants are first trained to discriminate between two anchor durations (short vs. long). They are then required to classify intermediate durations as being more similar to the short or long anchor durations.

Participants consistently underestimated neutral compared to emotional faces. Overall, research supports that emotional stimuli are timed differently than neutral stimuli (e.g., Angrilli, Cherubini, and Pavese, 1997; Droit-Volet, Brunot, and Niedenthal, 2004; Gil, Niedenthal, and Droit-Volet, 2007; Watts and Sharrock, 1984). but enumeration of emotional events has not been investigated.

Current Research

While previous research has demonstrated that (a) duration of neutral events are underestimated compared to emotional events, (b) attentional distraction influences time causing underestimation, and (c) a common mechanism may be used for both time and number, no research has investigated enumeration of emotional events or the role that attentional distraction plays in this process. Using a numerical bisection task, the current research investigated enumeration of emotional events (Study 1) as well as the influence of attentional distraction (Study 2).

Methods-Study1

Participants

Participants (n = 61) consisted of undergraduates in psychology classes at Utah State University. Participants received course credit for participating.

Materials: Apparatus and Stimuli

All participants completed a computer-based numerical bisection task that presented facial stimuli and recorded keyboard responses using E-Prime over the course of approximately 30 minutes. The experiment was run on a Dell Optiplex 755 computer with a 21-inch monitor in a dimly lit room. Participants sat approximately 45 cm from the display. Participants made all responses using a keyboard.

So that numerosity did not always co-vary with other quantitative properties such as surface area, three stimulus sizes were used within each stimulus set. The stimuli presented during the practice trials were neutrally valenced and consisted of small (8 x 11 cm), medium (22 x 16 cm), and large (44 x 32 cm) female face photographs (Tracy, et.al., 2009). The stimuli presented in testing trials consisted of the same small, medium, and large sizes used in the practice but included (1) angry, (2) happy, and (3) neutral female faces. All faces used had been previous coded for purity of expression (Tracey, et.al., 2009). In both phases, varying the position of presentation on an invisible 12 x 12 grid randomized the position of the stimulus.

Procedure

Participants were instructed to sit comfortably in front of the keyboard and to use two hands when responding to the task. A numerical bisection task was presented with two trial phases: (1) practice, and (2) testing. Participants pressed the space bar to initiate each trial.

In the practice phase, neutrally valenced stimuli were presented in a large (24) or small (6) quantity. Participants were instructed to press the ‘d’ key if the quantity of stimuli was closer to 6 or the ‘k’ key if the quantity was closer to 24. Twelve trials were presented for each quantity, and feedback was given after each trial. Positive feedback consisted of a visual display of “Correct!” on the screen for 1500 ms, while negative feedback consisted of “Incorrect” for 1500 ms. Participants were then instructed to press the spacebar to begin the next trial. In the testing trials, feedback was eliminated, and valenced faces were also presented as the stimuli to be enumerated. Nineteen quantities, ranging between 6 and 24, were presented in random order. Each quantity had four presentations of each valence (angry, happy, and neutral), 12 trials for each quantity, for a total of 228 test trials.

Results

For the training phase, all participants performed on or above 90% demonstrating an understanding of the task. For the testing phase, the proportion of large responses was calculated for each participant separating each score by quantity and stimuli valence (i.e. 6 angry stimuli). To evaluate any significant differences between numerical estimations of different emotional facial expressions, a non-linear regression analysis was performed for each group of emotionally valenced stimuli (happy, angry, and neutral) [model: Y=1/(1+[x/T50]^-

E)] to acquire the numerical sensitivity (slope, E) and bias (point of subjective equality, PSE) for each participant. These values were compared using a repeated measures ANOVA.

Consistent with previous timing literature, no significant differences in sensitivity to change in number (k) were found (p = .1621). A significant difference in PSE was found (F (2,60) = 6.459, p = .0022) with angry faces being significantly underestimated compared to numerical estimations of neutral faces (t(60) = 2.800 , p< .05.; angry: M = 12.90, neutral: M = 12.47) and (b) happy faces significantly underestimated compared to numerical estimations of neutral faces (t(60) = 3.352, p<.05 ; happy: M = 12.98, neutral: M = 12.47). No significant differences between angry and happy faces were found (t (60) = 0.5521, p>.05). Overall, higher estimations of number were found for emotionally valenced faces compared to neutral ones supporting that perception of emotion causes a rightward shift of psychophysical functions of participants' numerical estimation.

Discussion

Study 1 found that emotional stimuli produced underestimation of number. Emotional stimuli capture attention more rapidly than neutrally valenced stimuli (Baumeister et al., 2001; Ito et al., 1998), possibly accounting for the similarities between attentional distraction and perception of emotion on enumeration. Study 2 was thus designed to tax attentional allocation to stimulus enumeration and therefore evaluate the role of attention on enumeration of emotional stimuli. Furthermore, the small mean difference found between enumeration of emotional and neutral stimuli in Study 1 may be due to a possible ceiling effect. As such, attentional distraction will increase the difficulty of the task.

Methods- Study 2

Participants

Participants (n= 28) consisted of undergraduates in psychology classes at Utah State University. Participants received course credit for participating.

Materials: Apparatus and Stimuli

All participants completed the same computer-based numerical bisection task used in Study 1. A concurrent attentional distracter task was run on a Dell Latitude D830 laptop with a 15.4-inch monitor. Two numbers, between 1 and 9 (e.g. 4 5), were presented in 18 size font on the center of the screen. Participants were instructed to press the spacebar every time the numbers added up to 10 or more. Once the spacebar was pressed the number immediately progressed to the next set. If the numbers did not add up to 10 or more the numbers automatically progressed to the next set after 2000 ms. Participants made all responses using the laptop keyboard.

Procedure

Similar to Study 1, participants were asked to sit comfortably in front of both computers. Prior to the numerical bisection task each participant was given verbal instruction on the attentional distraction task and asked to complete five practice trials with feedback presented for 1500 ms. Feedback consisted of "Correct!" every time (a) the two numbers added up to 10 or more and the spacebar was pressed or (b) the numbers did not add up to 10 or more and the participant waited for the next number set to be presented. Feedback of 'Incorrect" was presented for all other trials. The feedback was eliminated in test. Next, participants completed the numerical bisection task practice trials. Upon completion of each practice session the researcher instructed the participant that they would be performing both tasks concurrently. Furthermore, the participant was instructed to be as accurate as possible on the attentional distraction task. When the numerical bisection task was complete the session was finished.

Results

Again, all participants performed on or above 90% in practice demonstrating an understanding of the task. For the testing phase, within-subject analyses found significant differences in PSE (F(2,27)= 5.093, p = .00094) with (1) happy faces being significantly overestimated compared to angry faces (t(27) = 4.040, p < .05; angry: M = 12.37, happy; M = 11.60), (2) happy faces being significantly overestimated compared to neutral faces (t(27) =

3.763, p <.05; happy; M = 11.60, neutral; M = 12.32), and (3) no significant difference between angry and neutral faces (t(27) = .02770, p >.05). Post hoc rating (1 being negative, 10 being positive) of the three emotional faces suggests that participants perceived neutral faces (M = 5.2) to be closer in valence to angry (M = 2.5) than happy (M = 9.5) with a larger difference between neutral and happy (4.0) compared to neutral versus angry (2.9).

Discussion

Study 2 taxed attentional allocation and found significant underestimation of the number of neutral and negative faces compared to happy faces. Furthermore, a post hoc rating suggests that the neutral stimuli were perceived to be closer to angry than happy, creating a possible explanation for the similarity in enumeration of angry and neutral faces.

The tendency for negative faces to capture attention more rapidly is seen in the literature with participants attending preferentially and being more sensitive to negative over other types of information (Baumeister, et. al., 2001). Furthermore, extreme negative images produce larger amplitude late positive potentials as measured by ERP's than do equally extreme positive images in young adults (Ilt, et al., 1998).

Future studies can further investigate the role of attention and emotion on the mode-control model by evaluating attentional distraction during temporal perception of perceived emotion.

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