The Temporal Features of Emotional Capture of Attention:

Determining the Time Course of the Emotional Attentional Blink

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Abstract

Within a variety of stimuli, we selectively attend to the most emotionally relevant, often at a cost to the processing of the other stimuli. The emotional attentional blink (EAB) is an effect in which emotional distractor images capture attention for several hundred milliseconds so that individuals cannot detect subsequent target images. In this study, we hoped to pinpoint the time course of the emotional capture of attention by creating a multi-target design based on Most and colleauges' (2005) original EAB study. In Experiment 1, letters were presented on images following the distractor, and participants were asked to report which letter they first recalled seeing. We found that emotional distractor images, including erotic and gory conditions, induced greater deficits than non-emotional distractor images. In Experiment 2, participants reported not only the first letter they saw, but also the last number (presented before the distractor image) they saw. The task in Experiment 2 suggests an EAB that lasts between 200-400 ms. However, the use of two processing streams (the letters and images) suggests that modality serves an important role in the mechanisms of the EAB.

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Each day, we are presented with a variety of sensory stimuli, ranging from a ringing phone to a threatening dog to a neighbor's wave. To prioritize among such a quantity of perceptual information, we selectively attend to the most salient stimulus present at a given point in time. Evidence indicates that individuals more readily identify emotionally relevant stimuli amidst those that are emotionally irrelevant (Öhman, Flykt, & Esteves, 2001). It has been suggested that if something in the environment is perceived as threatening, survival can be maximized by prioritization of those emotion-evoking stimuli (Most & Jungé, 2008). To better analyze the interaction of emotion and attention, it is important to determine the temporal features of emotional capture of attention.

With the constant stream of sensory information presented to us, it is necessary to have a mechanism for detecting what is important. Research on attention has identified two distinct ways of allocating our attention throughout daily operations: goal-driven and stimulus-driven (Egeth & Yantis, 1997). According to Egeth and Yantis, goal-driven attention is implemented under voluntary control to concentrate on certain stimuli from the environment. For example, when someone searches for another in a crowd, his attention is concentrated on finding that person. However, our attention system must also be adaptable enough to attend to threatening or emotional stimuli to avoid harm and understand social situations, a necessary distractibility known as stimulus-driven attention (Most & Jungé, 2008; Egeth & Yantis, 1997). Task irrelevant identification has been proven to be driven by highly salient items and to utilize stimulus-driven attention (Yantis & Egeth, 1999).

Due to the variety and quantity of stimuli in our environment, there must be one or more mechanisms for allocating attention. Raymond and colleagues suggest that our attention system may be gate-modulated and identification of target information might involve an opening and closing of a gate to regulate the flow of visual information to conscious recognition (Raymond, Shapiro & Arnell, 1992). According to this idea, an attentional episode begins when a defining feature of a stimulus is detected and is completed upon target recognition. The presentation of new information before the original attentional episode is complete results in a disturbance in the processing of the visual information. Raymond et al. (1992) first described this disruption of attention, arguing that the identification of a first target (T1) within a stream impairs one's ability to detect the second target (T2) if there is a short time period between T1 and T2, a phenomenon referred to as the attentional blink (AB).

The attentional deficit in the attentional blink paradigm may be attributed to capacity-limited attentional resources (Dux & Marois, 2009). Chun and Potter (1995) proposed a two-stage bottleneck model to explain the capture of attention in the AB paradigm. In the first stage of the model, each stimulus is perceptually processed regardless of how fast it is presented. In the second stage of the model, identification and consolidation of the target into working memory occurs. Representations resulting from stage 1 processing are not sufficient for subsequent report and may deteriorate rapidly; thus, stage 2 processing is necessary for full identification of targets and registration in working memory. This model attributes the attentional blink to severe capacity limitations during the second stage of processing.

It is clear that our attention system responds differently to certain information, and a fruitful area of recent research focuses on the extent to which emotion or emotionally salient items can occupy attention. It has been found that emotional images disrupt attention more than their neutral counterparts (Anderson & Phelps, 2001). In conjunction with this idea, Most, Chun, Widders, and Zald (2005) created a modified version of the attentional blink paradigm to evaluate if task irrelevant emotional distractor images would elicit the same attentional deficiencies as task relevant T1 stimuli used in the attentional blink paradigm. In the original emotional attentional blink (EAB) task, participants were presented with a series of upright landscape or architectural images. Within this rapid serial visual presentation (RSVP) stream, a critical distractor (negative, neutral, or scrambled-negative) was placed either two or eight images before a target image. Targets included images rotated either 90 degrees left or 90 degrees right. At the end of each trial, participants were asked to report in which direction, if any, the target images were rotated. At lag 2, or by the second image following the distractor, participants demonstrated a significantly worse ability in detecting the target when it followed an emotional distractor as opposed to its neutral counterpart (Most et al., 2005). However, by lag 8, attentional deficiencies had recovered and participants' accuracy improved in target detection regardless of an emotional or neutral distractor image. This indicates that the attentional deficit that occurs following a distractor image is recovered by lag 8, or by the eighth image following the distractor.

The original studies testing the EAB used aversive or emotionally negative stimuli to demonstrate the effects of emotion-induced blindness (Most et al., 2005; Smith et al., 2006). Early detection of threatening or fear-evoking stimuli makes sense for survival since a more immediate response to such stimuli is necessary. However, research has suggested that erotic distractor images can induce an EAB that is often more robust than the effect produced by aversive distractor images (Most et al., 2007). The effect of erotic stimuli in occupying attention is not limited to visual scene stimuli: the emotional attentional blink can be observed in tasks analyzing target detection in cases of sexual or offensive distractor words in comparison to neutral distractor words (Arnell, Killman, & Fijavz, 2007). In a follow-up task examining the power of erotic distractor images, the EAB persisted even when participants were offered performance-based monetary incentive to concentrate on target detection accuracy in RSVPs with erotic distractors (Most et al., 2007). It appears that there may be an intrinsic capability of emotional stimuli to capture attention among other non-emotional distractors.

Despite the similarities between the attentional blink seen in the traditional AB paradigm and emotion-induced blindness found in EAB studies, subtleties distinguish how the attentional processes in each model differ from one another. The traditional AB task (e.g., Raymond, Shapiro & Arnell, 1992) demonstrates disrupted target detection due to a depletion of attentional resources; when T1 is detected and is undergoing stage 2 processing, subsequent stimuli cannot be processed if this stage is already occupied (Chun & Potter, 1995). On the other hand, the emotional attentional blink (e.g., Most et al., 2005) measures the impact of the stimulus-driven attentional capture on detection of target stimuli (McHugo, Olatunji, & Zald, 2013). These differences in the models of attention are important to consider when determining the impact of emotion in attentional processes.

The EAB has a characteristic time course. In the original EAB task created by Most and colleagues (2005), target images were placed at two temporal positions, either 200 ms (lag 2) or 800 ms (lag 8) following the critical distractor image. The data indicates emotion-induced blindness at lag 2, but a recovery of attention by lag 8. Recently, Ciesielski and colleagues (2010) further examined the time course of emotion-induced blindness by examining performance at 4 different lags (2, 4, 6 and 8). The authors found that in the emotional conditions, relative to the neutral ones, participants were significantly less accurate in their responses at lag 2, lag 4 and lag 6 (see Figure 1). However, at lag 8, participants were modestly, but statistically significantly, more accurate in identifying the target images following erotic, disgust, and fear distractors. As depicted in Figure 1, the magnitude of the blink is substantial at lag 2, but it weakens as the lag gets longer. Although emotion-induced blindness is present up until lag 6, results demonstrate a reduced effect between lags 4 and 6 before attention is enhanced at lag 8. This reduced effect indicates that attentional resources are likely to recover before the lag 4 to lag 6 window of time.

At present, the exact time course of the emotional attentional blink is unknown. As noted above, it is suggested that the effects of the emotional attentional blink are most robust at 200 ms; these effects are then reduced at intermediate lags (between 400 ms and 600 ms) before demonstrating normal or modestly enhanced detection at 800 ms (Ciesielski et al., 2010). We investigated the time course of the emotional attentional blink by implementing a modification of the EAB paradigm involving multiple targets to pinpoint when attentional resources become available again following an emotional distractor. Understanding the time course of affect is critical in assessing how emotion can impair attention, how the emotion and attention systems interlink, and how individual differences can alter these emotion-attention interactions.

Based on Ciesielski and colleagues' recent study (2010), it is suggested that some subjects will be able to on average start to recover between 200 and 400 ms following an emotionally salient image. However, there may be both intra- and inter- subject differences such that some trials or some subjects will require somewhere between 400 ms and 800ms to have full recovery from emotional effects. By asking participants to identify which target image they see first amongst a series of targets, we hope to better understand the time course that represents the extent of the effects of the emotional attentional blink following the distractor images.

Experiment 1

Method

Participants. Ten Vanderbilt undergraduate students participated in this study for research experience credit as part of psychology courses. All participants had normal or corrected-to-normal vision and were at least 18 years of age. The average age was 18.3 years old (*SD*=0.46). In this sample, nine participants were female and one was male. The study was approved by the Vanderbilt University Institutional Review Board (IRB), and each participant gave informed written consent, as per Vanderbilt University IRB guidelines.

Stimuli. The visual stimuli consisted of color photographs (320 pixels x 240 pixels) and included both critical distractor images and noncritical distractor images, both with numbers or letters imposed in the middle of them. Noncritical distractor images were drawn from a pool of 164 upright landscape and architectural photographs. There were four categories of critical distractors: neutral images, aversive images, erotic images, and scrambled versions of the erotic images. Scrambled versions of the erotic conditions were created to ensure that behavioral differences were not attributed to the white and skin-toned coloring of the images, but rather the emotionality of the erotic scenes (see Figure 2).

Each of these four categories of critical distractors contained 48 distinct images. Aversive and neutral images were drawn mostly from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). Erotic images were drawn partly from the IAPS and supplemented with pictures that have been previously used in our lab from publicly available sources. Scrambled images were created in Matlab (version 7.8.0, The MathWorks, Inc., Natick, MA) from the erotic images by rearranging the color pixels into a random presentation.

Examples of negative images include gory or bloody humans, individuals at gunpoint, or fear-evoking animals. The erotic pictures included images of nude couples engaging in sexual scenarios. Neutral images were scenes that included both animals and humans that did not elicit an emotional reaction.

Procedure. Experimental trials consisted of an RSVP of 17 images presented using E-prime Software (version 2.0, Psychology Software Tools, Inc., Pittsburgh, PA) on a high CRT Dell monitor with a 70 Hz refresh rate. Participants were seated approximately 60 centimeters from the screen. Sixteen of the 17 images were presented for 100 milliseconds. The critical distractor images (erotic, gory, neutral, or scrambled), however, were presented for 120 milliseconds to increase the likelihood that the distractor image was consciously perceived. All images in the stream were upright landscape or architectural photos except for the critical distractor image (see Figure 3). Both noncritical distractors (landscape and architectural images) and critical distractors were randomized within each trial. Depending on the trial, the forth, sixth, or eighth stimulus in the stream was the critical distractor: an aversive, erotic, neutral, or scrambled image.

Each of the images within the stream contained a letter, number, or symbol on it. Images that appeared before the critical distractor contained numbers (2, 3, 4, 5, 6, 7, 8, 9) or symbols (?, #, &, %, *, ~) imposed on the image. For the images following the appearance of the critical distractor, letters (A, Q, E, X, R, T, H, J) were imposed on the image. All text was presented in Constantia font at point size 50. After the eight letters following a critical distractor were exhausted, the remaining symbols were presented to finish the stream. A symbol was also presented on the critical distractor image so that it had a text target just as the other images. The numbers, letters, and symbols were presented in a light gray color dubbed “Silver” in E-Prime so that they could be seen regardless of the background image color. The location of each target (numbers, letters, or symbols) was randomized within the confines of each image on the screen, placing them in the vicinity of the center of each image. The numbers, letters, and symbols were also randomized within each trial. At the end of each trial, participants indicated which letter they first recalled seeing by pressing the corresponding key on the keyboard. Number and symbol responses were not permitted in this design to ensure that participants understood the instructions of the task and solely focused on the first letter that recalled seeing.

Participants began with a short practice session consisting of 12 trials that included no critical distractors or images from the actual experiment. The letters appearing on the screen in the practice trial differed as well (W, C, F, G, Y, B, P, U). Instructions emphasized that participants should focus on the first letter they remember seeing. After the practice session, participants were instructed that some of the images in the next portion of the task would be more emotional in nature. Following these instructions, 4 blocks of 48 trials each were presented. Within each block, the computer randomized the order of trials with 12 trials of each condition randomly intermixed throughout the block. The lag, or the time lapse between the distractor and the participant's letter response, was recorded for each trial. Because not all responses were letters that were actually presented, responses of invalid letters were recorded as lag 8 (thus treating 800 ms as the maximum length of a possible emotional attentional blink). Brief breaks were given between each of the self-contained blocks.

Results

Table 1 presents the mean lag at which a letter was accurately reported for each distractor type, which provides an index of the length of the EAB on each trial. Distractor type demonstrated robust effects across subjects. A repeated-measures analysis of variance revealed that participants responded at different lags depending on the distractor type [$F(3,9) = 41.83$, $p<.001$]. Post-hoc comparisons using two-tailed t-tests revealed that the mean lag in neutral and scrambled conditions did not significantly differ, $t(9)=1.31$, $p=0.22$. The gory condition produced lags significantly greater than both the scrambled and neutral conditions, $t(9)=8.60$, $p<.001$ and $t(9)=4.12$, $p=.003$. Erotic conditions also produced lags significantly greater than the scrambled and neutral conditions, $t(9)=9.09$, $p<.001$ and $t(9)=7.33$, $p<.001$. The erotic condition additionally produced statistically greater lag than the gory condition, $t(9)=4.54$, $p=.001$. The ability for erotic images to capture attention to a greater degree than gory images aligns with previous findings (Most et al., 2007; Cieselski et al., 2010).

Figure 4 reflects the distribution of target responses at each of the eight lags. In Experiment 1, frequency of responses at lag 1 was greater than frequency of responses at lag 2 in every condition except erotic. The high number of responses at lag 1 is notable in that it is faster than would be predicted given the length of the EBA in past studies. Additionally, age and gender did not correlate significantly with performance on each type of distractor, rs=.066-.453, N=10, *p*s=.120-.855 and rs=.227-.528, N=10, *p*s=.117-.528. However, there was a significant correlation between one's performance with one type of distractor and performance on each of the other distractors, ranging across conditions, rs=.748-.950, N=19, *ps*=.001-.013. For instance, mean lag in the gory condition was correlated with mean lag in the erotic condition, $r=0.75$, $N=10$, $p=.013$.

Discussion

The results from Experiment 1, using the first version of the paradigm are informative: erotic distractors captured attention longer than other distractor types. As suspected, gory images still capture attention significantly longer than their neutral counterparts, but less than erotic distractor images. We note that our results are not likely attributable to low-level feature differences between the erotic and scrambled-erotic pictures (such as color or luminance) since performance on erotic images was significantly poorer than on the scrambled-erotic condition. Although these results align with predictions, the length of the observed EAB appears different than in past studies. Except in the erotic condition, the frequency of the participant responding at lag 1 was greater than any other lag (see Figure 5). This suggests that in many trials – regardless of the distractor condition – an attentional blink did not occur.

One potential explanation for this outcome is that this variant of the EAB task produces a lag-1 sparing effect. Lag-1 sparing refers to an effect in which accuracy of responses creates a U-shaped curve reflecting the poorest performance at lag 2 instead of at lag 1 (Potter et al., 1998). This effect has be attributed a slow attentional-gate: the gate opens upon seeing T1, and while processing T1, the slow gate allows for T2 to access attentional resources as well. Most and Jungé (2008) observed substantial declines in accuracy at lag 1 following emotional images; the lack of lag 1 sparing in the EAB task supports arguments that the processes underlying the EAB can be distinguished from processes underlying the standard nonemotional attentional blink. In the case of Experiment 1, lag-1 sparing is not likely the best explanation for the high frequency of lag 1 responses; the lag-1 sparing would suggest a bimodal distribution, not accounting for the subsequent high frequency of lag 2 responses. It is also important to note the possible impact of how we coded situations in which participants failed to identify a target (an invalid response was recorded as a maximum lag): there are more responses recorded at lag 8 than actually occurred, which increases the mean lag.

In all, the EAB seen in Experiment 1 is relatively short. Several factors might account for this brevity relative to what would be expected from standard EAB designs. One source of this rapid ability to detect letters may reflect the study design. Participants do not have to process the images as holistically as they have in previous designs; this version allows participants to hone in on a single target instead of processing the entire image. The brevity of the EBA in this design may also be interpreted as a reflection of low task difficulty. By solely searching for a letter within the stream, participants are able to utilize top-down goal directed attention to filter which visual information they attend to. This allows individuals to ignore the numbers and symbols presented before the distractor image. Since this multi-target design could measure the EAB differently than previous studies, we want to increase sensitivity to EBA effects to understand the chronometry better by boosting task difficulty.

Experiment 2

In Experiment 2, participants will be asked to identify targets preceding the critical distractor image in addition to identifying targets following the distractor image. In this design, numbers are presented before the distractor image and letters are presented following the distractor image, which allows for a report of both number and letter targets following the RSVP. It is predicted that, in having to report two targets of different categories, the task will be more challenging in terms of attentional resources than Experiment 1, thus Experiment 2 will likely result in a longer emotional attentional blink than found in Experiment 1. It is also hypothesized that retroactive emotion-induced blindness will exist at lag-minus-1, but will recover by lag-minus-2 (Most & Jungé, 2008).

There are most likely intrinsic differences among individuals in components of emotional responding; such variability is evident in the intensity and sequence of emotional reactions to stimuli seen across individuals (Davidson, 1998). Greater understanding of this mental chronometry may highlight individual differences in affective behavior. By requiring the recall targets presented both before and after the emotional distractor image, Experiment 2 will provide a better representation of the time course of the emotional capture of attention, highlighting both inter- and intra- subject differences.

Method

Participants. Twenty Vanderbilt undergraduate students participated for course credit for psychology courses. The average age was 19.05 years old (*SD*=1.10). Participants were 20 Vanderbilt University undergraduate students (14 females) who each participated for course credit for psychology courses. All participants gave written consent as per Vanderbilt University Institutional Review Board (IRB) guidelines.

Materials and procedure. Stimuli and procedure were largely the same as those in Experiment 1 with a few exceptions. Most notably, images preceding the critical distractor image contained only a number instead of a both numbers and symbols (see Figure 5). Following the stream of images, participants were asked to recall the last number (presented before the distractor image) as well as the first letter (presented after the distractor image) they saw in the stream. If the response was an invalid letter, it was recorded as lag 8, making 800 ms the maximum length for an emotional attentional blink in this design

Additionally, in this experiment, participants were asked to respond to three surveys evaluating certain personality characteristics. The *Attentional Control Scale* (ACS) consists of 20 statements regarding different ways people focus and shift attention (Derryberry & Reed, 2002). Participants rated each statement on a four-item Likert scale, where one represents "almost never" and four represents "always." An example item includes: "When I am reading or studying, I am easily distracted if there are people talking in the same room." Attention-related processes have been demonstrated to play a role in anxiety and psychopathy diagnoses, and the ACS has been used to evaluate these risks (Baskin-Sommers et al., 2009). The harm avoidance subscale of the *Tridimensional Personality Questionnaire* (TPQ) examines characteristics including anticipatory worry, fear of uncertainty, shyness, and fatigability (Cloninger, Svrakic, and Przybeck, 1993). Participants were given 34 statements correlating to the harm avoidance scale, and they were asked to mark each statement as true or false based on how well it described them. Lastly, *The NEO Personality Inventory* (NEO) was administered specifically to evaluate the neuroticism personality trait (Costa & McCrae, 1985). Participants were asked to respond to 48 statements by using a five-item Likert scale, one representing "Strongly Agree" and five representing "Strongly Disagree." The neuroticism trait identifies individuals who are prone to psychological distress and emotional instability (Costa & McCrae, 1985). These surveys will be used in analyses to compare personality indicators with performance on the EAB task.

Results

Table 1 reflects the mean lag for each distractor type in this experiment, providing an indicator for the length of the EBA in each condition. As seen in Experiment 1, distractor type caused robust effects on individual performance. As expected, a repeated measures ANOVA revealed significant differences between the four types of distractor images, $F(3, 18)=23.13$, $p<.001$. Post-hoc paired t-tests demonstrated a significant difference between neutral, gory, and erotic conditions to the scrambled condition, $t(18)=4.43$, 6.39, 6.19 respectively, *p*s<.001. The emotional distractor types, gory and erotic, were significantly more demanding than the neutral condition, $t(18)=4.81$ and 4.48 respectively, *p*s<.001. In Experiment 2, however, there was not a significant difference between gory and erotic distractor types, $t(18)=1.69$, $p=.108$. Thus, as expected, participants performed worse on the emotional conditions (gory & erotic) than the non-emotional conditions (scrambled & neutral).

As seen in Experiment 1, performance for one distractor type was indicative of performance on the other three distractor types, as reflected in correlations ranging from rs=.595-.902, N=19, *p*s=.001-.018 . Additionally, low-level features such as color and luminance do not appear to have contributed to participants' performance on the erotic distractor conditions due to the significant difference between the erotic and color and luminance matched scrambled-erotic conditions. In examining possible covariates in the analyses, there was a suggestion of age as a possible significant factor, however the effect was limited to a nonsignificant trend in this small sample [$F(1, 18)=3.372$, $p=.084$]. However, the age range was very limited (all undergraduate students), making it difficult to draw conclusions from these data. There was no effect of gender on task performance [$F(1,18)=.004$, $p=.950$]. Lastly, performance on this task was not influenced by personality factors; the three personality tests administered (ACS, TPQ, and NEO) failed to demonstrate significant correlations with performance on this multi-target EAB task.

Cross-experiment analysis. To compare performance on the "forward" EAB between the task in Experiment 1 (name letters only) and the task in Experiment 2 task (name number before and letter after), a repeated measures ANOVA was performed with task group entered as a between subjects variable. Results revealed a robust effect of distractor type across experiments [$F(3,27)=42.267$, $p<.001$]. This effect appears stronger when the two experiments are examined together than within experiments alone, reflecting the greater number of subjects and the consistency of the effect across task design. The between-subjects comparison of task1 (Experiment 1) and task 2 (Experiment 2) revealed a significant effect of task type [$F(1,27)=10.65$, $p=.003$] revealing a longer lag in Experiment 2 (see Figure 7). In evaluating performance on each task, we see a similar plot, yet a later lag in Experiment 2. To investigate these differences, we examined the interaction between task type and performance to assess if there is a standard relationship of distractor type that transcends task type. There was no evidence of a linear interaction between task (experiment) and critical distractor [$F(1,27)=.002$, $p=.965$], but results indicate a significant trend for a quadratic relationship [$F(1,27)=3.21$, $p=.084$] This trend is likely attributable to the big task difference in both the erotic and scrambled conditions (see Figure 7).

Discussion

Several of these results are consistent with the findings from Experiment 1. First, the most challenging distractor type was erotic, followed by gory, neutral, and scrambled. Performance on one type of distractor image was indicative of performance on the others in both experiments. Additionally, the robust effect of distractor type in the second experiment indicates that performance on emotional distractors was significantly different than performance on non-emotional distractors as well. Although the second experiment created a more challenging design reflecting a decreased frequency of lag 1 responses (see Figure 6), this multi-target task was insufficient in identifying the impairment or enhancement of attention from emotional distractors as suggested in previous studies (e.g. Ciesielski et al., 2010).

It is clear that individuals respond differently to emotional situations, yet personality traits that have typically been correlated with attentional processes did not show an effect in this design. We ran a small sample size due to time and effort. It would be useful to run this multi-target task in larger samples before dismissing the relevance of the neuroticism, harm avoidance, and attentional control personality traits. Given variability, a sample size of 49 subjects would be needed in order to have strong enough effect ($r=.30$, $\beta >.80$).

General Discussion

The general finding of this study reflects how distractor type impacts EAB determinations and performance on other types of distractors. Both experiments in this study reflect similar findings in the performance differences based on distractor type. Yet by examining the differences in timing between Experiment 1 and Experiment 2, it is clear that the task required matters substantially in determining the chronometry of the emotional attentional blink. The results from this study design examining the time course may be informative in considering the mechanisms of the emotional attentional blink.

The models explaining the nonemotional AB have been distinguished from ones describing the EAB. One theory explaining the AB paradigm is the two-stage bottleneck model of the AB (Chun & Potter, 1995), which proposes that the attentional deficits seen in the attentional blink can be attributed to gate-modulated attention in which subsequent stimuli cannot be processed if stage 2 processing (the bottleneck stage) is already occupied. This model could be applied to the EAB as well, but Most and Wang (2011) argue that emotion-induced blindness does not come from a central bottleneck in attentional processing (McHugo, Olatunji, & Zald, 2013). In a task involving two simultaneous RSVPs to test spatial attention, Most and Wang (2011) found that emotional disruption was only present if the targets were in the same location as the emotional distractor. A central bottleneck model implies that perceptual resources should have been distributed uniformly regardless of spatial relationship (Wang, Kennedy, & Most, 2012). Most and Wang argue that emotional distractors create competition for perceptual resources during a first stage of processing instead of at a central bottleneck as seen in the AB paradigm (Most & Wang, 2011; Wang et al., 2012).

The parallel processing of letters and pictorial stimuli in our multi-target study demonstrates several similarities with the dual stream design that Most and Wang (2011) created. The high frequency of responses at early lags suggests that the letter target was processed in a distinct stream from the emotional distractor image. This finding supports the capacity-limited resources theory and the argument of competition at stage 1 processing (Wang et al., 2012). Nevertheless, we see an effect of distractor type that indicates some effect of the emotional distractor image on performance, which supports a bottleneck model and an argument for competition at stage 2. Thus, the processing may depend on a level of independence of the streams. Whereas Most and Wang (2011) used the same design in spatially distinct streams, our design reflects the effect of different modalities. Our data indicates the possibility of both the capacity-limited resources account and the bottleneck model, which suggests competition at both stage 1 and stage 2 of processing.

Attentional models may not be mutually exclusive. In the nonemotional AB model, Di Lollo and colleagues (2005) recently challenged the resource depletion model by using a multi-target design, but later argued that the attentional blink cannot be explained by a single attentional phenomenon (Kawahara, Enns, and Di Lollo, 2006). The same is likely true with the EAB. Although previous discussions have focused on competition at either stage 1 or stage 2 of processing, our data suggests that resource limitation is flexible: it is dependent upon the relative salience of items. We should instead dub the model a *dynamic* two-stage model to reflect how perceptual competition may occur at different points in processing.

The manner in which our task required attention differed from past EAB designs. In past studies, participants have been asked to identify which direction a single target image is rotated (e.g. Most et al., 2005) and accuracy was recorded. In our design, however, participants were asked to identify the first letter they recall seeing. It is likely that some participants disregarded some of the images to better focus on the letter search. The top-down attention was sometimes uninterrupted by the emotional distractor, potentially due to its categorical difference from the targets. To account for this tendency, future studies should include a multiple-target design that requires holistic processing of the target images in the RSVP. We have begun work on a design that presents images of animals following the distractor image and asks participants which image they first recall seeing. Additionally, a within-subject design testing both a "holistic" EAB task and this multi-target task will be helpful in addressing models of attention.

To understand the chronometry of the EAB, it is important to pay attention to modality and how different tasks affect results. These differences will lead to a better understanding of the mechanisms underlying the EAB, elucidating exactly how emotion captures attention and to what extent. Since we selectively attend to emotional events in our daily lives, it is important to understand the ways by which task-irrelevant objects can disrupt our goal-directed attention. For instance, how long will a car accident distract us from driving? Or how long will a threatening dog distract from a calm jog through the neighborhood? By refining the exact time frame of the emotional attentional blink, we can pinpoint the moment in time when attention is able to refocus on its goal.

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Figure 1. The data from a study conducted by Ciesielski et al. (2010) suggest that the attentional deficit caused by emotional distractors was greatest at lag 2, or 200 ms. It is hypothesized that between lag 2 and lag 6, attentional resources had recovered. At lag 8, participants demonstrated a heightened attention to the emotional distractors as compared to neutral counterparts.

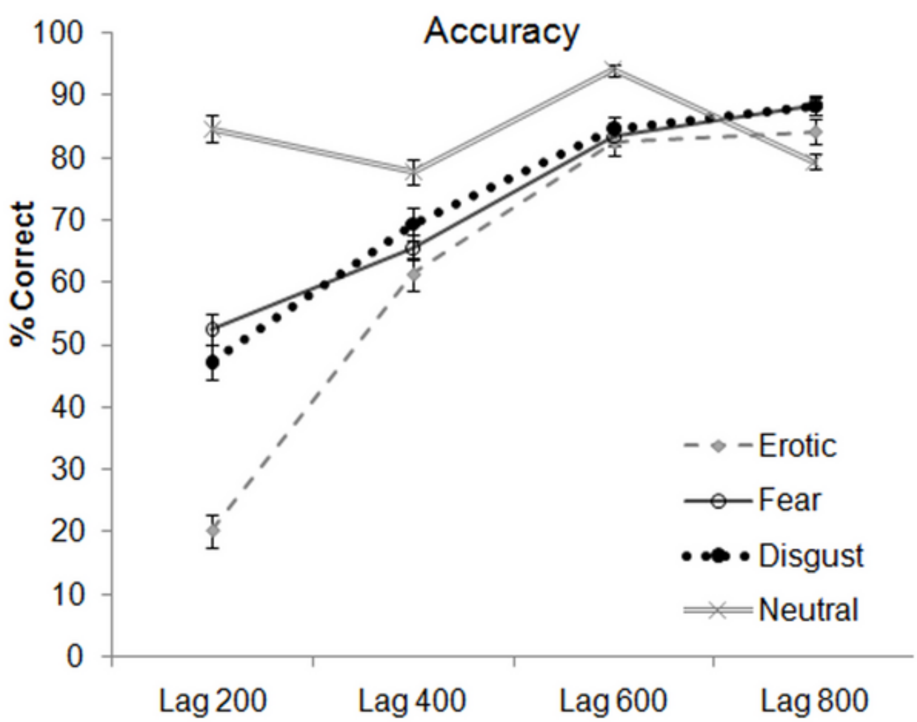

Figure 2. Example of a scrambled version of an erotic distractor image. These images were created on Matlab to ensure that it is the emotionality, and not the low-level features of an image such as color, is the reason for reduced ability to detect targets.

Figure 3. Schematic diagram of part of a trial. Distractors were erotic, neutral, aversive, or scrambled pictures. Images before the distractor contained a number in the middle of the image, while images following the distractor contained a letter. On each trail, participants were asked the last number they saw and the first letter they saw within the rapid stream of images. Each picture was presented for 100 ms, except the distractor image, which was presented for 120 ms.

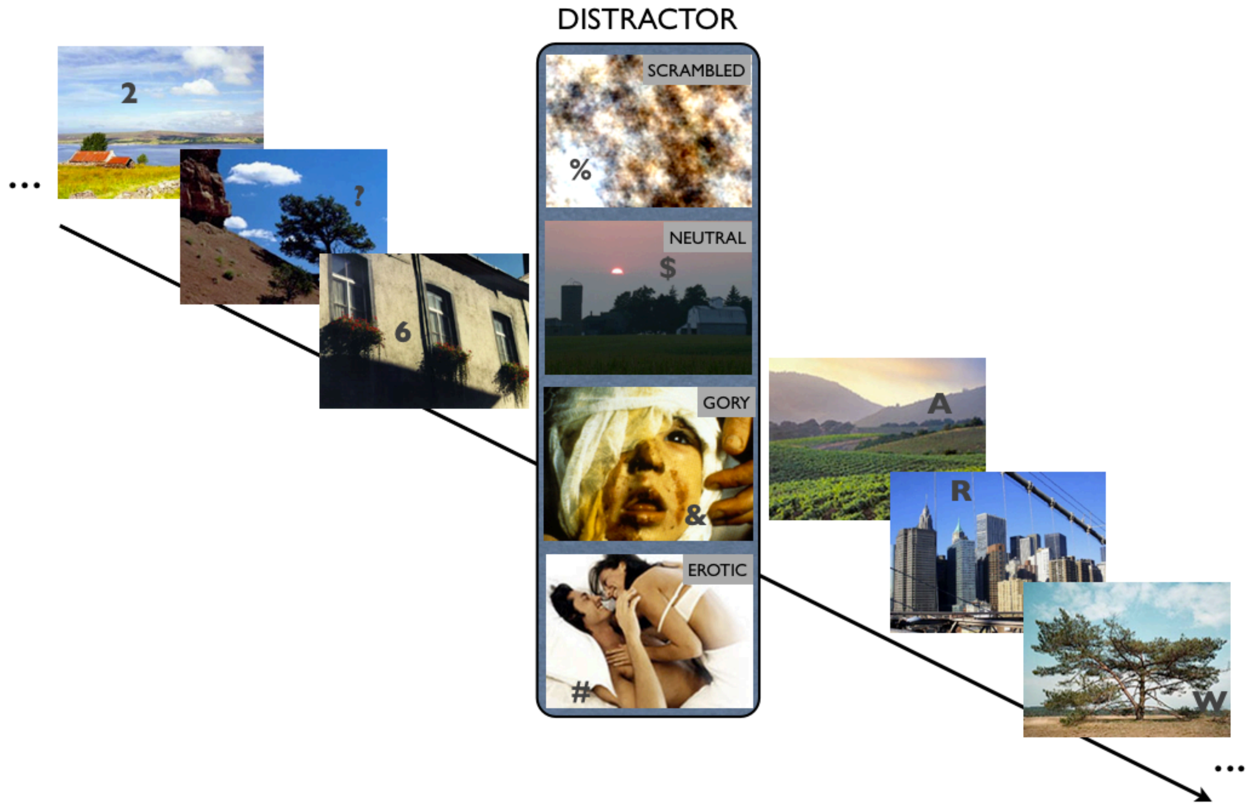

Figure 4. The frequency of each lag response varied depending on the distractor type (*N*=10). By evaluating this time course, we hope to pinpoint how long emotion can capture attention.

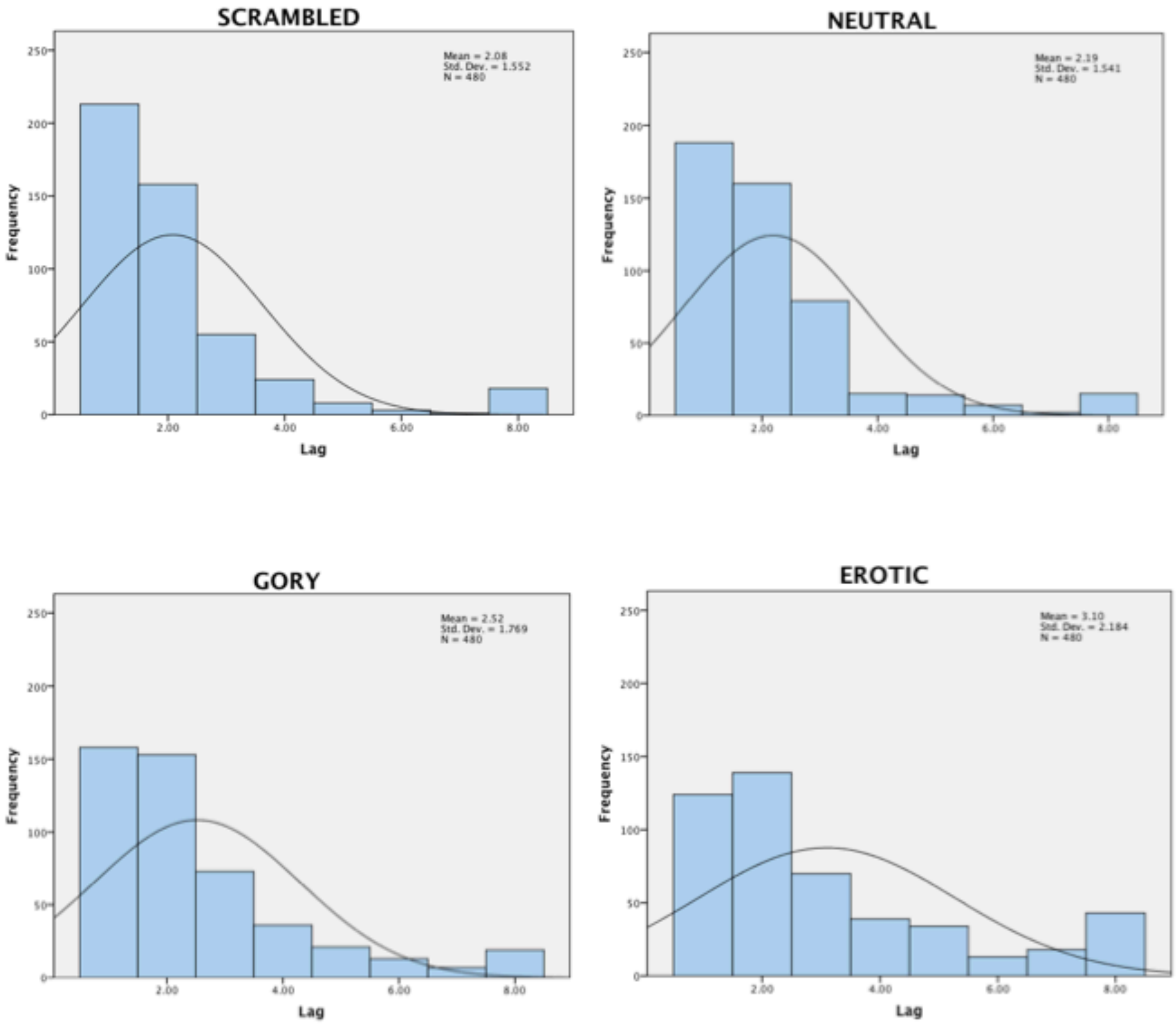

Figure 5. RSVP design used in Experiment 2. In this design, there are only numbers on images preceding the distractor image, and only letters on the slides following the distractor. Participants were asked to report the last number and the first number they saw.

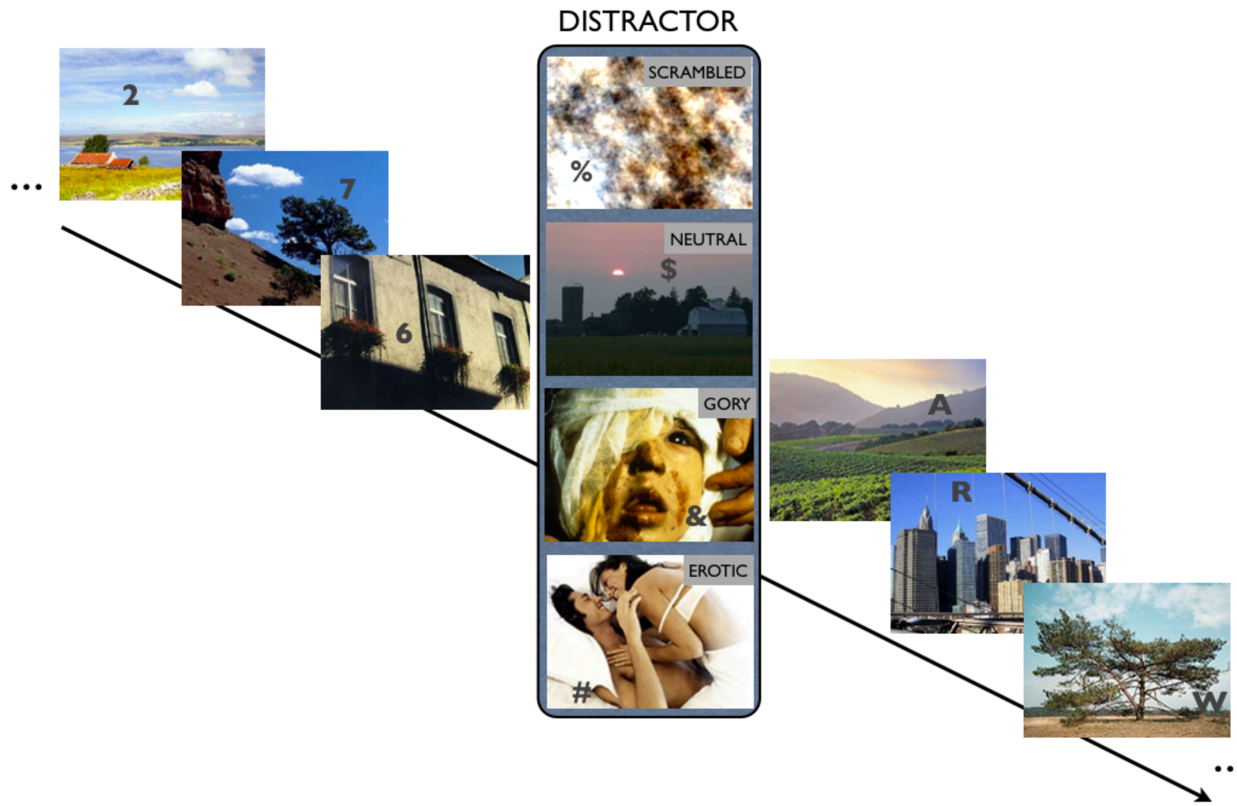

Figure 6. The frequency of each lag response was recorded based on the distractor type. The images reflect the distribution of responses in Experiment 2 (*N*=19).

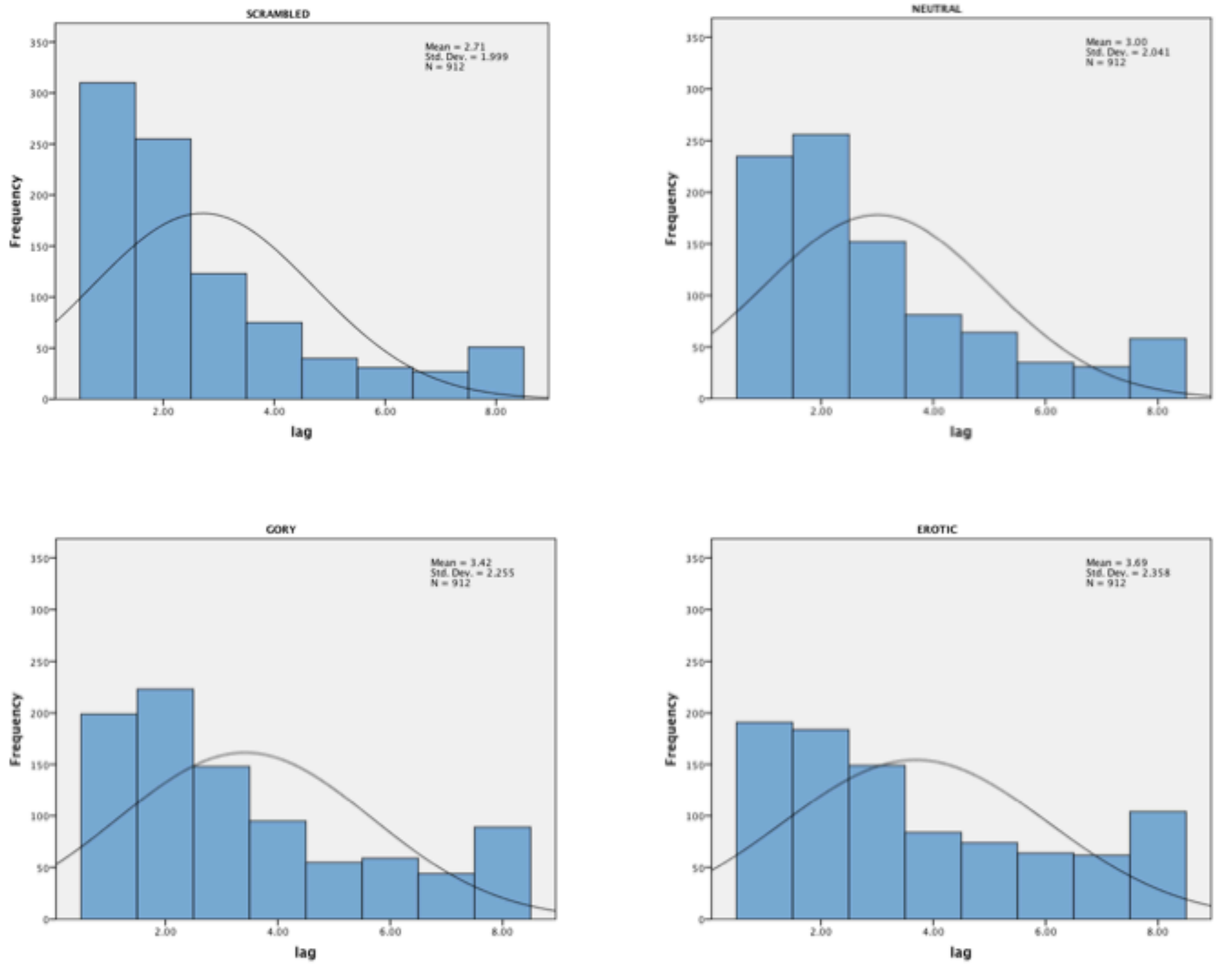

Figure 7. Following each trial, "lag" was recorded based on how many images after the distractor image the participant was able to recall the target. The average lag was calculated for each participant based on each distractor type. The graph below indicates the differences in Mean Lag based on Distractor Type in both Experiment 1 (*N*=10*)* and Experiment 2 (*N*=19).

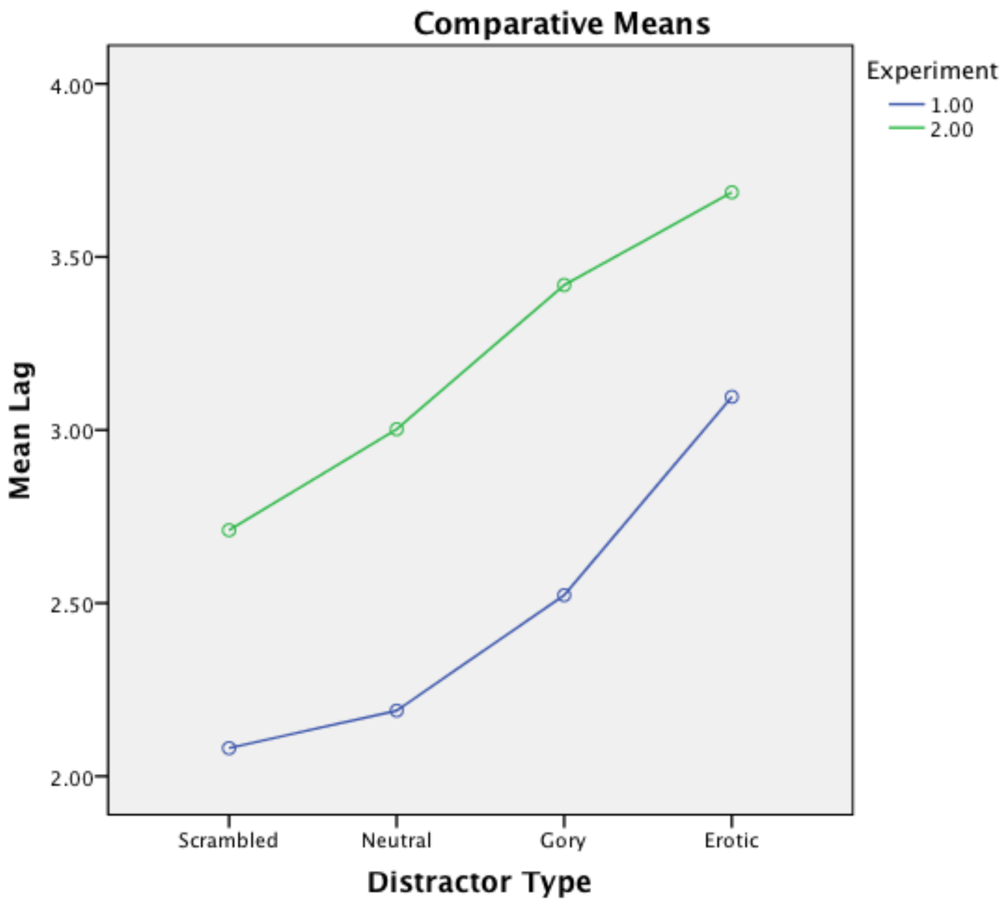

Table 1. The mean lags for each distractor type across four distractor types.

Distractor Type	Experiment 1 lag	Experiment 2 lag
scrambled	2.08 (*SD*=1.55)	2.90 (*SD*=2.00)
neutral	2.18 (*SD*=1.54)	3.18 (*SD*=2.04)
gory	2.52 (*SD*=1.77)	3.61 (*SD*=2.26)
erotic	3.10 (*SD*=2.18)	3.83 (*SD*=2.36)