EXPLORING the LIMITS of the EMOTIONAL ATTENTIONAL BLINK

by

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ABSTRACT

In the emotional attentional blink (EAB; also termed emotion-induced blindness), a single target in a rapid serial visual presentation (RSVP) stream of fillers is difficult to report when it is preceded by a task-irrelevant emotional distractor, indicating temporal attentional capture by emotion. However, recent research has shown that the EAB is weaker than previously assumed and has suggested that emotion is not a strong driver of stimulus-driven attentional capture, at least in RSVP tasks. This dissertation explored the limits of the EAB with two aims: Aim 1 asked if the EAB is actually driven by emotion, or rather visual distinctiveness that is then modulated by emotion. Using RSVP streams with critical distractors that were emotional, visually distinct, both, or neither, the results support the latter account, and further suggest that the EAB can be characterized as two phases. In Experiment 1.1 with image stimuli, visual salience (regardless of emotion) led to an immediate—but rapidly attenuating—blink, while emotion with low visual salience led to a delayed blink with sparing of early lags. Experiment 1.2 with word stimuli did not show this same effect. Aim 2 asked if emotion appears to be a weak driver of stimulus-driven attentional capture in the EAB because the rapid dynamics of RSVP tasks require general suppression of all stimulus-driven attention to enhance goal-driven attentional control. The two experiments for Aim 2 (Experiment 2.1 with images and 2.2 with words) utilized a novel “skeletal” EAB paradigm with most filler items removed (as previously used in some two-target attentional blink studies) and compared performance to the typical EAB paradigm. Contrary to predictions, similar EABs were observed in skeletal and RSVP paradigms, suggesting that general suppression of all items in RSVP streams does not lead to a weaker EAB. Together,

these aims provide a better understanding of the EAB and stimulus-driven attentional capture by emotional stimuli.

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I. INTRODUCTION

With the overwhelming amount of dynamic visual information in the everyday world, humans are forced to prioritize some information over other information. In such situations, it is often effortless to prioritize goal-relevant information, while filtering out information that is currently irrelevant. This attention toward stimuli based on predetermined goals is known as goal-driven attention (Theeuwes, 2019). For example, while driving, humans are able to attend to traffic signs and other cars, as they are crucial to the current task, while filtering out irrelevant distractors such as billboards or birds. Alternatively, attention is deployed towards stimuli that are inconsistent with momentary task goals, but have high salience or importance across a wide range of scenarios, sometimes called stimulus-driven attention (Theeuwes, 2019; Theeuwes et al., 2010)[1]. This can be beneficial in many cases, such as when an unexpected animal or jaywalker walks out in front of your car: the salience of these events can create stimulus-driven attentional capture, allowing you to react accordingly. It has even been suggested that there is an evolutionary reason for this type of capture, perhaps to allow humans to react quickly to potential threat, such as a bear attack (e.g., Öhman, 2009; Öhman et al., 2012). However, in cases such as "rubbernecking" (e.g., Mathewson et al., 2008; Most et al., 2005) toward an accident on the side of the road or diverting attention toward a ringing cell phone while driving, stimulus-driven capture can distract from current goals and become dangerous. In fact, unwanted distractions while

[1] There are several other mechanisms of attentional control, and it is likely that a goal-driven vs. stimulus-driven dichotomy does not capture the full spectrum of attentional control mechanisms (Awh et al., 2012; Benoni & Ressler, 2020). However, there is no widely-accepted framework, and thus the current study focused on the two mentioned here, as they are most relevant to the proposed research: goal-driven (also termed "top-down") and stimulus-driven (also termed "bottom-up"). Still, it should be noted that these do not rule out other mechanisms of attentional control, such as reward history or selection history (see Anderson, 2013 for review), although attempts to build a trichotomous framework that includes these mechanisms are still controversial (Ramgir & Lamy, 2020).

driving result in thousands of motor accidents per year—3,252 fatal motor accidents nation-wide in 2016 alone (*Facts + Statistics: Highway Safety | III*, n.d.).

Goal-driven and Stimulus-driven Attention in Space

In the research lab, goal-driven attention is examined by pre-defining targets to prepare participants in a multitude of tasks. For example, targets can be defined as being in a specific location, such as in spatial cuing paradigms that orient participants toward the potential target location (e.g., Posner, 1980). Targets can also be defined by their features, such as visual search tasks that require participants to search for a stimulus defined by a specific color, pattern, shape, orientation, size, motion, etc. in an array of distractor stimuli (see Wolfe, 1998; Wolfe & Horowitz, 2004). Such experiments show how participants are able to quickly allocate attention toward items matching the target-defining features in response to current goals.

In similar studies, researchers have examined how stimulus-driven attention can interact with goal-driven attention, showing that irrelevant distractors can capture attention. Stimulus-driven attentional capture to locations in space may be manipulated using abrupt onsets (Yantis & Jonides, 1984), feature singletons (e.g., Lamy et al., 2004; Theeuwes & Godijn, 2002), noninformative target cues (Leonard & Egeth, 2008), or peripheral cues (Posner, 1980). There is, however, much debate on whether these capture effects are purely stimulus-driven, with some arguing that goal-driven attention plays a large role in capture by salient task-irrelevant distractors. The contingent involuntary orienting hypothesis (also called contingent capture) states that capture is always contingent on goal-driven control settings, and that only stimuli that match those settings will capture attention (C. Folk et al., 1992). In another instance of stimulus-driven attention being contingent on goal-driven control settings, the singleton detection mode hypothesis states that when participants are searching for a singleton in a search array (e.g., a circle among squares), their attention will likely be captured by a task-irrelevant singleton of another featural dimension (i.e., the color red among green stimuli) because they are already searching for singletons (Bacon & Egeth, 1994; Gaspelin et al., 2015).

In addition, similar to the capture observed when diverting attention toward an emotionally unpleasant accident on the side of the road, task-irrelevant emotional stimuli can evoke stimulus-driven attentional capture, drawing resources away from neutral stimuli even when those resources are necessary to complete the task at hand (see Domínguez-Borràs & Vuilleumier, 2013 for review). For example, in dot probe paradigms with an emotional image presented next to a neutral image, participants are slower to detect the dot probe if it appears in the location previously occupied by the neutral image, as their attention has been captured by the emotional image presented in the opposite location (e.g., MacLeod et al., 1986). Similarly, participants respond more slowly in a visual search task when an emotional image is displayed as the background, compared to a neutral image (e.g., Zinchenko et al., 2020).

The Attentional Blink

Using rapid serial visual presentation (RSVP) paradigms, in which a stream of stimuli is presented in rapid succession, researchers have also been able to examine both goal-driven and stimulus-driven attention in dynamic scenes across the temporal domain. When participants are told to search for a single pre-defined target from the RSVP stream, which requires goal-driven attention, they are able to detect said target very efficiently. In fact, participants are able to report a target in a RSVP stream when the stream is presenting stimuli at a rate of up to 16 items per second (Lawrence, 1971), showing the speed of goal-driven attention. However, there are nonetheless limitations in humans' temporal goal-driven attention. One such limitation is known as the attentional blink (AB), in which the second of two targets in a RSVP stream of filler items is difficult to report when the two targets are presented within 500 ms of one another (Raymond et al., 1992). While the exact mechanisms of the AB are still debated, it is generally accepted that the ongoing processing of the first target (T1) hinders the processing of the second target (T2), resulting in poor report of T2, while reporting T1 is rarely impaired (see Dux & Marois, 2009 for review). When the T1 to T2 lag (the temporal position of T2 relative to T1) is increased, it attenuates the AB as processing resources once again become available before the presentation of T2 (Raymond et al., 1992). Of note, there is also a phenomenon known as lag 1 sparing, in which two targets presented back-to-back, without an inter-target distractor, are spared from a blink effect (Chun & Potter, 1995). The probable explanation for this is that the presence of a distractor is needed to end the attentional episode and initiate general suppression, which would lead to the blink of T2 (Wyble et al., 2009). This lag 1 sparing effect is not of major importance for the proposed research, but is nonetheless worth mentioning as it is portrayed in figures throughout this report. See Fig. 1 for a visual representation of the AB.

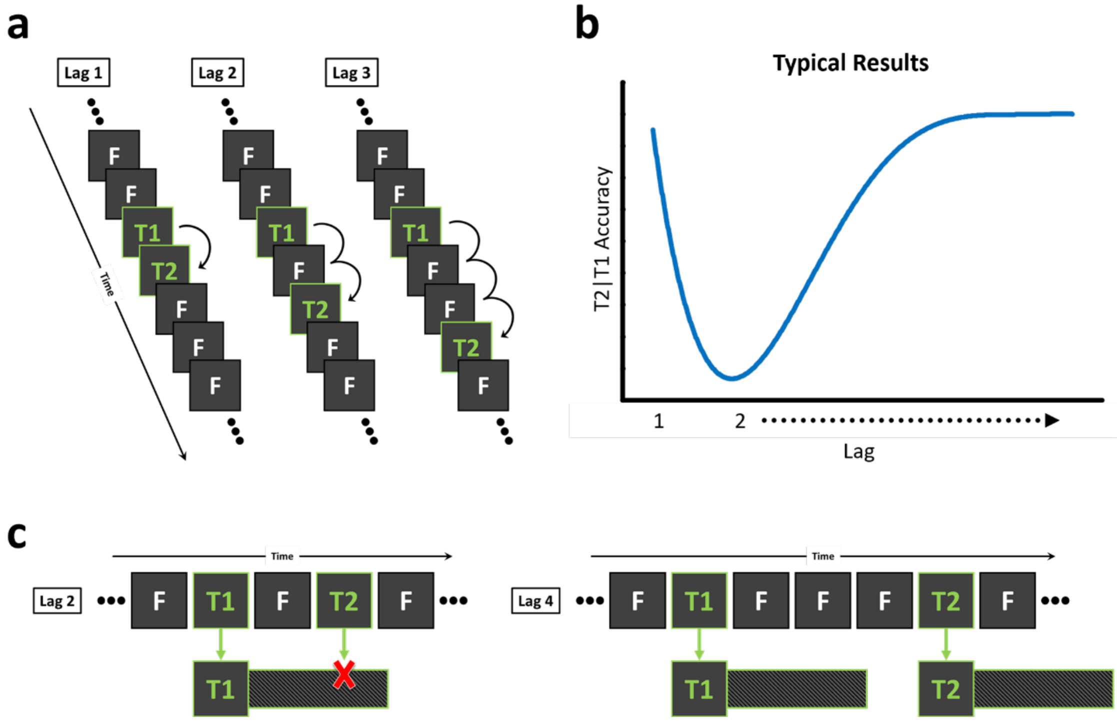

Fig. 1. A visual representation of the attentional blink (AB). **(a)** A schematic of the classic AB rapid serial visual representation (RSVP) paradigm, with a varying number of pre-target filler (F) items, a first target (T1), a varying number of inter-target filler items, a second target (T2), and a varying number of post-target filler items. The first RSVP stream depicts T1 to T2 lag 1, where the temporal position of T2 is one spot away from T1. The second RSVP stream depicts T1 to T2 lag 2, where the temporal position of T2 is two spots away from T1. The third RSVP stream depicts T1 to T2 lag 3, where the temporal position of T2 is three spots away from T1. **(b)** The typical results of AB studies, showing lag 1 sparing, poor T2 performance at lag 2 (the "blink"), and the rapid recovery as the T1 to T2 lag increases. **(c)** Boxcar models of the AB showing that the processing of T1 leads to lack of resources for processing T2 at shorter lags (here lag 2) and that increasing the T1 to T2 lag (here lag 4) allows for T1 processing with replenished resources to process T2.

While a vast majority of AB research utilizes the RSVP stream in which all stimuli are presented in rapid succession, there have also been studies using what is called the "skeletal" AB paradigm (Ward et al., 1996). In such paradigms, many of the RSVP stimuli are removed from the streams, leaving only a few critical stimuli—usually T1, a T1 mask, T2, and a T2 mask (Ward et al., 1996). Such simplified paradigms have been shown to produce an AB effect (Lagroix et al., 2012; Nieuwenstein et al., 2009).

In addition, studies have also used emotional targets in the AB paradigm and have shown that emotional T1s result in poorer T2 accuracy, increasing the AB effect (e.g., Ihssen

& Keil, 2009), and emotional T2s result in better T2 accuracy, attenuating the AB effect (e.g., Keil & Ihssen, 2004). Although this has been explained as the emotional stimuli "capturing" attention, because the emotional stimuli in such studies are targets, it is really a mixture of goal-driven *and* stimulus-driven attention, and thus considering it as "capture" is flawed and complicated to interpret.

The Emotional Attentional Blink

Given that reporting T1 is minimally affected in the AB and that single targets can be reported even after very high-speed presentations (e.g., Lawrence, 1971), one might expect that temporal attention limitations could never be observed when participants are searching for a single target in a RSVP stream—without a T1 to draw resources away from a T2, an AB should not be evoked. However, this is not always the case—as with stimulus-driven attentional capture seen in spatial attention research (outlined in the Goal-driven and Stimulus-driven Research section above), task-irrelevant stimuli can also capture temporal attention at the expense of goal-driven attention to search for targets. Using RSVP streams, researchers have discovered that task-irrelevant stimuli with extreme salience, such as color singletons (Maki & Mebane, 2006), can capture attention and hinder recall of a single subsequent target. More commonly, research has focused on the capture effects of emotional stimuli on temporal attention. Such research has shown that an emotional distractor preceding a single target by a short lag in a RSVP stream can capture attention and create a stimulus-driven "blink", as if it were a T1 in the AB paradigm. This phenomenon is known as the emotional attentional blink (EAB; also referred to as emotion-induced blindness), and is typically understood as a stimulus-driven AB-like impairment on target processing and report (Arnell et al., 2007; Ciesielski et al., 2010; Olatunji et al., 2022; Singh & Sunny, 2020;

see McHugo et al., 2013 for review). While the exact mechanisms of the EAB remain a topic of debate, it is typically discussed as a stimulus-driven equivalent of the goal-driven AB (e.g., McHugo et al., 2013; Olatunji et al., 2022): the emotional salience of the distractor is thought to engage attention and interfere with processing of a subsequent target, similar to how goal-driven attentional engagement by a T1 interferes with processing of a subsequent T2 in the AB (Mathewson et al., 2008; Wang et al., 2012). See Fig. 2 for a visual representation of the EAB.

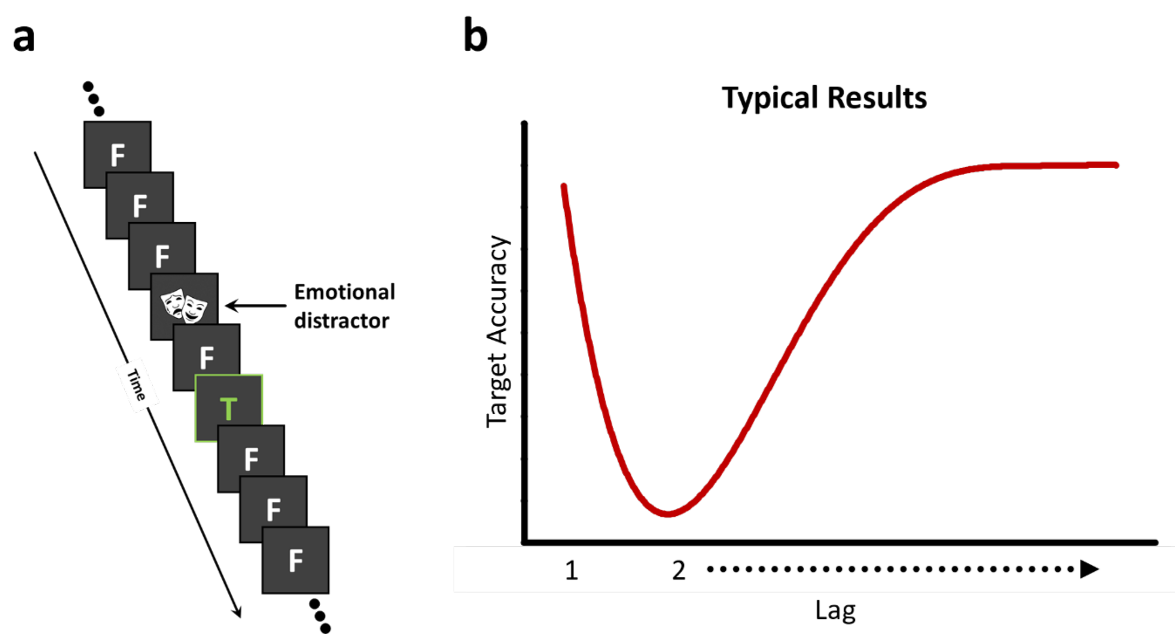

Fig. 2. A visual representation of the emotional attentional blink (EAB). **(a)** A schematic of the classic EAB rapid serial visual representation (RSVP) paradigm. As with the AB, the EAB RSVP streams begin and end with a varying number of filler items and contain a varying number of filler items separating the two critical items. However, instead of a first (T1) and second (T2) target, there is an emotional distractor item preceding a single target (T). The stream presented here depicts an emotional distractor to target lag 2. **(b)** The typical assumed results of EAB studies.

Issues with Previous EAB Research

Although the stimulus-driven emotional capture that results in the EAB effect is assumed to be similar to the goal-driven AB effect, claiming that the EAB is a stimulus-driven AB induced by emotion is problematic. The original (and most common) EAB paradigm is a RSVP stream in which landscape images act as fillers, rotated landscape images act as targets (participants indicate whether the target image was rotated to the left or right), and the critical distractors are either neutral or unpleasant images of humans or animals (Most et al., 2005a). While this paradigm has been widely used in EAB research and is well designed, there is nonetheless a key flaw that could potentially affect the interpretation of the results: the critical distractors, both neutral and unpleasant, are images of humans or animals in a stream of landscape images, making them visually and categorically distinct from the surrounding RSVP stimuli. This alone could lead to capture, as either categorical or visual distinctiveness could be considered a singleton feature in the search for another singleton feature (rotation), consistent with singleton detection mode hypothesis (Bacon & Egeth, 1994; Gaspelin et al., 2015). One could argue that in addition to this key flaw, it is suboptimal that the task requires only surface-level perceptual processing of RSVP stimuli (orientation), and that the 50% chance performance (left or right) limits the range of outcomes and makes floor or ceiling effects more likely. However, the task consistently yields an EAB without ceiling or floor effects (at least at the group level), and thus these additional concerns are not major.

Although the rotated-landscape paradigm is most common in EAB studies, other paradigms have been used that avoided some of the aforementioned concerning aspects. For example, Kennedy & Most (2015) used a paradigm that had participants select targets from an array of 20 possible images, which significantly decreased chance performance and, in theory, increased the potential range of results (with floor at 5% instead of 50%) and had the potential to make the valence differences more robustly observable. However, the targets were defined as images outlined in blue (with other images lacking any outline), which encouraged surface-level processing of RSVP stimuli to select targets. Moreover, the critical distractors were humans or animals in a stream of common everyday objects, once again making them visually and categorically distinct from the surrounding RSVP stimuli.

Another EAB study by Huang et al. (2008) used RSVP streams of all black text, and showed taboo words (e.g., “ORGASM”) to be the most effective category of critical distractors. Participants were told to search for fruit words that they typed in following each trial. This allowed Huang et al. (2008) to test the EAB in a paradigm that required participants to semantically process all stimuli to select their targets. Huang et al. (2008) observed a difference between blinks caused by neutral distractor words and taboo distractor words only when participants searched for the fruit target words, rather than their other condition that required surface-level perceptual processing to select targets (i.e., search for capitalized word). However, the emotional distractors and targets were words among filler items comprised of random numbers and symbols. Thus, even in their semantic processing condition, the critical distractors were visually and categorically distinct from the surrounding stimuli, which resulted in strong blinks for the taboo *and* neutral critical distractor words (Huang et al., 2008). In addition, the targets were the only other words in the streams. This choice assigns a target-defining feature to the critical distractors and conflates emotion and goal-driven attention. Thus, their results cannot be interpreted as showing a reliable stimulus-driven capture of attention by emotion.

Other EAB studies by MacLeod et al. (2017) and Arnell et al. (2007) also used RSVP streams of all black text with taboo words as emotional distractors that yielded an EAB, but used color names (e.g., “BLUE”) as targets. Following each trial, participants were shown a list of the ten potential color names to choose from, which lowered chance performance to

10%, increasing the potential performance range. Unlike Huang et al. (2008), MacLeod et al. (2017) and Experiments 2 and 3 from Arnell et al. (2007) used nonwords (e.g., "FALOTH") as filler items, making the filler text more visually similar to targets and critical distractors, which was also meant to increase the chances of semantically processing all RSVP stimuli. However, even if visually similar, the taboo words and color name targets were still categorically distinct from the surrounding filler items, which raises the same issue of conflating emotion and goal-driven attention that accompanied the Huang et al. (2008) paradigm. In addition, because participants were shown the list of potential target options following each stream, they could have created an attentional set for the targets and developed alternative strategies, rather than semantic processing, to search for targets in each stream.

Finally, EAB studies by Mathewson et al. (2008), Experiment 1 from Arnell et al. (2007), and Experiment 3 from Santacroce et al. (2023) used the same paradigm mentioned above with taboo emotional distractors and color name targets, but the filler items were also words. This paradigm eliminated most of the issues with the classic EAB paradigms mentioned above: First, the task required participants to semantically process all RSVP stimuli, including the emotional distractor, to search for the target color name, rather than target detection relying on surface-level features such as image rotation or frame color. They also had ten potential color names for participants to choose from, which lowered chance performance to 10% and increased the potential performance range. Finally, because the targets, fillers, and critical distractors were all black capitalized words, the critical distractors were not visually or categorically distinct from the surrounding RSVP stimuli. While this paradigm corrected a number of issues raised in the classic EAB paradigm, participants were still shown the list of potential target options following each stream which could have allowed for an attentional set for the targets or alternative strategies other than semantic processing. In addition, the results using this paradigm from Mathewson et al. (2008) yielded a relatively small effect size for the valence × lag interaction ($\eta^2 = .06$), Arnell et al. (2007) failed to yield an EAB (i.e., no valence or arousal x lag interaction; they did not report effect sizes), and Santacroce et al. (2023) also failed to observe an EAB effect and had a similarly small effect size for the valence × lag interaction ($\eta^2 = .05$). This constellation of weak or non-significant effects highlights the ambiguity in the results of EAB studies using RSVP streams of visually-similar words. Of note, a recent study by Santacroce & Tamber-Rosenau (under review) used an all-word EAB paradigm with the same task as Huang et al. (2008): participants searched for and manually entered fruit words. Santacroce & Tamber-Rosenau (under review) found an EAB in the taboo condition (leading to the choice of this as the paradigm for the present Experiments 1.2 and 2.2, which, to anticipate the results, also yielded EABs), which further highlights the ambiguity of all-word EAB paradigms.

Even with these issues facing the paradigms, the EAB is a widely accepted effect that has been replicated numerous times. While the results from previous EAB studies are undoubtedly real and provide evidence that emotion can influence the processing of stimuli, they have mostly failed to carefully control for confounds that could potentially be driving the EAB such as goal-relevance or physical salience. That is, while the resulting blinks may be stimulus-driven, it is not clear to what extent they are actually emotion-driven because there are alternative but seldom-discussed explanations for what may drive these effects.

Empirical Evidence Challenging the EAB

Recent research has challenged the strength of emotional stimuli and their ability to automatically capture temporal attention. For example, in an AB study by Santacroce et al. (2021) they examined whether emotional stimuli could survive and modulate the already-limited attentional resources in the classic, two-target AB. In their novel paradigm, a distractor that was either pleasant, neutral, or unpleasant was placed between two targets in a RSVP stream. Assuming emotional distractors are strong enough to automatically capture temporal attention and override current goals, as with the EAB, the valence of the task-irrelevant emotional stimulus would survive the already limited attentional resources set forth by T1 and modulate T2 performance. However, their results showed that this was not the case—the valence of the critical distractor did not affect the AB. The only exception was in one experiment, in which the critical distractor was extremely salient: a nearly full-screen image in a RSVP stream of word fillers and targets. Only then did the emotional valence survive the AB and modulate T2 report accuracy. This suggests that emotional stimuli are unable to automatically capture temporal attention when positioned inside the blink caused by the goal-driven demands of T1, unless under extremely salient conditions (Santacroce et al., 2021).

Similarly, a recent study by Baker et al. (2021) showed that emotional distractors could only yield a strong EAB when they were visually distinct from the surrounding RSVP stimuli (targets and fillers). In their study, they used an EAB paradigm with a single target following either an unpleasant, neutral, or absent (baseline) distractor in a RSVP stream of images. Critically, they had two conditions: one in which the unpleasant and neutral distractors depicted humans or animals in a RSVP stream of landscape fillers and targets, and one in which all filler images depicted humans or animals, and thus matched the emotional distractors. The former, in which the critical distractors were visually and categorically distinct from the surrounding stimuli in the stream, is typical of most EAB studies and yielded an EAB as expected. However, when all distractors in the streams depicted humans or animals, the EAB was significantly reduced. This suggests that unless visually/categorically distinct from the surrounding stimuli, an emotional stimulus does not capture attention nearly as well. Also of note, they also found a "blink" resulting from the neutral distractor images (although weaker than that from the unpleasant distractor images) when they were humans or animals among landscapes, a result that is ubiquitous in the literature (e.g., Huang et al., 2008; Kennedy et al., 2014; Kennedy & Most, 2015; Most et al., 2005b), yet rarely discussed. It is possible, then, that it is actually visual/categorical distinctiveness that initiates the capture of attention, and then the emotional valence can prolong the dwell time of that capture (Baker et al., 2021).

A recent study by Santacroce et al. (2023) directly tested the strength of goal-driven temporal attention and stimulus-driven attentional capture by directly comparing randomly intermixed AB and EAB trials within the same participants. Through four experiments, their results showed that the EAB was far weaker than the AB (and was often absent). This suggested that stimulus-driven attentional capture by emotional stimuli does not measure up to the goal-driven attention allocated towards a T1. In addition to this main finding, they also showed that emotion alone was not enough to capture attention and elicit an EAB with four unique EAB paradigms that manipulated the visual distinctiveness of the emotional distractors and the type of processing required to select targets (see Fig. 3 for their manipulations and the resulting blinks). Experiment 1 used a RSVP of images that could come from a wide range of categories (landscapes, humans, animals, objects, etc.), much like the study by Baker et al. (2021). This meant that the emotional distractors were visually similar to surrounding RSVP stimuli, unlike classic EAB studies (e.g., Most et al., 2005b). Targets were defined by frame color, which only required surface-level perceptual processing of the RSVP stimuli in order to select targets. With these conditions, the only distinguishing factor of the emotional distractors was their emotional valence, and thus any capture effect would rely solely on emotion. In this experiment, the data failed to yield an EAB effect. In their Experiment 3, Santacroce et al. (2023) used the RSVP stream of all black words outlined above. In this paradigm, every stimulus in the stream was visually similar (including the emotional distractor), to test if an emotional distractor could create a blink in the absence of visual distinctiveness. In addition, targets were defined by category (color names), which required participants to semantically process all stimuli in order to make their target selection, essentially forcing them to read all words in the stream (including the emotional distractor). Given this, participants should have been able to semantically process the meaning of each word in the stream, and thus the valence of the emotional distractors, which should produce an EAB if emotion alone is able to capture temporal attention. However, the results still did not yield an EAB, failing to replicate results from Mathewson et al. (2008), outlined above, suggesting that emotion alone cannot produce a blink, even when the emotional distractor was likely to have been semantically processed. In Experiment 2, Santacroce et al. (2023) used a RSVP stream of filler images containing common everyday objects, targets were defined as fruit images, and emotional distractors were either of humans or animals. Because this paradigm also defined targets by category (fruits), this also required participants to semantically process all stimuli in order to select the target. This, again, should increase the likelihood of participants semantically processing the emotional distractor. In addition, because the emotional distractors were images of humans or animals among a RSVP stream of objects and fruits, the emotional distractors were visually distinct from the surrounding stimuli. Here, in the optimal EAB conditions where the emotional stimuli were visually distinct and the task required semantically processing all RSVP stimuli, their results finally yielded a significant EAB, although still much weaker than the AB effect. Finally, in Experiment 4, Santacroce et al. (2023) adapted the paradigm from Kennedy & Most (2015), which used RSVP streams of filler images containing common everyday objects, defined targets as the images with a blue frame, and used emotional distractors that contained humans or animals. This paradigm required only surface-level perceptual processing of the RSVP stimuli to select a target image with a blue frame and the emotional distractors were visually distinct from surrounding RSVP stimuli. This experiment also yielded an EAB effect (replicating Kennedy & Most (2015), described earlier) that was still weaker than the AB. To summarize, the results of Santacroce et al. (2023) showed that the stimulus-driven attentional capture by emotional stimuli does not measure up to the goal-driven attention allocated towards a T1. In addition, the emotional distractor and task manipulations suggest that emotion in the absence of visual distinctiveness is not sufficient to capture temporal attention, even when the task requires participants to semantically process all RSVP stimuli in order to select the targets.

Emotional distractor similarity to surrounding RSVP stimuli		Task processing requirements: Semantic processing	Task processing requirements: Perceptual processing
	Visually distinct	**Experiment 2** emotional valence + visual distinctiveness + forced semantic processing ↓ EAB effect	**Experiment 4** emotional valence + visual distinctiveness ↓ EAB effect
	Visually similar	**Experiment 3** emotional valence + forced semantic processing ↓ No EAB effect	**Experiment 1** emotional valence alone ↓ No EAB effect

Fig. 3. Breakdown of manipulations across four prior experiments (Santacroce et al., 2023) and their resulting emotional attentional blink (EAB) effects. Experiments varied in two dimensions: processing requirements needed to identify targets (semantic processing vs. surface-level perceptual processing) and the visual distinctiveness of the emotional distractors compared to the surrounding RSVP stimuli (visually distinct vs. visually similar). Each cell of the figure lists potential sources of attentional capture that could have driven an EAB in the corresponding experiment. Across four experiments, those with visually distinct distractors yielded an EAB, while those with visually similar distractors did not yield an EAB.

Current Research

To gain a better understanding of how and when emotional stimuli capture temporal attention, the current research addressed two main questions derived from the weak EAB, as discussed above. Each question was examined in its own aim using two separate paradigms, for a total of four proposed experiments.

Aim 1: Is the stimulus-driven attentional capture in the EAB actually driven by emotion, or rather by visual distinctiveness? The experiments in Aim 1 (Experiments

1.1 and 1.2) used EAB RSVP paradigms to examine the precise time courses of the "blinks" caused by critical distractors that are either emotional, visually distinct, or both. The results from Aim 1 were expected to show that distractors with emotional salience create a small blink (if at all), visually distinct distractors create a magnified but short-lived blink, and the visually distinct distractors *with* emotional salience create an even more magnified blink with a longer duration (Fig. 4). This would suggest that emotional stimuli simply prolong the dwell time of attention following capture by a physically salient stimulus.

Aim 2: Does the cognitively demanding nature of RSVP streams encourage general suppression of task-irrelevant stimuli (including emotional distractors), weakening the ability of emotional valence to capture temporal attention? The experiments for Aim 2 (Experiments 2.1 and 2.2) implemented the "skeletal" AB paradigm (Ward et al., 1996) that was briefly explained above in The Attentional Blink section. This paradigm was adapted for the EAB and each RSVP stream contained the manipulated critical distractor (either neutral or emotional), a neutral mask, a target, and a target mask. Note that the stimuli in Aim 2 did not include the visual distinctiveness manipulation, and thus all stimuli were visually similar to one another (aside from the unpleasant and neutral images in Experiment 2.1, which were distinct because of their categories, but whose low-level visual salience was not manipulated). The EAB in the skeletal RSVP task were compared to the EAB in the typical RSVP task in the same participants. The results from Aim 2 were expected to show that the skeletal EAB task, in which there are fewer distractors that must be suppressed, would minimize the general suppression of all stimulus-driven attention to non-targets, leading to a more robust EAB. This would indicate that the high cognitive demands of the typical RSVP stream led to general stimulus-driven suppression and a weak EAB.

II. AIM 1: VISUAL DISTINCTIVENESS OR EMOTIONAL VALENCE?

The results from the studies that challenge the EAB outlined in Chapter I (Baker et al., 2021; Santacroce et al., 2021, 2023) suggest that emotional stimuli are weak drivers of temporal attentional capture, and may not even capture attention at all. This notion undermines some theoretical explanations for the value of such stimulus-driven attentional capture—namely that it serves as an alerting signal to override goal-driven attention when there is danger in the environment (see Corbetta & Shulman, 2002). Previous EAB research relies on the assumption that the stimulus-driven attentional capture that draws resources away from a target is driven by the emotional salience of the distractor. However, it seems that a stimulus-driven attentional capture by task-irrelevant emotional stimuli is contingent on the emotional item's visual distinctiveness from surrounding RSVP stimuli—participants must first attend to the distractor before its valence can affect target detection. As noted above, many EAB studies often show a weak "blink" driven by neutral valence distractors when they are also visually distinct from surrounding RSVP stimuli (Huang et al., 2008; Kennedy et al., 2014; Kennedy & Most, 2015; Most et al., 2005b; Singh & Sunny, 2017), which also supports this view (see Fig. 4 for a visual representation of the capture hypotheses). To return to the driving example, emergency vehicles often use flashing lights to notify other drivers of their presence. A work van with flashing lights should thus capture your attention, but a police vehicle with flashing lights will almost certainly capture your attention and will likely hold your attention for a longer duration, given its emotional valence. At the same time, an undercover police vehicle without flashing lights is less likely to capture attention, despite the emotional valence that is still assigned to police vehicles.

Therefore, Aim 1 asked the question: Is the stimulus-driven capture in the EAB actually driven by emotion, or rather by visual distinctiveness? In two separate experiments with different EAB RSVP paradigms, critical distractors that are visually distinct, emotional, or both were compared to distinguish the distinct time courses of their resulting “blinks”. Visual distinctiveness was expected to magnify the blink effect and emotional valence was expected to increase the duration of the blink, indicating that visual distinctiveness is the main cause of the EAB and that emotional valence only prolongs the blink once attention has already been captured. Even a pure dwell-time effect may have appeared to increase the magnitude of the EAB in past studies because of the coarse timing of RSVP events compared to the continuous nature of attentional control. However, it was still predicted that magnitude changes primarily stem from visual distinctiveness, while emotion primarily leads to an extended blink duration.

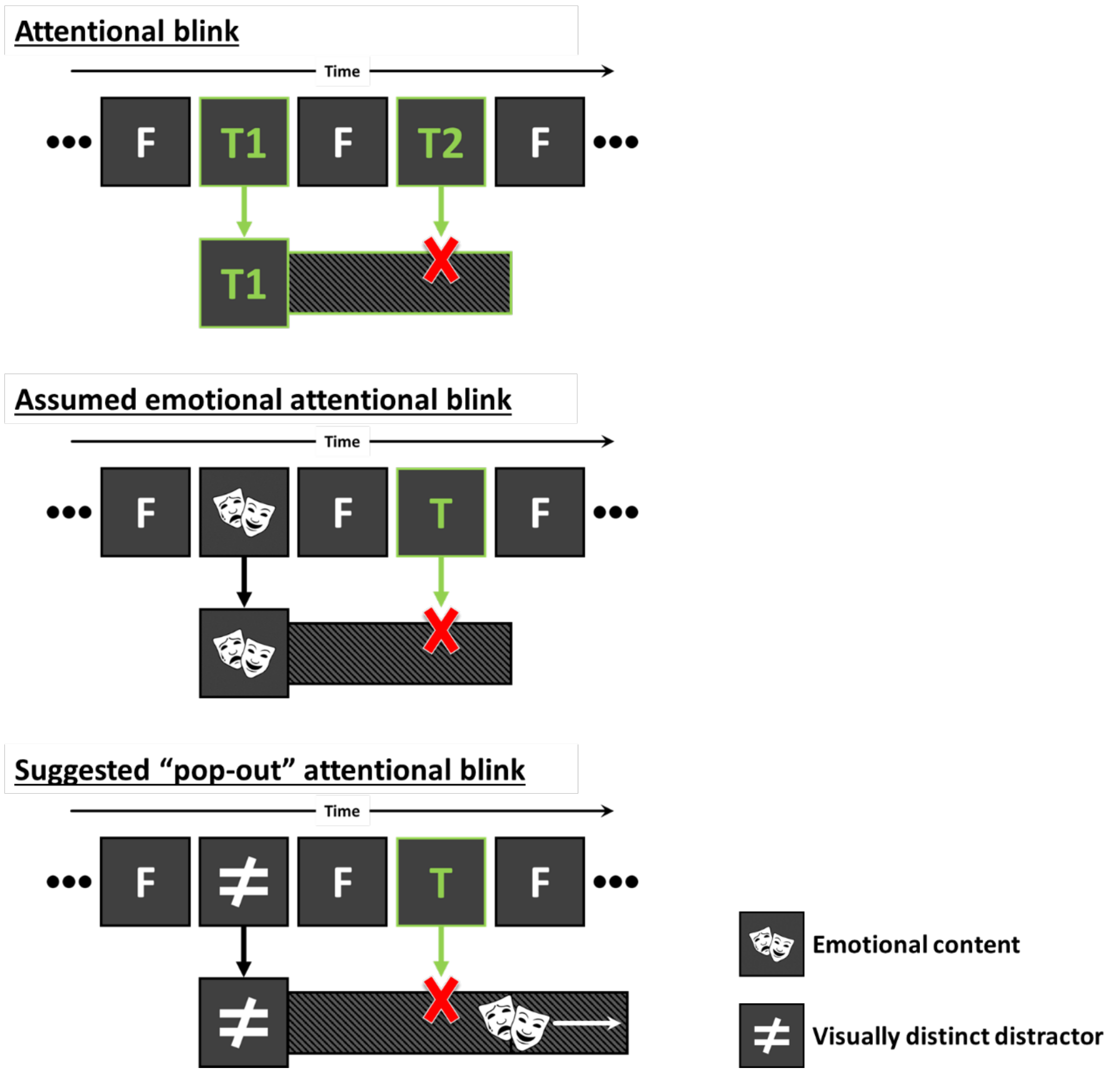

Fig. 4. Boxcar models representing the theories of attentional capture in the attentional blink (AB), what has been assumed in the emotional attentional blink (EAB), and the current hypothesis about the EAB (labeled as the "pop-out" attentional blink). In the AB, the goal-driven attention and subsequent processing of T1 leads to poorer T2 report. The EAB is assumed to be similar, but instead of goal-driven attention to a T1, stimulus-driven attentional capture by an emotional stimulus leads to a similar "blink" on a single target. The current proposed hypothesis of the EAB is that visual distinctiveness is actually what captures attention, and then the emotional valence prolongs the dwell time of the capture, resulting in a "blink".

Aim 1 General Method

Participants

The participants for the experiments in Aim 1 (as well as Aim 2) consisted of University of Houston students participating for course credit through the university's Sona system. Participants were screened via self-report and were omitted if they reported any of the following exclusion criteria: younger than 18 years of age, have poor and uncorrected vision, are color blind, partake in regular or task-concurrent use of psychoactive drugs, or have a neurological disorder, brain injury, or other diagnosis known to affect cognition. Informed consent was gathered from all participants under a protocol approved by the University of Houston Institutional Review Board.

Analytical Approach

The two experiments for Aim 1 (as well as the two experiments for Aim 2) used Bayesian hypothesis tests throughout, rather than standard null hypothesis significance testing, because the current study was interested in showing invariance between conditions, in addition to or instead of differences. Bayesian hypothesis tests yield Bayes factors (BFs), which, unlike *p*-values, are a symmetrical degree of evidence favoring one model over others (e.g., Rouder et al., 2009), given the observed data. That is, while *p*-values are asymmetric and can only provide evidence for rejecting the null hypothesis, BFs are continuous symmetrical values that can provide evidence *for* the null or for the alternative (Dienes, 2016). The use of significance testing can therefore never provide support *against* the research hypothesis (and thus, *for* the null hypothesis) while Bayesian statistics can.

The Bayesian analyses were conducted in the JASP statistical program (JASP Team, 2018) which yielded a Bayes factor (BF_{inc}) quantifying evidence for or against including the main effects or interactions of interest, compared to the null. These analyses were conducted across matched models stripped of the effects (also known as Baws factor; Mathôt, 2017). As introduced by Jeffreys (1961), Bayes factors (BF_{inc} and BF_{10}) greater than 1 are interpreted as evidence for the effect (support interpretation levels: 1 – 3 anecdotal, 3 – 10 moderate, 10 –

30 strong, 30 – 100 very strong, and >100 extreme) and values less than 1 are interpreted as evidence against the effect (support interpretation levels: 1/3 – 1 anecdotal, 1/10 – 1/3 moderate, 1/30 – 1/10 strong, 1/100 – 1/30 very strong, and <1/100 extreme). Recent practice in the cognitive psychology literature has been to view any Bayes factor greater than 3 or less than 1/3 as readily interpretable (Brown et al., 2021; Harrison & Bays, 2018; Santacroce et al., 2021; Yörük et al., 2020).

Power and Sample Size Justification

Because the proposed study used Bayesian statistics, there was no need to specify an a priori sample size because BFs are not biased by sample size the way *p*-values are. Significance testing is highly influenced by sample size, which can lead to p-hacking: optional stopping whenever a significant *p*-value has been achieved. This, in turn, contributes to the 'credibility crisis' in science (Pashler & Wagenmakers, 2012). On the other hand, BFs are driven in opposite symmetrical directions depending on which model is true and thus the direction of the value is not affected by sample size, meaning data collection can be stopped at any point (Rouder, 2014; Rouder et al., 2016; Savage et al., 1962; Tendeiro et al., 2022). Additional participants only provide additional support for the true effect (Dienes, 2016). Therefore, the current experiments in Aim 1 (and Aim 2) intended to stop data collection once the key interaction of interest (lag × valence × visual distinctiveness; see Design section below) indicated statistical support for or against the interaction (a BF_{inc} of greater than 3 or less than 1/3). Although this method would have sufficed (Doorn et al., 2019; Schönbrodt & Wagenmakers, 2018), because it had the possibility of yielding a smaller sample size than is typical of similar studies, the current experiments collected data from a minimum of 20 participants, which is comparable to previous studies (e.g., Arnell et al., 2007; Keefe & Zald, 2020; Most & Jungé, 2008; Santacroce et al., 2023). After collecting data from the initial 20 participants, data from additional participants were collected in increments of at least 5 (or more, depending on participant sign ups via the Sona system) until the BF_{inc} criterion was met.

Design

The experiments for Aim 1 implemented common EAB RSVP paradigms, where participants searched RSVP streams of filler items for a pre-defined target that they were instructed to report following each stream, and a manipulated critical distractor preceded the target by a varying number of lags. To differentiate the effects of physical distinctiveness and emotional valence on the magnitude and duration of blinks caused by critical distractors, the experiments for Aim 1 manipulated the critical distractor on the basis of physical distinctiveness (distinct or similar to the surrounding RSVP stimuli) and emotional valence (neutral or emotional). Thus, trials had critical distractors that were Emotional + Distinct, Baseline + Distinct, Emotional + Similar, or Baseline + Similar (true baseline). Because the differences in blinks (specifically the blink durations) might be very slight, it was crucial that the paradigm was maximally sensitive to the time course of the blinks caused by the different distractor conditions. Thus, the stimulus durations were as short as possible with participants still being able to complete the task and there were many critical distractor to target lag conditions to get the most precise time courses possible. These conditions led to a three-way factorial design with physical distinctiveness, emotional valence, and critical distractor to target lag as within-subjects factors. The initial analysis was a three-way Bayesian ANOVA to see if distinctiveness or valence interacted with lag (i.e., the "blink").

In order to measure the time courses and durations of the individual blinks, this dissertation initially proposed using the width parameter from the Cousineau et al. (2006) AB descriptive model, which measures the duration of the blink (lowest performance) to the blink recovery. While this would have been an ideal method to be sensitive to blink time courses, the AB model unfortunately did not fit the EAB effects in the current study well (R^2 between 0.18 and 0.61; see Fig. A1) and the shape of the model-predicted/actual blinks varied drastically (Fig. A2), and thus this method was not viable or interpretable enough to be reported further. Instead, in addition to the main Bayesian ANOVA, individual Bayesian t-tests were conducted to compare each experimental condition (Emotional + Similar, Baseline + Distinct, Emotional + Distinct) to the true baseline condition (Baseline + Similar) at each lag, which, along with the rapid stimuli duration and many lags, determined the precise start and duration of the blinks based on their deviation from the true baseline condition. For these analyses, a BF showing at least moderate support (BF = 3+) for deviation from baseline was considered "inside the blink", and any other BF was considered "outside the blink". Although some of the tests yielded BFs that were trending toward supporting deviation from baseline (e.g., BF = 2.13), these instances are still considered anecdotal and thus were considered as outside the blink for the sake of this discussion, but were acknowledged in the figures.

Apparatus

All experiments were constructed using the PsychoPy experiment builder (Peirce et al., 2019) that creates JavaScript and HTML code to be hosted on Pavlovia.org. Participants first provided consent, reported demographic information, and read the task instructions on a Qualtrics.com survey, accessed through a link on the University of Houston's Sona System.

Upon completion of the Qualtrics survey, participants were directed to the online experiment. To assure they understood the task, participants were given more detailed instructions on the first few screens of the experiment, and then completed three practice trials before continuing to the real experiment. Each practice trial contained only 9 stimuli, never contained a manipulated critical distractor, and participants were given feedback following each trial. Additionally, the first practice trial presented RSVP stimuli 100 ms slower than the actual experiment, and the presentation time decreased by 50 ms for each trial until it reached the experiment speed on the third trial. All stimuli presentation rates were approximate and were rounded to the number of frames closest to the desired presentation speed, calculated per-participant based on their monitor's exact refresh rate (for all experiments throughout).

In order to keep stimulus size uniform across different participants' monitors, participants also completed a credit card screen scale (Morys-Carter, 2020) calibration at the start of the experiment. Specifically, an image of a credit card was displayed on the screen and participants were instructed to hold up a credit card to the screen and adjust the image until it precisely matched the size of the credit card. The output from the credit card calibration was used to scale the task stimuli to the desired dimensions, regardless of the participants' monitors.

In attempts to combat setting variability that accompany online experiments and to maximize task performance, participants were instructed to complete the experiment while sitting up straight at a table in a secluded room, minimize distractions as much as possible (put away cell phone, do not listen to music, do not have the TV on, etc.), complete the experiment on a computer or laptop (no phones or tablets), close all other programs and Internet browser tabs, use the Google Chrome or Microsoft Edge browser, plug in laptops and turn off battery saver, and complete the experiment in one sitting (although they could take short breaks between trials as needed).

Experiment 1.1

Method

Participants. A total of 28 participants (21 women, 5 men, 2 preferred not to answer; Mean age = 22.93 years, *SD* = 6.99 years) participated in Experiment 1.1. All participants met the requirements outlined in the General Method.

Procedure. In Experiment 1.1, participants began each trial by pressing the space bar, which initiated a fixation cross presented for 300 ms, a blank screen for 100 ms, and a RSVP stream of 20 images presented at a rate of 50 ms/image (Fig. 5). This paradigm has yielded an EAB and overall high performance (means of about 80% in the worst performing condition and about 90% in the best performing condition) in two previous studies (Santacroce et al., 2023; Santacroce & Tamber-Rosenau, under review) when the images were presented at a rate of 70 ms/image, and thus increasing the speed to 50 ms/image was reasonable for participants, while also allowing for a more precise timing measurement for the potential blink effects. The RSVP stream consisted of 3-5 pre-target filler images, a critical distractor image, 0-15 inter-target filler images, a target image, and 4-20 post-target filler images, for a total of 25 images per stream. Participants were told to search for a fruit image in each stream and to report it following each RSVP stream by selecting it out of an array of 20 different fruit images using their mouse. Because the targets were defined by category (fruits), participants were encouraged to semantically process each image in the stream in order to make their target selection, which increased the likelihood of processing the valence of the critical distractor. The RSVP filler images were comprised of common everyday objects and the target images were fruits.

The critical distractors were manipulated by visual distinctiveness (distinct or similar) and emotional valence (unpleasant or baseline with no critical distractor), leading to four different critical distractor types: Emotional + Distinct, Baseline + Distinct, Emotional + Similar, and Baseline + Similar. The critical distractors in the unpleasant condition were unpleasant images of humans (i.e. threatening or gory) and the baseline condition contained another filler image in place of a critical distractor. During the visually distinct trials, the critical distractor was brighter than the images in the rest of the stream. One could argue that the unpleasant critical distractors (neutral or unpleasant humans) might capture attention on the basis of categorical distinctiveness, and while that was hypothesized to be true, the current experiment created an additional visually distinct dimension in all valence conditions that added to the already present categorical distinctiveness. Also, while most EAB studies use a neutral valence condition (with neutral images of humans), the current study only included the unpleasant and baseline conditions because similar + neutral critical distractors were hypothesized to have a similar effect to the Baseline + Distinct critical distractors, and therefore did not add much to the experiment. In addition, this reflected a practical consideration: it lead to fewer conditions, which left room for more trials per condition in a single experiment session whose duration was already long due to the need to examine a large number of lags (7, compared to 2-3 in many EAB studies).

To be sensitive to the more precise time courses of the blinks in each critical distractor condition, there were 7 critical distractor to target lags: lags 1-6 and lag 16 (50 ms, 100 ms, 150 ms, 200 ms, 250 ms, 300 ms, and 800 ms). With all of the conditions, the current experiment had a 7 (lag: 1, 2, 3, 4, 5, 6, 16) × 2 (visual distinctiveness: distinct or similar) × 2 (valence: unpleasant or baseline) within-subjects factorial design. Each of the 28 conditions was presented 20 times each, for a total of 560 trials.

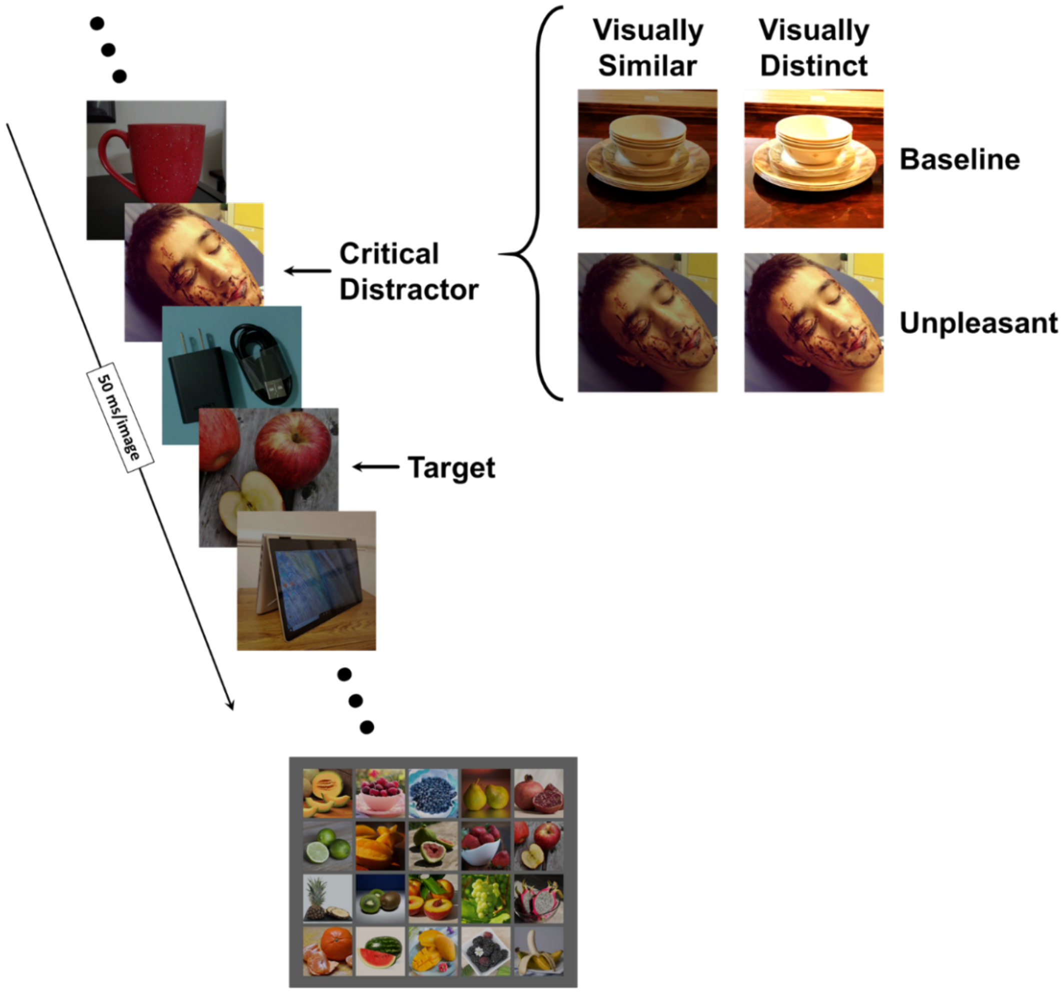

Fig. 5. A visual representation of the task in Experiment 1.1. Participants search for a fruit target in a RSVP stream of object fillers, and all images are simultaneously masked by a black box at 50% transparency to appear darker. Following each trial, participants are to select the fruit image they saw from an array of 20 fruits using their mouse. The trial depicted here on the left is a visually distinct, unpleasant, lag 2 trial. The black box is removed for the critical distractor, which is an unpleasant image. The right shows the four possible conditions for the critical distractor. Note that the images presented in the figure are all fair use: the filler images were taken by the author, the fruit images were gathered from Pixabay.com (which does not require permission for commercial use), and the unpleasant distractor was provided by a member of the author's lab (not from the IAPS database).

Apparatus and Stimuli. Images in Experiment 1.1 consisted of 420 filler images of common everyday objects, 20 target images of fruits, and 72 images of unpleasant humans (i.e., threatening or gory). The 420 filler images and 20 fruit images were collected from publicly-available sources or were taken by the researchers. The unpleasant critical distractor images came from the International Affective Picture System (IAPS; Lang et al., 2008) database based on normative valence and arousal ratings using the Self-Assessment Manikin (Bradley & Lang, 1994) 9-point scale. The critical distractor IAPS images used in Experiment 1.1 (and Experiment 2.1) were hand-selected and hand-cropped into squares to assure that the 72 unpleasant images were the most graphic (arousal: mean = 6.28, *SD* = 0.65; valence: mean = 2.16, *SD* = 0.63) and the cropping did not cut out the main subject of the images. All images were normalized for luminance using the SHINE Toolbox (Willenbockel et al., 2010) and were approximately 11.68 cm × 11.68 cm (made uniform across participants' monitors by the credit card screen scale calibration) centered on the screen. The images were covered by a black square with 50% transparency, which was removed for the critical distractor during distinct trials in order to make the image appear brighter than the surrounding RSVP stimuli.

Results and Discussion

When the data from Experiment 1.1 (Fig. 6a) were subjected to the initial lag × visual distinctiveness × valence Bayesian ANOVA, the results indicated strong support for an effect of lag (BF_{inc} = 97,171.77), valence ($BF_{inc} = 3.24\times10^{8}$), visual distinctiveness ($BF_{inc} = 1.13\times10^{11}$), and an interaction between lag and visual distinctiveness ($BF_{inc} = 4.27\times10^{8}$). Contrary to predictions, this test provided evidence against the lag × valence (BF_{inc} = 0.12), valence × visual distinctiveness (BF_{inc} = 0.36), and, crucially, lag × valence × visual distinctiveness (BF_{inc} = 0.30) interactions, suggesting that visual distinctiveness did not modulate the EAB (with the EAB characterized by the lag × valence interaction).

However, when blink timecourses were evaluated by conducting Bayesian t-tests comparing each experimental condition (Emotional + Similar, Baseline + Distinct, Emotional + Distinct) to the true baseline condition (Baseline + Similar), an interesting pattern arose (Fig. 6b). Based on the BF interpretations detailed in the General Method, the blink in the Emotional + Similar condition started around lag 3 and recovered around lag 5, thus lasting around two lags (100 ms). The Baseline + Distinct condition started around lag 1 and recovered around lag 3, also lasting around two lags (100 ms), but starting much earlier. Crucially, the Emotional + Distinct blink started around lag 1, as with the Baseline + Distinct blink, and lasted until at least lag 5, as with the Emotional + Similar condition, and thus lasted a total of at least four lags (200 ms).

The results from Experiment 1.1 support the hypothesis that physical distinctiveness initially captures attention, and emotional valence prolongs the capture in the EAB. Specifically, capture by physical distinctiveness seems to begin right away at lag 1 (50 ms), as shown in the Baseline + Distinct condition, and then emotional valence plays a role around lag 3, as shown in the Emotional + Similar condition. Moreover, because the Emotional + Distinct condition shows both of these stages back-to-back, it suggests that the EAB reflects two sequential phases: first the capture from visual distinctiveness that begins right away (at lag 1), and then emotional modulation that happens later in the RSVP sequence (at lag 3).

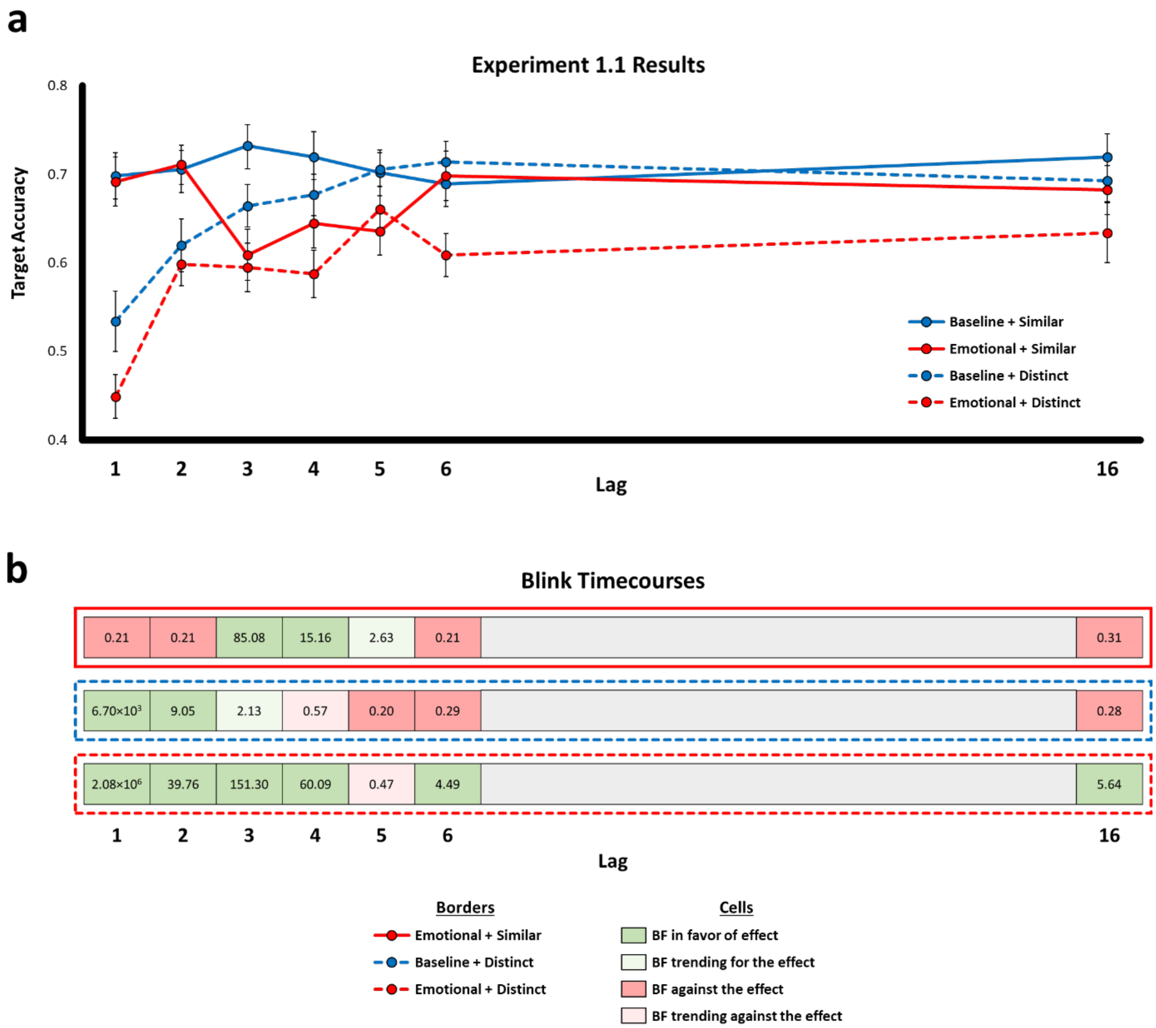

Fig. 6. Results from Experiment 1.1. **(a)** Graph of performances for each condition across lags. Error bars represent standard error of the mean. **(b)** Timecourses of the "blinks" in each experimental condition, indicated by the results of the Bayesian t-tests comparing the experimental conditions to baseline at each lag. Each cell represents a lag and the numbers are the BFs providing support for or against a difference.

Experiment 1.2

While the task in Experiment 1.1 was ideal for presenting the stimuli exceptionally fast and yielded the hypothesized effect, the use of images for the task meant that the emotional distractors had to be physically distinct from the surrounding RSVP stimuli (unpleasant images of humans among object fillers and fruit targets), much like previous EAB studies. Thus, the visual distinctiveness manipulation could only add an additional level of visual distinctiveness, and it remains likely that the EAB effect observed in the Emotional + Similar condition was still driven by visual/categorical distinctiveness. While the additional distinctiveness manipulation accomplished its intended goal of manipulating the degree of distinctiveness (as seen in the Baseline + Distinct condition), it could not create a zero-distinctiveness condition and thus was not a pure way of examining the role of visual distinctiveness in the classic EAB paradigm. Therefore, Experiment 1.2 used RSVP streams with word stimuli, in which visual distinctiveness can be more closely controlled.

Method

Participants. A total of 21 participants (16 women, 4 men, 1 non-binary; Mean age = 20.76 years, *SD* = 3.49 years) participated in Experiment 1.2. All participants met the requirements outlined in the General Method.

Procedure. In Experiment 1.2, participants began each trial by pressing the space bar, which initiated a fixation cross presented for 300 ms, a blank screen for 100 ms, and a RSVP stream of 20 words presented at a rate of approximately 100 ms/word (Fig. **7**). The stream consisted of 3-5 pre-target filler words, a critical distractor word, 0-7 inter-target filler words, a target word, and 4-15 post-target filler words. Participants were told to search for a fruit word in each stream and to report it following each trial by typing the word out using their keyboard, similar to the task used in a previous study by Huang et al. (2008) and Santacroce & Tamber-Rosenau (under review). Participants were told that incorrect spellings will not affect their performance, and all responses were coded for typos (e.g., “APPEL” was accepted as well as “APPLE”). Because the targets are defined by category (fruits) and the task requires recall without knowing the options, participants had to semantically process each word in the stream in order to make their target selection, which increased the likelihood of processing the valence of the critical distractor (Huang et al., 2008). Each word in the stream was presented in the same color (aside from some critical distractors), but that color varied from trial to trial to avoid participants adjusting to a single color and learning to attend to or suppress any particular color.

The critical distractor was manipulated by visual distinctiveness (distinct or similar) and emotional valence (baseline or taboo), leading to four different critical distractor types: Emotional + Distinct, Baseline + Distinct, Emotional + Similar, and Baseline + Similar. Taboo words were used as the emotional distractors, because this category of words have yielded the largest EABs in previous studies (Arnell et al., 2007; Mathewson et al., 2008; Santacroce & Tamber-Rosenau, under review). Although taboo words failed to produce a blink in the study by Santacroce et al. (2023), they were nonetheless most likely to create a blink in the current task, which directly replicated a study that did produce a blink with identical stimuli and task (Santacroce & Tamber-Rosenau, under review). During the distinct trials, the critical distractor was presented in a different color than the rest of the stream, and that color also varied from trial to trial. To be sensitive to the precise time courses of the blinks in each critical distractor condition, there were 7 critical distractor to target lags: lags 1-6 and lag 8 (100 ms, 200 ms, 300 ms, 400 ms, 500 ms, 600 ms, and 800 ms). With all of the conditions, the current experiment was a 7 (lag: 1, 2, 3, 4, 5, 6, 8) × 2 (visual distinctiveness: distinct or similar) × 2 (valence: neutral or taboo) within-subjects factorial design. Each of the 28 conditions was presented 20 times each, for a total of 560 trials.

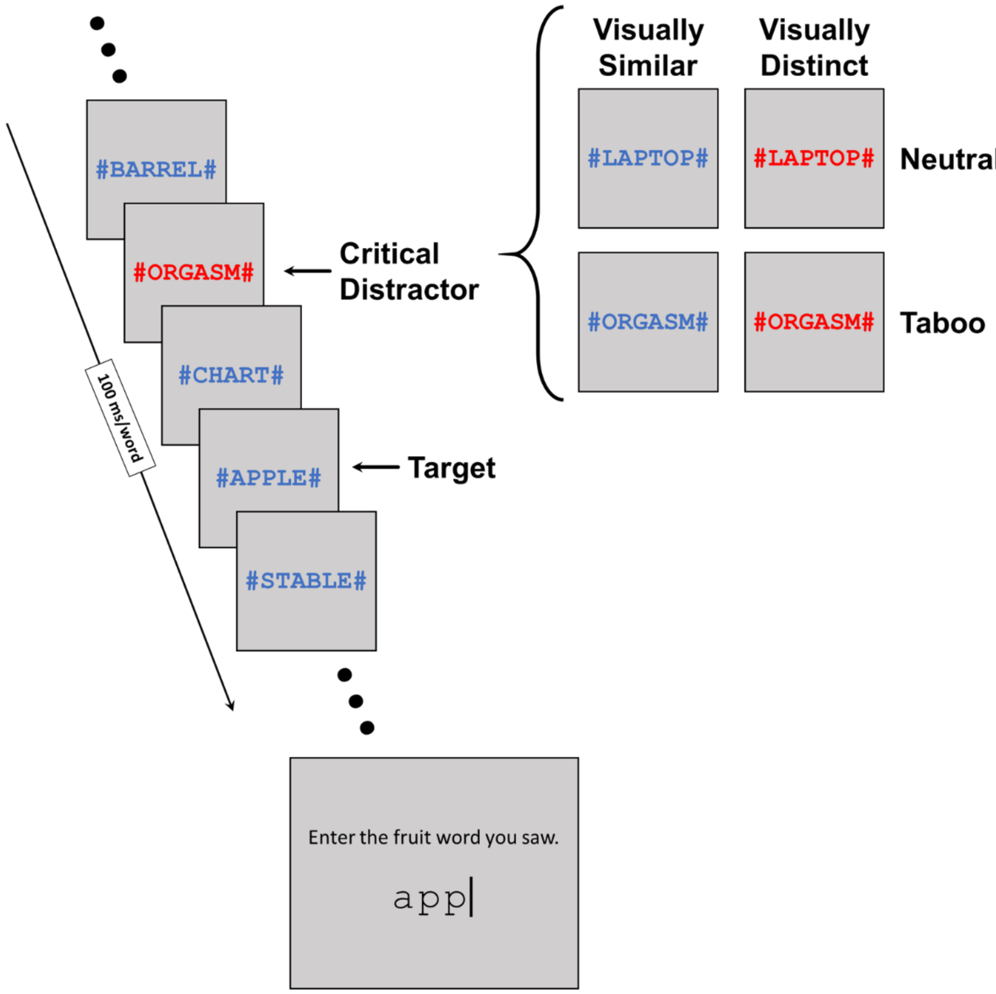

Fig. 7. A visual representation of the task in Experiment 1.2. Participants searched for a fruit target word in a RSVP stream of neutral filler words presented in a random color (here, the stream color is blue). Following each trial, participants were prompted to enter the fruit word they saw using their keyboard. The trial depicted here on the left is a visually distinct, taboo, lag 2 trial. The critical distractor depicted in the stream here is a taboo word presented in a different color than the rest of the stream (here, the color is red). The right shows the four possible conditions for the critical distractor. Note that the words shown here are surrounded by one pound symbol (#) on each end, but the words in the experiment were surrounded by enough pound symbols to make the words a total of twelve characters long.

Apparatus and Stimuli. Word stimuli were taken from Santacroce & Tamber-Rosenau (under review), which included 120 neutral filler words, 30 taboo distractors, and 30 fruit targets, all between four and ten letters long (Table B1). Their fruit words were carefully selected to ensure that they were common enough to be recognized by participants, and thus they avoided more obscure fruits (e.g., “DURIAN” or “LOQUAT”) or ambiguous fruits (e.g., "AVOCADO" or "TOMATO"). Their taboo words were gathered by first selecting 60 words between four and ten characters long that were deemed "not safe for work" (*List of Swear Words, Bad Words, & Curse Words - Starting With A*, n.d.). Then, the 30 "worst" (most taboo) were selected by the author and several colleagues using a ranking program adapted from an html code found in a Tumblr blog post (Vivi, 2018). The program presented two words at a time and those who completed the program were to select the word they felt was the most taboo out of each pair of words. The program then took the pairwise responses and generated a ranking of all of the words from 1-60. Rankings were averaged across individuals, and the top 30 words were selected for the experiment. The neutral filler words were then selected to match the lengths of the other words and never contained food words that might interfere with detecting fruit words.

All words were centered on the screen, presented in Courier New font, with a height of approximately 0.64 cm (made uniform across participants' monitors by the credit card screen scale calibration). In order to correct for word length and thus minimize visual transients, each word was padded with pound symbols (#) so that they were all a total of 12 characters long. The font color for each stream was chosen randomly from a list of 180 colors on an approximately equiluminant color wheel (Zhang & Luck, 2008). On visually distinct trials, the critical distractor was presented in a color that is opposite from the stream color on the color wheel +/- 30°. This method ensured that the critical distractor was adequately distinct, while also minimizing the possibility of participants learning to attend to a certain color while suppressing the critical distractor color.

Results and Discussion

When the data from Experiment 1.2 (Fig. 8a) were subjected to the initial lag × visual distinctiveness × valence Bayesian ANOVA, the results indicated strong support for an effect of lag (BF_{inc} = 870.32), valence (BF_{inc} = 181.96), an interaction between lag and valence (BF_{inc} = 327.53), but no support for an effect of visual distinctiveness (BF_{inc} = 0.53). Contrary to predictions, this test provided evidence against the lag × visual distinctiveness (BF_{inc} = 0.03), valence × visual distinctiveness (BF_{inc} = 0.25), and lag × valence × visual distinctiveness (BF_{inc} = 0.06) interactions, suggesting that visual distinctiveness did not modulate the EAB.

When blink timecourses were evaluated by conducting Bayesian t-tests comparing each experimental condition (Emotional + Similar, Baseline + Distinct, Emotional + Distinct) to the true baseline condition (Baseline + Similar), the results were less explicit than in Experiment 1.1 (Fig. 8b). Based on the BF interpretations detailed in the General Method, the blink in the Emotional + Similar condition started around lag 2 and recovered by around lag 3, thus lasting approximately one lag (100 ms). The Emotional + Distinct blink also began around lag 2, but continued to around lag 5, lasting approximately three lags (300 ms). This might suggest that there is increased dwell time on the emotional distractor when it is also visually distinct. However, the Baseline + Distinct condition in Experiment 1.2 failed to yield a blink at all, suggesting that visual distinctiveness alone does not capture attention, at least in the current paradigm with word stimuli. Moreover, these results might suggest that *visual distinctiveness* alone fails to capture attention in this EAB paradigm, but might prolong initial capture caused by *emotion*, which is the opposite outcome than what was hypothesized and what was observed in Experiment 1.1.

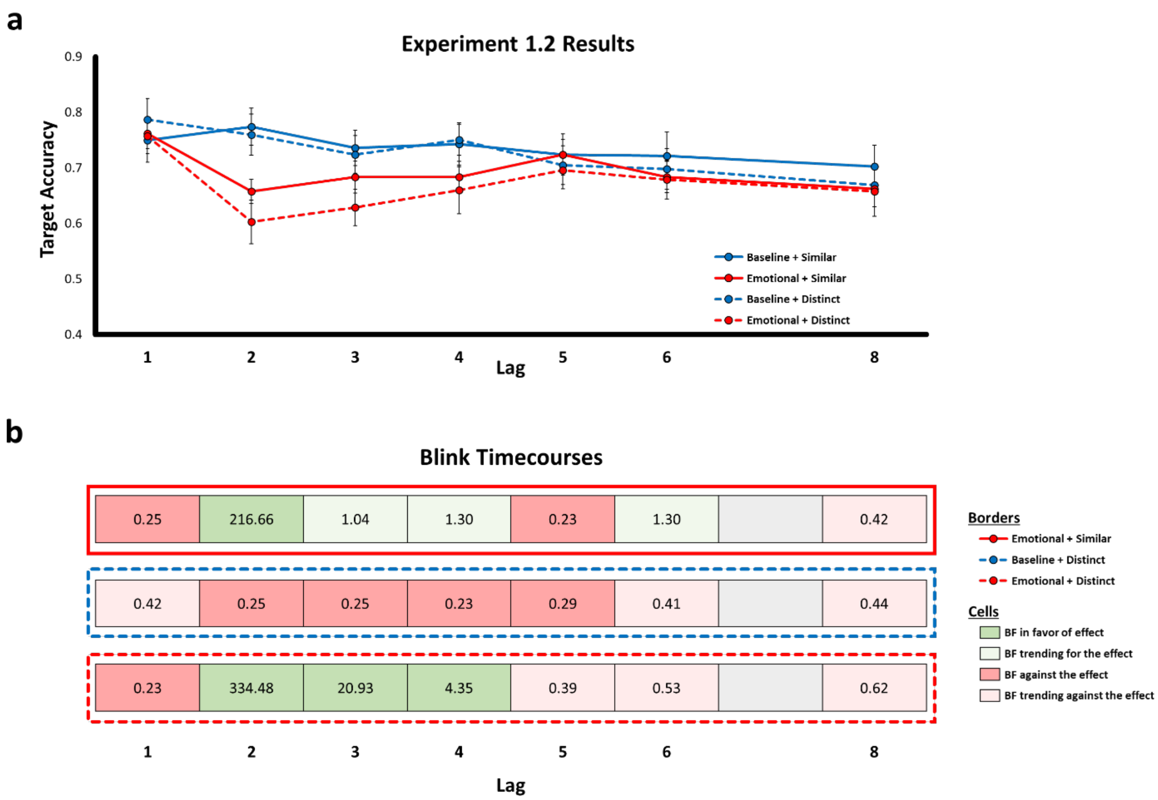

Fig. 8. Results from Experiment 1.2. **(a)** Graph of performances for each condition across lags. Error bars represent standard error of the mean. **(b)** Timecourses of the "blinks" in each experimental condition, indicated by the results of the Bayesian t-tests comparing the experimental conditions to baseline at each lag. Each cell represents a lag and the numbers are the BFs providing support for or against a difference.

Aim 1 Discussion

The goal of Aim 1 was to test if the EAB effect was truly caused by emotional capture, or rather by the visual distinctiveness of the emotional distractor that could then be prolonged or magnified by its emotional valence. EAB research has historically been conducted using emotional distractors that are visually distinct from the surrounding RSVP stimuli, such as unpleasant images of humans or animals among landscapes (Most et al., 2005b), unpleasant images of humans or animals among common objects (Kennedy & Most, 2015; Santacroce et al., 2023), or taboo words among random strings of numbers/symbols (Huang et al., 2008). Recent research, however, has suggested that in the absence of this visual distinctiveness, the emotional distractor fails to capture attention and yield an EAB (Baker et al., 2021; Santacroce et al., 2023), which led to the current hypothesis for Aim 1.

The two EAB experiments for Aim 1 manipulated the valence (emotional or baseline) and visual distinctiveness (similar or distinct) of critical distractors in RSVP streams with many consecutive critical distractor to target lags in order to examine the precise time courses of the resulting blinks. Experiment 1.1 used RSVP streams of images with unpleasant images as the emotional distractors and brighter images as the visually distinct distractors. Experiment 1.2 used RSVP streams of words with taboo words as the emotional distractors and words presented in a different color as the visually distinct distractors. Unexpectedly, the two experiments led to divergent results.

Experiment 1.1's image-based task provided evidence that the EAB is a two-phase process: the first phase is capture by visual distinctiveness, which begins right away and which was observed in both visually distinct conditions. The second phase is modulation by emotion, which happens later on and which was observed in both emotional conditions. Experiment 1.1 thus supported the hypothesis that visual distinctiveness drives the initial attentional capture in the EAB, which can then be modulated by emotion. The results from Experiment 1.2's word-based task, however, painted a different picture and showed that visual distinctiveness does not modulate the EAB effect.

A number of reasons could explain why the results of the two experiments contradict one another. For one, because the emotional image distractors of unpleasant humans in Experiment 1.1 were also from a different category than the object filler items, unlike the words in Experiment 1.2, this could suggest that it is *categorical* distinctiveness that captures attention in the EAB, rather than *visual* distinctiveness. This could also be supported by the "neutral" blink found in Huang et al. (2008) using word stimuli—their word critical distractors in a stream of random number and symbol strings were not only *visually* distinct from the surrounding RSVP stimuli, but also *categorically* distinct as words among non-words, which might be why they found a blink with neutral words while the same was not true with the strictly *visually* distinct distractors in Experiment 1.2. However, this idea likely falls short because Experiment 1.1 still showed an added effect when the brightness was manipulated.

It is also probable that EAB studies using RSVP streams of words simply cannot be compared to those using streams of images because the different processing mechanisms lead to different blinks. Compared to image stimuli, word stimuli take longer to categorize as a target (Azizian et al., 2006) or by valence (Houwer & Hermans, 1994), are less automatically processed (Başgöze et al., 2015), show less task interference when highly arousing (Sutton & Lutz, 2019), are less likely to be recalled later when actively being ignored (Walker et al., 2017), and reveal different neural activation patterns in response to emotion (Kensinger & Schacter, 2006). In addition, results from EAB studies with word stimuli often yield mixed, unreliable results (see Arnell et al., 2007; Mathewson et al., 2008; Santacroce et al., 2023; Santacroce & Tamber-Rosenau, under review). Thus, the EAB resulting from word stimuli likely stem from different mechanisms, which would make it difficult to interpret the results from Experiments 1.1 and 1.2 jointly, and future research should avoid assuming that EABs in word paradigms are comparable to or stem from the same causes as those in image paradigms. Given that image paradigms are much more common in EAB studies, the results from Experiment 1.1 still help to explain a majority of the EAB literature that use visually/categorically distinct emotional distractors. Nonetheless, future research should consider separating categorical and visual distinctiveness, particularly in word RSVP paradigms.

III. AIM 2: LESS SUPPRESSION WITH A LESS DEMANDING TASK?

Aim 1 considered the possibility that the EAB appears to be weak when visual salience is well controlled. Aim 2 turns to another potential explanation for the weakness of the EAB, that the RSVP task is too cognitively or perceptually demanding to allow for consistently strong stimulus-driven attentional capture by a task-irrelevant stimulus (even if capture does occasionally happen), which is what the experiments in Aim 2 test. It seems that, at least in rapidly-changing dynamic settings such as in a RSVP stream, salient task-irrelevant stimuli are less likely to take priority over current goals. This, in turn, could affect attentional capture by otherwise salient task-irrelevant stimuli. Referring back to the driving example from earlier, you are likely to notice a disturbing billboard advertisement when driving on an open road and it might momentarily capture your attention. On the other hand, if you are instead driving through heavy traffic during rush hour when cars are merging, exiting, and swerving all around, you are probably less likely to notice or be captured by the disturbing billboard because you are too preoccupied with the cognitively-demanding dynamic scene around you. This notion aligns with visual search research showing that increasing task demands by increasing the task's perceptual load (Lavie, 1995), decreasing display time (Kiss et al., 2012), or by increasing the number of display items (Cosman & Vecera, 2009; Leonard & Egeth, 2008) leads to more rapid suppression of physically salient task-irrelevant stimuli. This notion could also explain the findings by Santacroce et al. (2021) showing that unless extremely visually salient, a task-irrelevant emotional stimulus cannot survive the AB when its presented between two targets—searching for two targets in a RSVP stream is much more cognitively demanding than searching for just one target, as with typical EAB studies.

Thus, it is possible that the high attentional demands and time pressure of a RSVP task makes it necessary for participants to rapidly suppress all task-irrelevant stimuli, including the emotional distractor, to successfully detect targets. RSVP streams typically used in AB and EAB studies are essentially composed of sequential abrupt onsets of new items, and abrupt onsets presented in isolation are generally known to be extremely strong drivers of stimulus-driven attentional capture (e.g., Remington et al., 1992; Yantis & Jonides, 1984, 1990). It seems likely, then, that successful performance of a cognitively demanding RSVP task requires constantly overriding stimulus-driven capture by abrupt onsets. One way to accomplish suppression of these serial abrupt onsets comprising the RSVP stream may be to enhance top-down control relative to salience-driven control for all kinds of stimulus-driven salience, rather than specific to abrupt onsets presented in isolation. If so, it may be that stimulus-driven capture is suppressed more generally in rapid dynamic settings like RSVP, leading to the suppression of all distractors that do not share target features. Visuospatial attention research has shown that even when features (color, location) of a salient distractor are unpredictable, they can nonetheless be suppressed when their presence is expected (Won et al., 2019). This aligns well with general suppression in RSVP tasks because task-irrelevant distractors are always present, and are therefore expected. Such broad suppression would also be consistent with results from Folk et al. (2002, 2008), who showed that salient distractors capture attention in RSVP primarily when they share a target-defining feature (such as color) with targets, but not when they are salient without sharing such a feature. As a result, the task-irrelevant stimuli, including the emotional distractor, would be suppressed, leading to the apparent weakness of the EAB compared to the AB even when visual salience and emotion both are available to drive a potential capture effect. However, this suppression sometimes fails and task-irrelevant stimuli do make it through, which is why EABs are still observed in RSVP streams.

Similarly, a phenomenon known as inattentional blindness shows that humans tend to miss salient distractors while they are focusing on an unrelated task (Mack & Rock, 1998). Perhaps the most famous example of inattentional blindness is the experiment in which participants were so focused on counting the number of ball passes in a video that many of them failed to notice the gorilla that entered the scene (Simons & Chabris, 1999). Inattentional blindness research has shown that by decreasing cognitive demands of the task, participants are more likely to be captured by a task-irrelevant stimulus (Cartwright-Finch & Lavie, 2007). Thus, it makes sense that the cognitive demands from the typical RSVP task could result in general suppression of all stimulus-driven attention, making it less likely for the emotional distractor to capture attention away from current goals in the EAB. Therefore, Aim 2 sought to answer the question: Does the cognitively demanding nature of RSVP streams lead to general suppression of all stimulus-driven attentional control toward task-irrelevant stimuli (including an emotional distractor), weakening the EAB effect? To answer this, the current Aim 2 experiments (Experiments 2.1 and 2.2) implement a "skeletal" EAB paradigm (Ward et al., 1996), and thus each RSVP stream contained the manipulated critical distractor (either neutral or emotional), a critical distractor mask, the target, and a target mask. The skeletal EAB task was then compared to the typical EAB task in the same participants, with the hypothesis that the skeletal EAB task, in which there were fewer distracting events that must be suppressed, would lead to a more robust EAB. This result would indicate that the high cognitive demands of the typical RSVP stream led to broad suppression of stimulus-driven attentional control, and thus only relatively weak (or infrequent) attentional capture and a weak EAB.

Aim 2 Terminology

Although Aim 2 used two different paradigms that are typically accompanied by different terminology, specific terms used here will continue to align with those from EAB studies in order to maintain consistency between the two paradigms. First, the *typical* RSVP paradigm refers to what is used in typical EAB studies (with all stimuli presented in rapid succession), which was compared to the *skeletal* RSVP paradigm. In addition, the critical distractor, the critical distractor mask, the target, and the target mask are referred to collectively as the *critical stimuli* in the skeletal RSVP paradigm (not to be confused with the *critical distractor* which has been and will be used throughout to refer to the manipulated distractor). Because the typical EAB RSVP paradigm uses a continuous stream of stimuli, while the skeletal paradigm will have blank screens surrounding the critical stimuli, the term *positions* is used here to describe the placeholders that could be filled with either a stimulus or a blank screen. Also for this reason, the term *stream* will continue to be used to describe the stimuli presentations in each trial. In other words, each trial contained a *stream* of 20 *positions* that were each filled with a stimulus in the typical RSVP paradigm, but was filled with blank screens or the critical stimuli in the skeletal RSVP paradigm. Thus, the streams in both paradigms always lasted the same amount of time. Finally, because the positions between the critical distractor and target appeared as a continuous blank screen, skeletal blink studies would typically report the effects of a manipulation of stimulus onset asynchrony—the time from the onset of the critical distractor to the target. However, to ease comparisons between typical and skeletal paradigms, all delays in the present study will instead be described in terms of *lags*, meaning the number of *positions* separating the critical distractor and the target. For example, if the skeletal RSVP positions are presented at a rate of 100 ms per item (as with Experiment 2.2), at lag 4, participants saw the critical distractor, a mask filler for 100 ms (1 stimulus position), and then a blank screen for 200 ms (2 stimulus positions) before the target appeared.

Aim 2 General Method

Participants

As with Aim 1, the participants for Aim 2 consisted of University of Houston students participating for course credit through the university's SONA system. Participants were screened via self-report and were omitted if they reported any of the following exclusion criteria: younger than 18 years of age, have poor and uncorrected vision, are color blind, partake in regular or task-concurrent use of psychoactive drugs, and have a neurological disorder, brain injury, or other diagnosis known to affect cognition. Informed consent was gathered from all participants under a protocol approved by the University of Houston Institutional Review Board. The experiments in Aim 2 were also be analyzed using Bayesian hypothesis tests, and thus sample size was determined the same as with the experiments in Aim 1: a minimum of 20 participants were collected and then increased in increments of 5 until a BF_{inc} of greater than 3 or less than 1/3 was achieved in the main analysis of interest. This indicated moderate evidence for or against the effect.

Design and Apparatus

In order to test the hypothesis that the cognitively demanding nature of the typical AB/EAB RSVP paradigm forces participants to generally suppress stimulus-driven attention in order to locate targets (and thus limits the possibility of emotional stimuli capturing attention), Aim 2 utilized a simpler, skeletal RSVP paradigm (Ward et al., 1996). Skeletal RSVP paradigms are sometimes used in AB studies and often consist of a T1, a T1 mask, a blank T1-T2 interval, a T2, and a T2 mask. Such simplified paradigms have been shown to produce an AB effect, as long as the two targets are immediately masked with at least one distractor (Lagroix et al., 2012). With fewer distractors that must be suppressed, it was hypothesized that there would be less general suppression of stimulus-driven attention to non-targets, leading to a more robust EAB.

Each experiment for Aim 2 had two blocks of trials, presented in a random order: one that utilized the skeletal RSVP paradigm and one that utilized the typical RSVP paradigm. In both blocks, each trial began with a fixation cross for 300 ms, a blank screen for 100 ms, and then a RSVP stream with 20 stimulus positions, each presented at a fixed rate (presentation times for each position varied by experiment). The streams consisted of 3-5 filler positions, a critical distractor, a lag of a varying amount of filler positions, a target stimulus, and then post-target filler positions. The block with the typical RSVP paradigm was identical to the paradigms used in Aim 1 (aside from the brightness/color manipulations and stimuli presentation times), where each RSVP position was filled with a stimulus and thus the items in the stream were presented in rapid succession. In the skeletal block, only four of the RSVP positions were filled in each stream: the critical distractor, the critical distractor's mask, the target, and the target's mask. All other positions were presented as blank screens for the same duration. Thus, each skeletal trial began with a blank screen for a varying amount of time, a critical distractor, a filler item (the critical distractor mask), a blank screen, the target, another filler item (the target mask), and then finished with a blank screen for a varying amount of time before participants were prompted to make their response.

Because Aim 2 was less interested in the exact time course of the blinks compared to Aim 1, the experiments here only included lags 1, 2, 3, and 10. The main analysis of interest was the RSVP type × valence × lag within-subjects Bayesian ANOVA to see if there was a difference in the neutral and emotional blinks in the different RSVP types. There were 20 trials per condition. The apparatus used in the Aim 2 experiments were identical to the experiments in Aim 1.

Experiment 2.1

Method

Participants. A total of 25 participants (19 women, 5 men, 1 non-binary; Mean age = 20.24 years, *SD* = 2.85 years) participated in Experiment 2.1. Data were collected from one additional participant, but was not included in these results because their overall performance in all baseline conditions were 3 standard deviations below the mean. All participants met the requirements outlined in the General Method.

Procedure and Stimuli. Experiment 2.1 followed similar procedures to Experiment 1.1, but with the design for Aim 2 (Fig. 9). The RSVP stimuli consisted of all colored images: the filler images contained common everyday objects, the critical distractors (when present) were neutral or unpleasant IAPS images of humans, and the targets were fruits. Unlike the images in Experiment 1.1, the images in Experiment 2.1 were not darkened and thus the RSVP stimuli all had the same brightness. Following each trial, participants selected the fruit they saw out of an array of 20 fruits. Each RSVP position was presented at 70 ms per position because precise timing was less important for Aim 2 and this particular paradigm has been previously used with images presented at this rate (Santacroce et al., 2023; Santacroce & Tamber-Rosenau, under review). Thus, the critical distractor to target lags were lags 1, 2, 3, and 10 (0 ms, 70 ms, 140 ms, and 630 ms long) and each stream of 20 stimulus positions lasted a total of 1,400 ms. Unlike Experiment 1.1, however, Experiment 2.1 included a neutral valence condition in addition to the baseline and unpleasant conditions, which is common in EAB studies and was more feasible in Aim 2 with its fewer lag conditions. The neutral critical distractor images also contained humans, as with the unpleasant images, but they had a neutral valence. The neutral condition also contained 72 images from the International Affective Picture System (IAPS; Lang et al., 2008) database, and were hand-selected and hand-cropped into squares to assure that they are truly neutral (arousal: mean = 3.79, *SD* = 0.62; valence: mean = 5.85, *SD* = 1.07) and the cropping did not cut out the main subject of the images. Thus, the valence of the critical distractor was either neutral, unpleasant, or absent (baseline). This led to two RSVP types (typical, skeletal), three valences (neutral, unpleasant, baseline), and four lags (1, 2, 3, 10), for a total of 24 conditions. At 20 trials per condition, each session contained a total of 480 trials (240 per block).

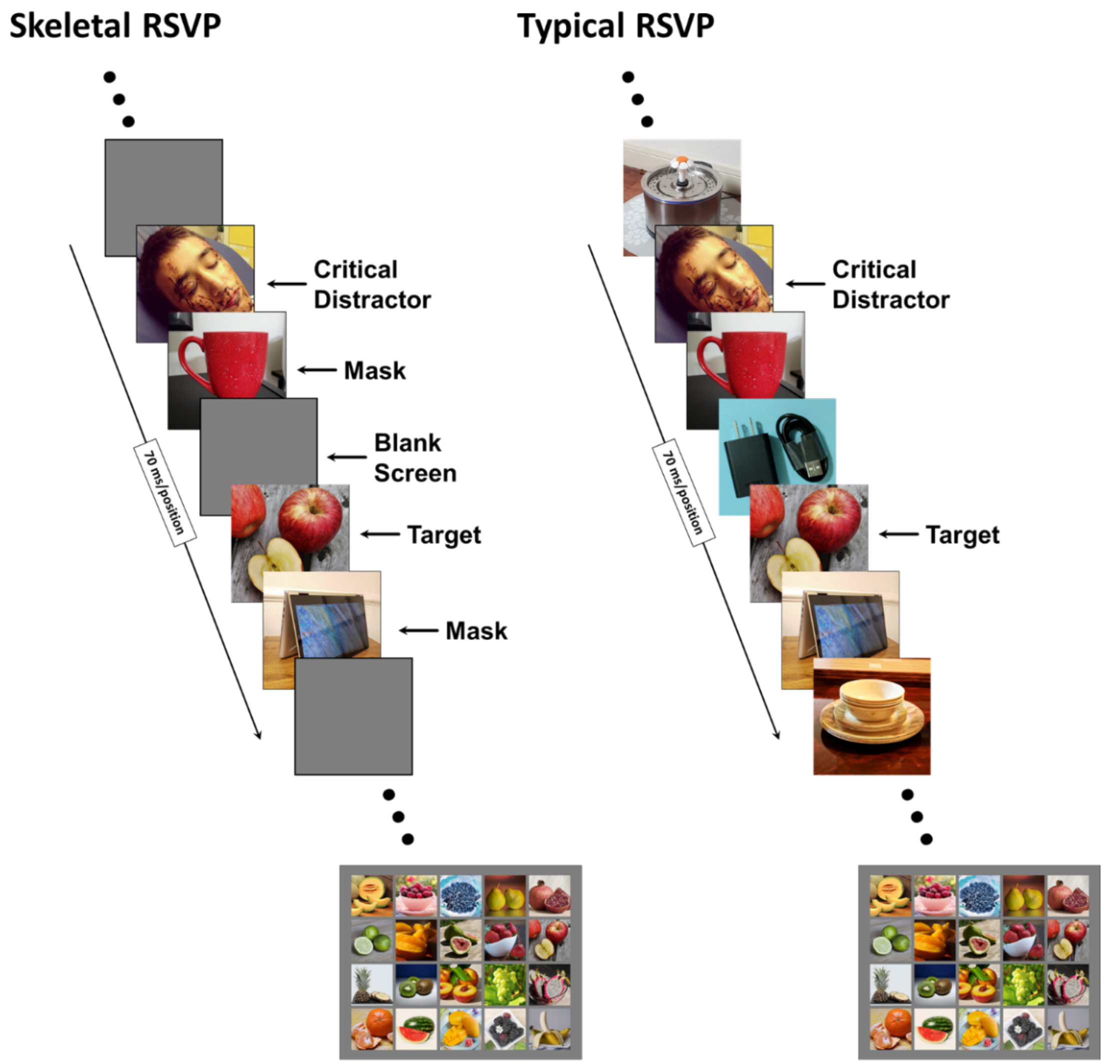

Fig. 9. A visual representation of the task in Experiment 2.1. Participants searched for a fruit target in a RSVP stream and selected the fruit image they saw from an array of 20 fruits using their mouse. The left RSVP stream depicts the skeletal RSVP, in which only the critical distractor, a critical distractor mask, the target, and target mask are present, while the other stimulus positions were blank screens. The stream on the right depicts the typical RSVP streams where every positions is filled with an image. Both streams showcase lag 3 unpleasant conditions, where the target is three RSVP positions away from the unpleasant critical distractor. Note that the images presented in the figure are all fair use: the filler images were taken by the author, the fruit images were gathered from Pixabay.com (which does not require permission for commercial use), and the unpleasant distractor was provided by a member of the author's lab (not from the IAPS database).

Results

When the data from Experiment 2.1 (Fig. 10) were subjected to the initial lag × RSVP type × valence Bayesian ANOVA, the results indicated support for effects of lag (BF_{inc} =

4,635.79) and valence (BF_{inc} = 3.96), and a lag × valence interaction (BF_{inc} = 5.93), indicating an EAB effect. However, the results provided evidence against an effect of RSVP type (BF_{inc} = 0.11), as well as its interaction with each other factor and interaction (BF_{inc}s = 0.09 – 0.42). This suggests that the EAB was not affected by the RSVP type.

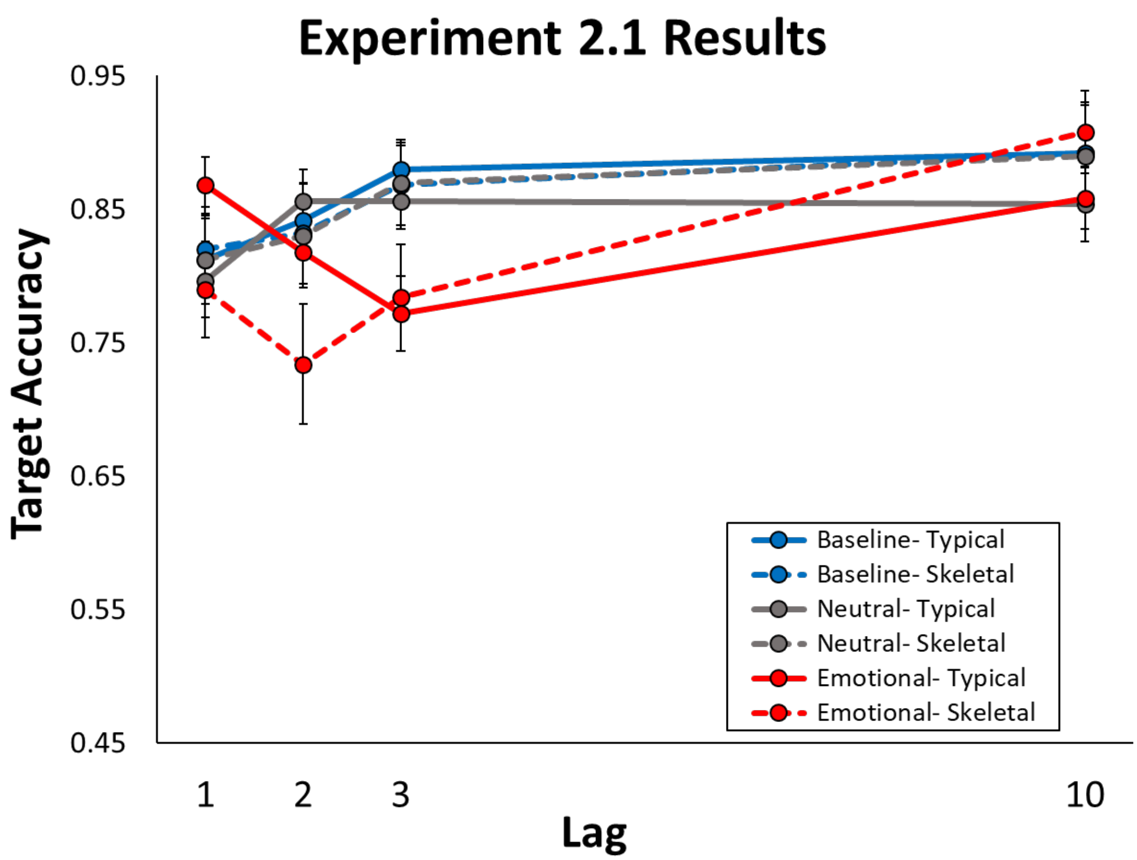

Fig. 10. Results from Experiment 2.1. Note that the baseline skeletal and neutral skeletal conditions yielded very similar results, so the lines mostly overlap in this figure. Error bars represent the standard error of the mean.

Experiment 2.2

Method

Participants. A total of 29 participants (23 women, 5 men, 1 preferred not to answer; Mean age = 21.31 years, *SD* = 3.13 years) participated in Experiment 2.2. All participants met the requirements outlined in the General Method.

Procedure and Stimuli. Experiment 2.2 followed similar procedures to Experiment 1.2, but with the design for Aim 2 (Fig. 11). The RSVP stimuli consisted of all words: the filler words were neutral everyday words, the critical distractors were taboo words (or additional neutral words in the baseline valence condition), and the targets were fruit words. Unlike the words in Experiment 1.2, all words in Experiment 2.2 were always black. Following each trial, participants entered the fruit word they saw using their keyboard. Each RSVP position was presented at 100 ms per position, and thus the critical distractor to target lags were lags 1, 2, 3, and 10 (0 ms, 100 ms, 200 ms, and 900 ms long) and each stream of 20 stimuli positions lasted a total of 2,000 ms. The valence of the critical distractor was either baseline or taboo. Note that Experiment 2.2 did not contain a neutral condition like Experiment 2.1 did because the filler words were also neutral, and thus there would be no difference between neutral and baseline conditions. This led to two RSVP types (typical, skeletal), two valences (neutral, taboo), and four lags (1, 2, 3, 10), for a total of 16 conditions. At 20 trials per condition, each session contained a total of 320 trials (160 per block).

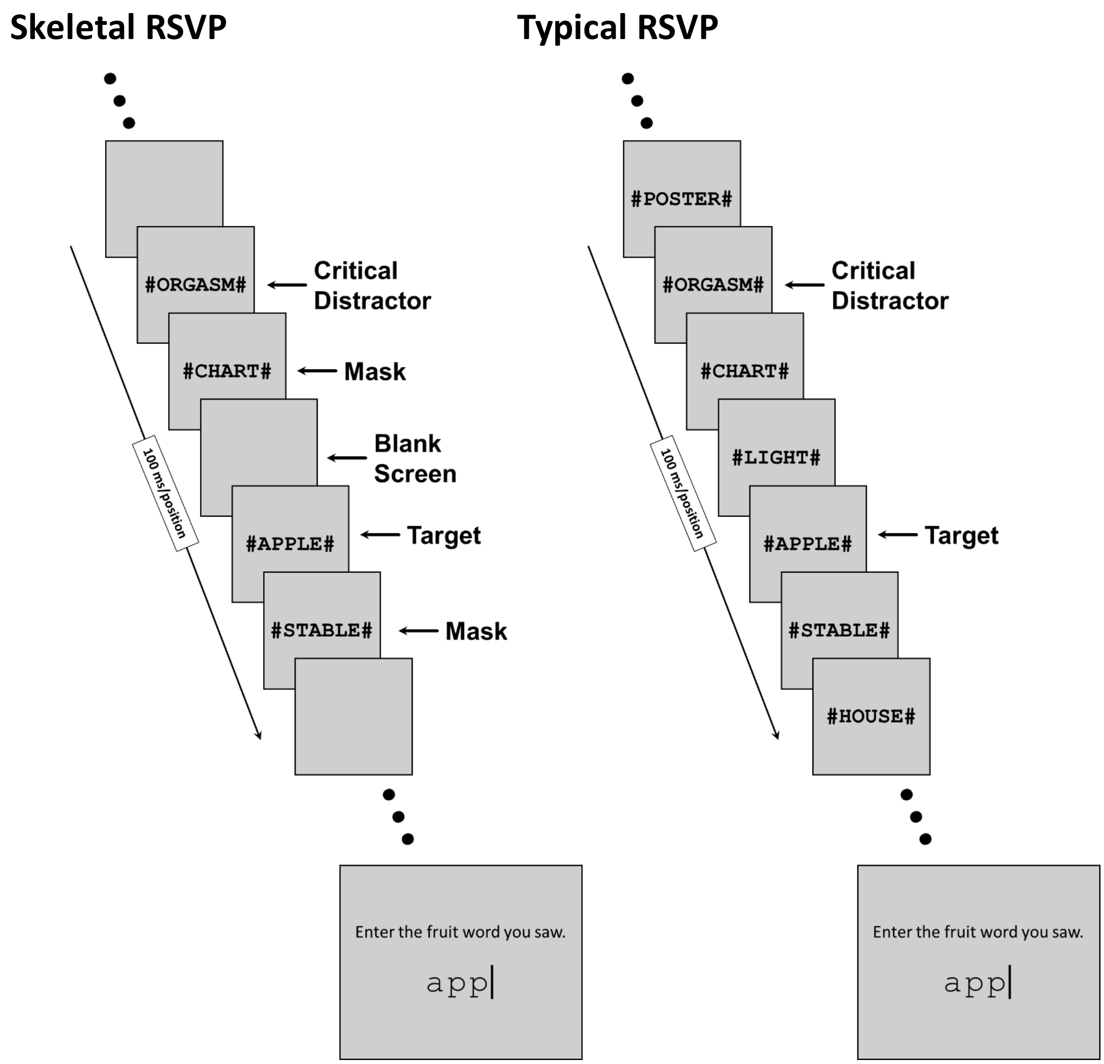

Fig. 11. A visual representation of the task in Experiment 2.2. Participants searched for a fruit target word in a RSVP stream and entered the fruit word they saw at the end of each trial. The left RSVP stream depicts the skeletal RSVP, in which only the critical distractor, a critical distractor mask, the target, and target mask are present, while the other stimulus positions will be blank screens. The stream on the right depicts the typical RSVP streams where every position is filled with a word. Both streams showcase lag 3 taboo conditions, where the target is three RSVP positions away from the taboo critical distractor. Note that the words shown here are surrounded by one pound symbol (#) on each end, but the words in the experiment were surrounded by enough pound symbols to make the words a total of twelve characters long.

Results

When the data from Experiment 2.2 (Fig. 12) were subjected to the initial lag × RSVP type × valence Bayesian ANOVA, the results indicated support for effects of lag (BF_{inc} = 457.21) and valence (BF_{inc} = 58.16), and a lag × valence interaction (BF_{inc} = 7.44), indicating an EAB effect. While the results indicated an effect of RSVP type ($BF_{inc} = 2.56 \times 10^6$), this factor only interacted with lag (BF_{inc} = 1,590.82), where overall higher performance was observed in the skeletal RSVP task. RSVP type did not interact with valence (BF_{inc} = 0.19) and, crucially, the results provided evidence against the lag × valence × RSVP type interaction (BF_{inc} = 0.10), suggesting that the EAB was not affected by the RSVP type.

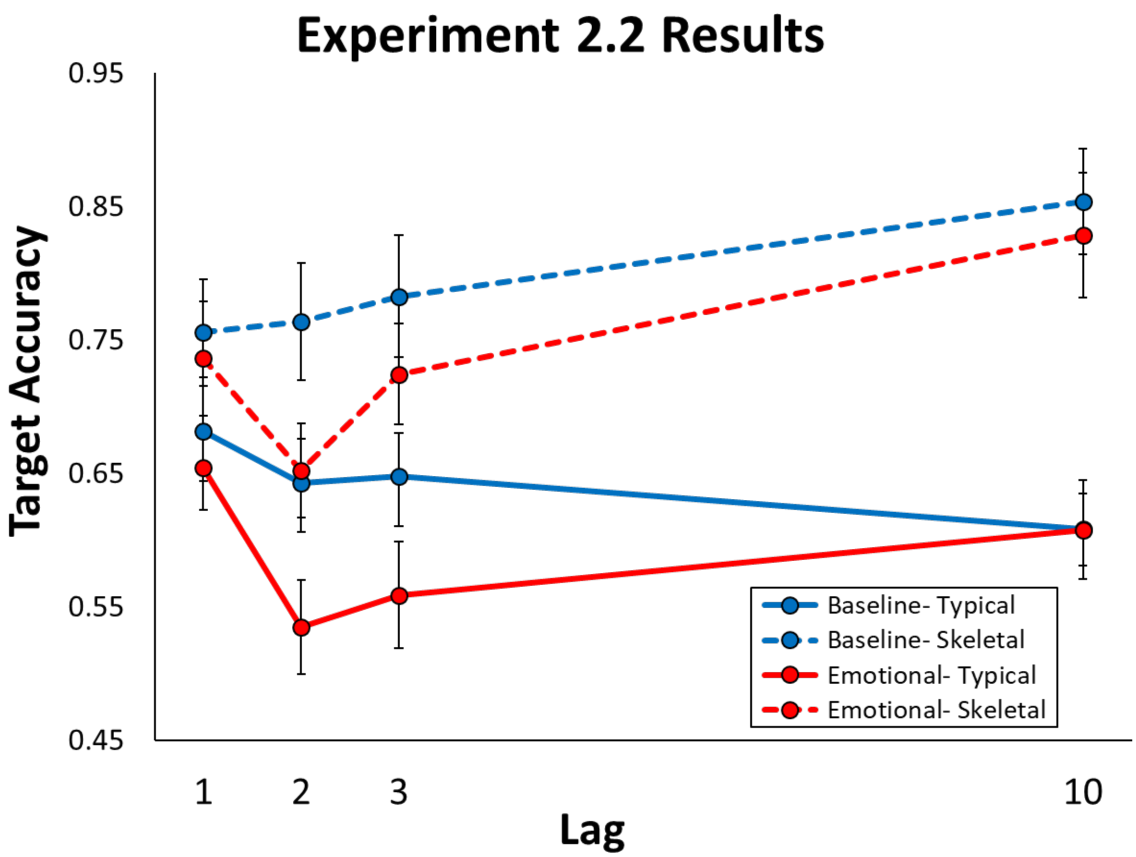

Fig. 12. Results from Experiment 2.2. Error bars represent the standard error of the mean.

Aim 2 Discussion

Aim 2 asked if the cognitively demanding nature of RSVP streams encourages general suppression of task-irrelevant stimuli (including emotional distractors), which in turn weakens the ability of emotional valence to capture temporal attention. The two experiments for Aim 2 implemented the skeletal RSVP paradigm (Ward et al., 1996) and compared the resulting EABs to those elicited in the typical RSVP paradigm. It was hypothesized that the skeletal EAB task, in which there were fewer distractors to suppress, would minimize the general suppression of stimulus-driven attention to non-targets and lead to a more robust EAB. However, the results suggested that this is not the case: the number of stimuli (i.e., use of skeletal vs. RSVP paradigms) did not modulate the robustness of the EAB using either image stimuli (Experiment 2.1) or word stimuli (Experiment 2.2).

There are a number of aspects of these experiments that could provide explanations for these unexpected results. For one, in Experiment 2.1 with RSVP streams of images, the skeletal RSVP task did not even affect overall task performance compared to the typical RSVP task, which could indicate that the skeletal RSVP streams did not succeed in decreasing the demanding nature of the RSVP task. Without a noticeably easier task (based on average target accuracy), it might be difficult to interpret the results as providing evidence for or against the hypothesis that a less demanding task yields a more robust EAB. On the other hand, Experiment 2.2, which used word stimuli, did yield overall better performance in the skeletal RSVP task, suggesting that it was a less demanding task to complete. Even still, the RSVP type did not affect the EAB effect, which might suggest that having fewer items to suppress does not increase the likelihood of capture by the emotional distractor in the EAB. However, further research should be conducted using more difficult image paradigms to ensure that this extends to images as well. Nonetheless, the results from the Aim 2 experiments show that an EAB effect can be obtained using the skeletal RSVP paradigm, which has historically been used only in AB studies. This finding alone benefits EAB and attentional capture researchers who might consider implementing a similar paradigm in future research.

IV. GENERAL DISCUSSION

The current research helped provide better explanations as to when and how emotional stimuli capture temporal attention in dynamic RSVP paradigms. The EAB, in which an emotional distractor is thought to create a stimulus-driven attentional capture that draws attention away from a target in a RSVP stream, has recently been questioned (Baker et al., 2021; Santacroce et al., 2023). Specifically, the stimulus-driven EAB has been found to be weak in comparison to a goal-driven AB, which is a similar blink effect caused by a T1 (Santacroce et al., 2023), and the emotional capture might be contingent on the visual distinctiveness of the critical distractor (Baker et al., 2021; Santacroce et al., 2021, 2023). The research presented here addressed the weak EAB with two aims that asked two specific questions.

The first question, addressed in Aim 1, asked if visual distinctiveness, rather than emotional valence, is actually the driving factor in classic EAB tasks. EAB research typically uses paradigms in which the emotional distractor is also visually distinct from the surrounding RSVP stimuli. Specifically, distractors are usually images of humans or animals in a stream of images not containing humans or animals (Kennedy & Most, 2015; Most et al., 2005b). Recently, studies by Baker et al. (2021) and Santacroce et al. (2023) suggested that emotional distractors in the absence of visual distinctiveness create less of a stimulus-driven EAB, if at all. It is likely, then, that emotional valence does not create the capture, but can intensify the capture effect once it has been achieved by visual distinctiveness. With two experiments using different RSVP paradigms, Aim 1 introduced a visual distinctiveness factor in the EAB to examine the blinks created by task-irrelevant stimuli that were visually distinct, emotional, both, or neither. Using RSVP streams with exceptionally rapid display times and many critical distractor to target lags, the Aim 1 experiments were able to examine the precise time courses of the blinks under each condition, allowing for accurate measures of the magnitude and duration of each blink. Using these critical distractor manipulations (emotional valence: baseline, emotional; visual distinctiveness compared to surrounding RSVP stimuli: distinct, similar), Experiment 1.1 using RSVP streams of image stimuli showed an immediate capture by visual distinctiveness (observed in the Baseline + Distinct and Emotional + Distinct conditions) and a delayed effect of emotion (observed in the Emotional + Similar and Emotional + Distinct conditions). This suggests that visual distinctiveness does, in fact, initiate the blink prior to emotional modulation of the blink and indicates that the EAB is a two-phase process. Experiment 1.2 using word stimuli, on the other hand, did not show this same pattern, which, because Experiment 1.2 had a more pure visual distinctiveness manipulation compared to the image paradigm, could suggest that the initial capture in the EAB is the result of *categorical*, not *visual*, distinctiveness. Alternatively, the different results between the two experiments could be explained by the different processing requirements of words versus images. Regardless, the results from Aim 1 lead to a better understanding of how distinctiveness plays a role in the EAB.

The second question, addressed in Aim 2, asked if the rapid dynamic nature of typical RSVP paradigms is too cognitively or perceptually demanding, requiring general suppression of stimulus-driven attention, leading to the weak EAB. Because stimulus-driven attentional capture research outside of RSVP/EAB studies has shown that increasing cognitive/perceptual load during a task affects the likelihood that that participants will suppress even salient task-irrelevant distractors (e.g., Cosman & Vecera, 2009; de Fockert & Bremner, 2011; Kiss et al., 2012; Lavie, 1995), it would make sense that this could be the case in rapid, dynamic RSVP streams. In order to test this hypothesis, the experiments in Aim 2 utilized a skeletal RSVP paradigm (Ward et al., 1996), in which only the critical distractor, the target, and their subsequent masks were present. This skeletal paradigm was compared to results from the classic EAB RSVP paradigm in two experiments (Experiment 2.1 with image stimuli and Experiment 2.2 with word stimuli) to see if the simpler paradigm containing fewer distractors that required suppression would magnify the resulting EAB. The results from both experiments showed no difference in the EABs elicited by the RSVP and skeletal paradigms, suggesting that the demanding nature of the classic EAB task does not explain the weak EAB. This instead supports recent studies suggesting that emotional stimuli are simply too weak to create a strong stimulus-driven attentional capture (Santacroce et al., 2021, 2023), even with fewer cognitive or perceptual demands.

Together, the results of the two aims provide further insight on stimulus-driven attentional capture by emotional stimuli in dynamic RSVP tasks. Given that the EAB effect is widely accepted, the results of the current experiments challenge what was previously assumed to be a stimulus-driven AB caused by emotional distractors. It also challenges the general idea of emotional capture in many other domains (e.g., spatial attention, cuing paradigms, etc.), for this capture is unlikely to be purely the result of emotional valence. Returning back to the driving example, the results presented here suggest that an undercover police vehicle would not capture attention, even though it would likely evoke an emotional response should it happen to be detected by a speeding driver (Aim 1). Moreover, the amount of traffic on the road would not affect the ability of a disturbing billboard to capture attention (Aim 2).

In addition, the EAB is beginning to be considered for application in clinical screening/diagnosis (Onie & Most, 2021), and thus it is important to closely consider the effects and their underlying mechanisms. Future EAB research should now either avoid or focus on distinctiveness when examining the effects of the EAB, depending on study-specific goals. That is, future studies on the potency of emotion as a stimulus-driven attention cue should avoid confounding emotion with other drivers of stimulus-driven attention. On the other hand, future research on the modulatory effect of emotion on other forms of attentional capture should increase the visual distinctiveness of the critical distractor to show more robust capture effects that could make it easier to detect slight differences with manipulations, even in dynamic RSVP paradigms. Overall, the emotional attentional capture field as a whole must reconsider how it interprets the surprisingly complex phenomenon of stimulus-driven attentional capture by emotional distractors.

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APPENDICES

A. Cousineau (2006) AB Model Fitting

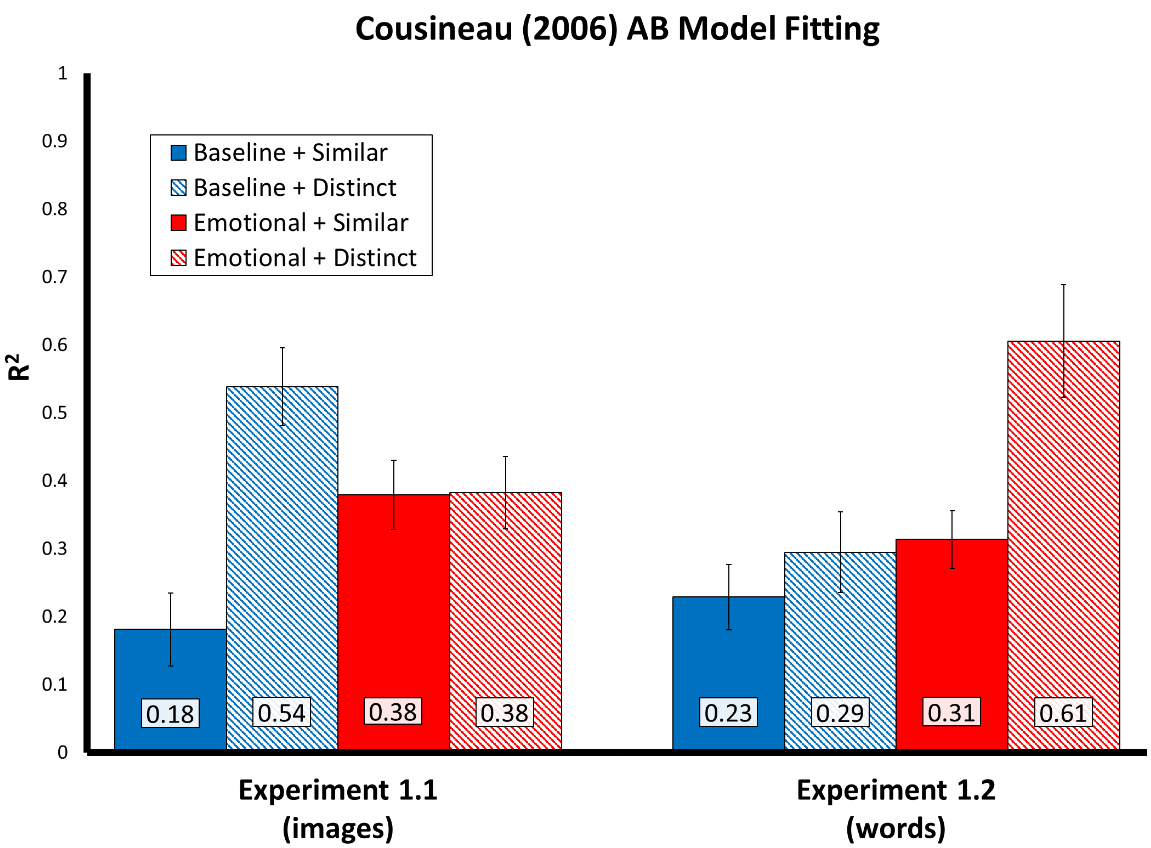

Fig. A1. Averaged R2 statistics from the Cousineau, et al. (2006) AB descriptive model when fitted to the data from Experiments 1.1 and 1.2, indicating the poor fit to the current data. The "Emotional" conditions reflect the "Unpleasant" condition in Experiment 1.1 and the "Taboo" condition in Experiment 1.2. Statistics were averaged across participants and the error bars represent the standard error of the mean.

Cousineau (2006) AB Model Fit to Participant Data

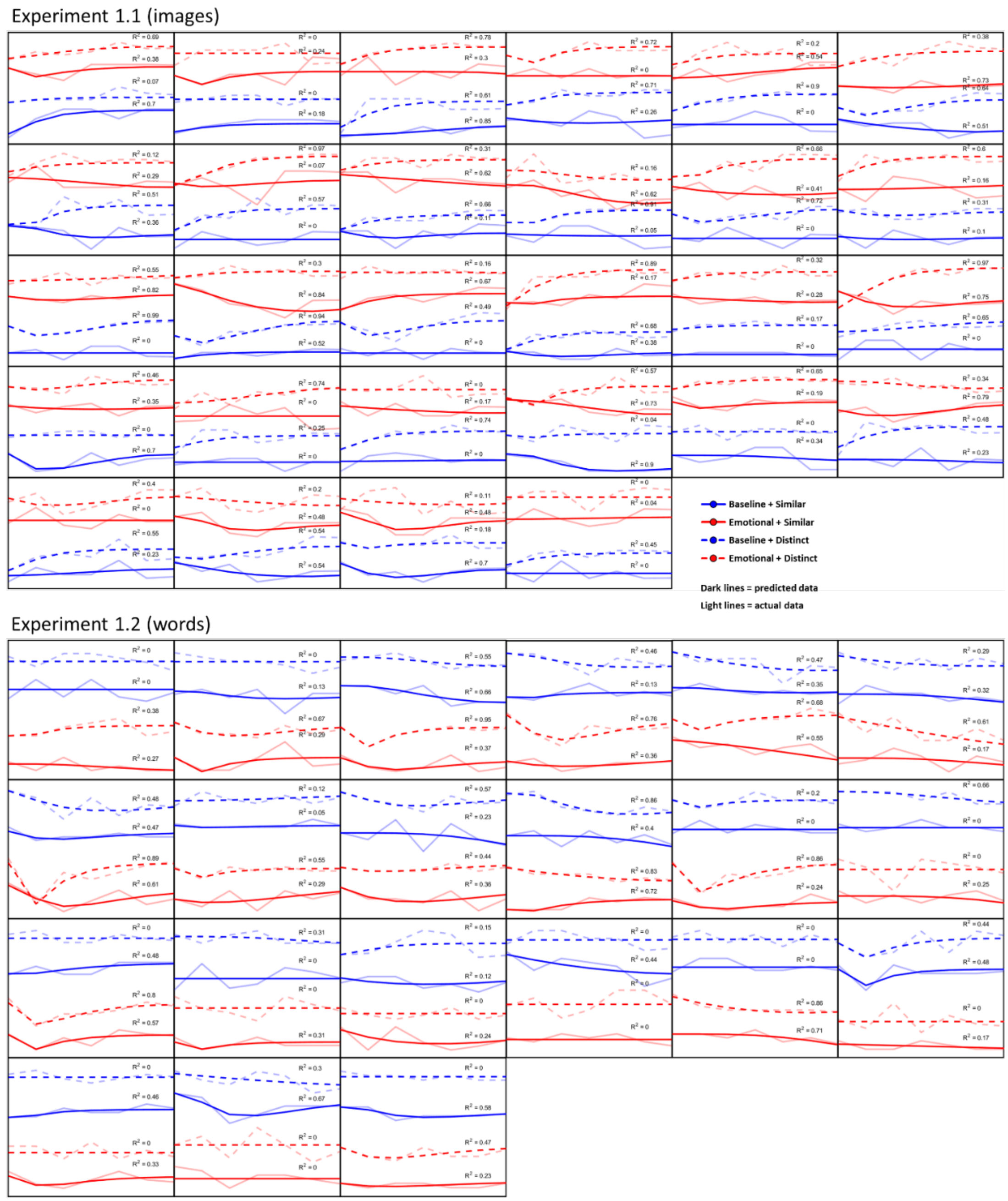

Fig. A2. Results of the Cousineau et al. (2006) AB model fit to individual participant data from Experiment 1.1 (top) and 1.2 (bottom). Each box contains data from a single participant during each condition. Darker lines correspond to the data predicted by the model and the lighter lines correspond to the participant's actual data. Note that each condition's data were stacked on top of one another in order to create a compact figure, but the relationships between data and model fits were not modified by this visualization procedure. In addition, the x-axes are the lags presented sequentially (i.e., lag 16 in Experiment 1.1 appears as lag 7). Above each line is the R^2 value derived from the model's fit to the actual data.

B. Word Stimuli from Experiments 1.2 & 2.2

Table B1

Neutral, Taboo, and Fruit Word Stimuli Used for the Experiment

Neutral				Taboo	Fruit
ACCOUNTANT	CONTRAST	INSTRUMENT	PICTURE	ASSHOLE	APPLE
ADJECTIVE	COVER	INTRODUCE	PILLOW	BITCH	APRICOT
AFTERNOON	DEGREE	INVENTION	PLANET	BLOWJOB	BANANA
AISLE	DELIVERY	INVISIBLE	PURSE	BONER	BLACKBERRY
ANYTHING	DESK	INVITATION	QUARTER	CLITORIS	BLUEBERRY
ARMCHAIR	DESKTOP	JACKET	RAILWAY	COCK	CANTALOUPE
ARTICLE	DETAIL	JUSTIFY	RECORD	COOCHIE	CHERRY
AUTUMN	DISHWASHER	KEYBOARD	RESTAURANT	CUNT	COCONUT
AVERAGE	DOORWAY	KNOWLEDGE	RUFFLED	DICK	CRANBERRY
BASKETBALL	DRAWERS	LAMP	SECTION	DICKHEAD	FIGS
BATTERY	EDUCATION	LAPTOP	SHOP	DILDO	GRAPE
BINDER	ENVELOPE	LAYER	SOMETHING	ERECTION	GRAPEFRUIT
BLANKET	EVENT	LEAGUE	SPARE	FUCKER	GUAVA
BLIMP	EVERYWHERE	LIFESTYLE	SPEAK	FUCKING	HONEYDEW
BOOK	FACT	LINK	STAIRCASE	HANDJOB	KIWI
BOOKLET	FEEDBACK	LITERATURE	STANDING	INCEST	LEMON
BOTTLE	FIELD	LOOP	STAPLE	MASTURBATE	LIME
BRANCH	FISH	LUNCH	STRUCTURE	ORGASM	MANGO
CABLE	FLUCTUATE	MAGNET	SUBJECT	ORGY	MELON
CANVAS	GATE	MATERIAL	SUITCASE	PENIS	NECTARINE
CARD	GENERATION	MECHANIST	SUNLIGHT	PUSSY	ORANGE
CELLPHONE	GENETIC	MEETING	TECHNOLOGY	QUEEF	PAPAYA
CENTER	GLASSES	MICROWAVE	TOWEL	RAPE	PEACH
CHARACTERS	GLOVE	NOTE	TRUCK	RIMJOB	PEAR
CHAT	HAIRTIE	NOTEBOOK	UNDERSTAND	SKANK	PINEAPPLE
CHEW	HEADLIGHT	OPERATOR	UNIFORM	SLUT	PLUM
CHILDREN	HEATER	PAINTING	VIDEO	TITTY	RASPBERRY
CLASS	HELICOPTER	PAPER	VIOLA	TITTYFUCK	STRAWBERRY
COMPUTER	IDENTICAL	PATROL	WIRE	TWAT	TANGERINE
CONFERENCE	INDIVIDUAL	PENCIL	ZIPPER	WHORE	WATERMELON

Note. The neutral words were used for the filler words and for the critical distractors in the neutral conditions. Taboo words were used for the critical distractors during the emotional valence conditions. The fruit words were used as the targets.