Foveal and Peripheral Processing of Emotional Faces in an Attentional Blink Task

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Abstract

The attentional blink (AB) paradigm was used to assess the effect of emotional stimuli (angry, neutral) and location (fovea, periphery) on early visual attention in neurotypicals. The attentional blink is a lapse in perceptual awareness during the rapid presentation of stimuli within a 200-400ms time lag between the two targets. Certain aspects limit the AB effect, as they do a better job of catching our attention, with emotional stimuli as the second target being one of them. In addition, almost all past AB studies have focused on the fovea, and little work has been done in the periphery until now. During an attentional blink task, participants had a higher Target 2 accuracy when stimuli were presented in the fovea. Emotion showed unexpected results, with neutral faces leading to a higher accuracy than angry faces. Both emotion and location showed the expected attentional blink pattern.

Introduction

Our attention and visual processing of the world is thought to be broken down into two unique stages (Broadbent and Broadbent 1987; Chun and Potter 1995). Stage one, or early processing, allows us to rapidly take-in input and unconsciously categorize the information in preparation for later processing. The second stage is limited in attentional capacity, and chooses what we are actually conscious of based on the input from stage one. This stage has an attentional bottleneck, as there is too much stimuli in the world to take in. Not everything that we visually process is consciously reported, or not everything that makes it through stage one of processing makes it into stage two, and one way to explore these stages of attentional processing is through the attentional blink (AB) paradigm.

During the attentional blink task, stimuli such as pictures, letters, numbers, etc., are presented in rapid serial visual presentation (RSVP). RSVP helps measure the 'temporal dynamics' of visual processing (Shapiro, 1994). During this presentation, two of the stimuli will be the designated targets, also called T1 and T2. All other shown stimuli are called 'distractors,' and they differ from the designated targets in some way. When the second target stimuli is presented within a time frame of 200-400ms after identification of the first within this RSVP, the second target is more likely to be indistinguishable. This lapse in perceptual awareness is what is known as the 'attentional blink.' It is a blink in attention after an object has been detected, which inhibits conscious detection of the second. With regards to the attentional visual processing stages, both targets make it through stage one, but with stage two having a limited capacity, only the first target is consciously perceived. The 'blink' only happens within this time frame though, as when the second target is presented within 100 ms after the first, it is processed. This is known as Lag 1 sparing-- as when two targets are sequenced immediately after each other, then they are processed together. This is in contrast to a target, a distractor, and then another target, where the brain must differentiate between the two types of stimuli. This therefore enters the attentional processing bottleneck, as this categorization of the two different types of stimuli takes more processing power (Chun, Potter, 1995). In addition, when Target 2 is presented more than 400ms after the first, there is enough time for both targets to be processed by both stages of processing, leading to a more accurate processing of Target 2.

The attentional blink is thought to show limits in attentional resources, as one is devoting their attention towards identifying Target 1, so Target 2 is allocated less resources (Fox, Russo, & Georgiou, 2005) and therefore cannot be included in the conscious processing stage. Initially, it was explored if the attentional blink was due to limitations in memory or perception. Raymond et al. (1992) ran an experiment to test this, running an AB apparatus, but having the participant only report T2. No attentional blink effect was found, suggesting that the paradigm is not due to perceptual problems, as T2 could be reported when there was no requirement to process at T1. Memory is accounted for in that the items are presented so quickly that our visual short term memory should be able to hold more than the duration of an attentional blink experiment. The attentional blink paradigm is used to study awareness and unconscious processing, as stimuli presented have proven to be processed by the brain, yet often not reported or noticed. It helps measure how quickly humans can clear information in order to go on to the next stage of processing (Rinehart, 2010).

There are various theories as to why humans have this lapse in perception. One suggestion is that it helps reduce the computational complexity that we experience daily, as the targets presented are considered part of the same 'event'. The second target is not attended to with the amount of resources as the first, thus making it acceptable to condense the second target in order to reduce processing requirements (Shapiro, 1994). In the Threaded Cognition Model (Taatgen et al., 2009), we have an attentional control mechanism that overworks, and stops stimuli detection during the time that another stimulus is being processed. In the Boost and Bounce model (Olivers and Meeter, 2008), the attentional blink is used to stop stimuli from interfering with working memory. Finally, in the eSTST model (Wyble et al., 2009), the attentional blink is used to help separate visual input into different attentional episodes.

fMRI studies have been conducted to find what areas of the brain were active during both conscious and unconscious processing during the attentional blink task. The medial temporal cortex is activated during the attentional blink during both when the target was consciously reported, as well as when it was not (Marois, 2004). Contrasting that, the frontal cortex was only reported active when the target was consciously perceived. This supports the two stage theory, as different brain regions are activated based on the physical world and the perception of the physical world.

Certain stimuli can reduce the attentional blink effect, overcoming the attentional bottleneck in stage two of processing. When emotional and arouding stimuli are used as the second target, compared to neutral stimuli, the attentional blink is reduced, or accuracy detecting target two is increased (Shapiro, 1997; Anderson, 2005). For example, Shapiro found that when the second target was the participant's own name, the effect was reduced. Other examples include the stimuli being aversive or negative (Keil, 2004).

The aim was to test the attentional blink with a stimuli such as an angry face as the emotional stimulus, instead of words, as an angry face could be perceived as a threatening or aversive item (Maratos, 2008). As our world is filled with various threats, it is thought that we have specialized and advanced processing mechanisms for threatening information (Davis & Whalen, 2001; LeDoux, 1996; Mogg & Bradley, 1998; Ohman, 1996; Pessoa, 2005). Our attentional resources are then involuntarily devoted to these threats over more neutral stimuli, as we need to be prepared as a survival instinct. This involuntary attentional processing stream is bottom-up, compared to voluntary top-down attentional processes. In addition, this way we can address questions about emotional and facial attentional processing. Emotional and facial processing is a key part in social cognition, which is necessary for humans to interact properly in their daily lives. Some argue that emotional and facial processing is an automatic process, as faces are biologically significant and social stimuli (Hansen, 1994). Coming full circle, this automatic facial process evolved to address incoming threats, so facial expressions suggesting threat may cause conscious attention.

Negatively salient facial expressions demand attention; this has been shown in many different visual search task experiments (Eastwood, 2001). The visual search task is about conscious processing, versus the attentional blink's focus on unconscious attentional processing. While the effect of negative emotions on the attentional blink has been studied, little has been done regarding the positioning of the targets during the task. Unconscious processing in the periphery has yet to be studied, as most studies thus far have solely focused their target locations in the fovea. Items perceived in the fovea are seen with a much greater crispness and acuity than when items are perceived in the periphery, as the photoreceptor and retinal ganglion cell density is 200x stronger here (Curcio and Allen 1990). However, this may not matter if exposure to a target is extremely limited anyways, and our unconscious processing streams may still take in the same amount of information, whether in the fovea or periphery.

MEG studies have found that the early processing of emotion in the fovea versus the periphery activates different areas of the brain. In a study looking at faces either in the center or one of the four quadrants of the periphery for a very short period of time, it was found that when faces are presented in the fovea they are first processed by the right superior temporal sulcus (STS), then followed by the right amygdala (Liu, 2010). However, for faces presented in the periphery, processing started in the ipsilateral amygdala of the quadrant presented in, and then followed by the contralateral STS. Liu et al. came to an interesting conclusion about the roles of the amygdala and STS in early visual processing based on these asymmetries. The amygdala preps sub-cortical centers for fight or flight responses, while the STS allows for more evaluation of the situation and reaction.

In this study, the role of foveal versus peripheral emotional facial processing during an attentional blink task was explored. While many studies have looked into the effect of emotional faces during an unconscious processing task, few have also included an aspect of peripheral vision. This is important to look at not only to show the extent and strength for which emotional faces affect our processing, but also in terms of disorders. Autism Spectrum Disorder (ASD) is a developmental disorder in which the processing of social information is thought to be impaired, particularly the processing of facial emotions (Boucher & Lewis, 1992; Dawson et al., 2002a). In addition, individuals with ASD do not like to engage in direct eye contact, and they often compensate for this by using their peripheral vision. Pertaining to these two deficits, questions arise about ASD emotional processing in the periphery, and whether that differs from foveal processing, as focal gaze is often avoided. Answering questions about peripheral abilities and processing in neurotypicals first will help us then move on to an ASD population.

In the attentional blink paradigm for this experiment, pictures as well as letters were used for stimuli. White letters were the non-target/distractor items, and Target 1 and Target 2 were both pictures of faces with either angry or neutral expressions. Letters were always placed in the fovea, and the targets were randomly placed in either the fovea or periphery, with set lag times between them.

Methods

Participants

23 students at the University of California: San Diego between the ages of 18 and 23 were recruited through an online university recruitment tool called SONA, and received class credit for their participation in this study. Students were prescreened for normal to contact-corrected vision before participation. Out of the 23 who participated, a total of 17 were used due

to incomplete sessions where the participant could not complete a satisfactory number of trials for analysis (>400).

Materials

All stimuli were displayed on a black background at a viewing distance of 177.8 cm on a 60-inch monitor (143.51 x 80.72 cm) using PsychoPy (version 1.83.04-win32). Color face photographs of adult faces with neutral and angry facial expression were obtained from the KDEF set. All images were cropped to the same size circular shape. 62 color face photographs were used from the KDEF set for neutral expressions, and 67 color face photographs were used for angry expressions. The same sets of face photographs were used for both the emotional identification task and the attentional blink task.

Emotional Identification Task

This task assesses the participant's ability to distinguish between the angry and neutral faces of the KDEF set accurately in both the fovea and the periphery. The task consisted of 120 trials. Beginning the experiment, the prompt "Please indicate when you're ready" is displayed. A fixation point is then presented in the center of the screen for 1 second, followed by a stimulus (either an angry or neutral face) for 130ms in either the periphery or the fovea. A foveal angle of 6.0° was used to calculate the foveal radius of 9.32cm. The peripheral angle of 12.9° was used to calculate the peripheral radius of 20cm. The radii were then used to calculate stimuli coordinates with the appropriate distances. Angry and neutral faces are presented randomly in the fovea and periphery. After the presentation of one face, "Please indicate your response" is displayed. Using his or her dominant hand, participants then have four seconds to make a response on a button pad. A green button marked 'neutral' for a neutral facial response, and red and 'angry' for an angry facial response. After four seconds, the fixation cross will reappear, marking a new trial.

Average recognition accuracy of 70% or higher was considered successful emotion discrimination and allowed participants to partake in part two.

Attentional Blink Task

The attentional blink task consisted of 480 trials broken down into three equivalent sections, with mandatory 5 minute breaks between the sections. An eye tracker was calibrated to each participant's eyes before starting the task, as trials would only continue to run if the participant was looking at the center fixation cross, registered by the eye tracker. Once correctly fixated, Target one would appear for 130ms, then a rapid serial visual presentation (RSVP) stream of white letters for time lags from 100 to 600ms in intervals of 100ms, followed by Target two for 130ms (Figure 1). The trial would end with the prompt "Please indicate your response" for 5 seconds. The participants were briefed beforehand to respond on the keypad with green and 'neutral' for a neutral facial expression, or red and 'angry' for an angry expression. Participants made two responses each time, both for T1 and T2.

The attentional blink task consisted of sixteen types of trials, each with six different time lags, for a total of 96 possible variable conditions. There were no catch trials, and mandatory 5 minute breaks were implemented as a substitute. For each trial, variables included (a) location of T1 (fovea or periphery); (b) location of T2 (fovea or periphery); (c) emotion of T1 (angry or neutral); (d) emotion of T2 (angry or neutral); lag time between targets (100ms, 200ms, 300ms, 400ms, 500ms, 600ms). All types of trials were randomized. Before starting actual testing, participants were given instructions, and then given ten practice trials before starting.

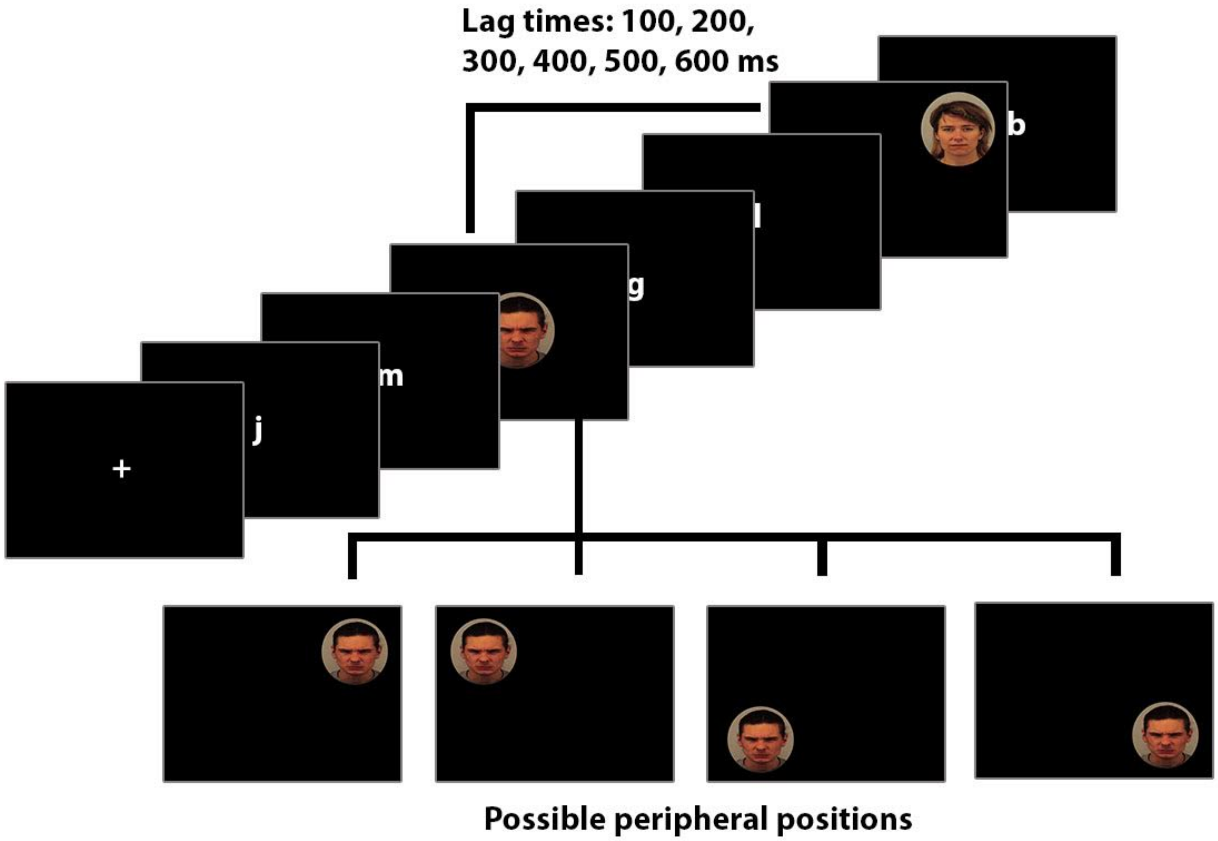

Figure 1. Diagram of Part 2: Attentional Blink Task. Targets varied by being either an angry or neutral expression, and were placed either in the fovea or anywhere in the periphery. Lag time varied between trials, ranging from 100-600ms in increments of 100ms.

Results

Performance on the Emotional Identification Task (Part 1) was above 70% for all 22 participants who participated. This meant that all subjects moved onto the Attentional Blink Task (Part 2). For the AB task, Target 2 responses were scored even if the response for Target 1 was not correct. Trials with only one response, or no response, were removed. For each participant, accuracy (the percentage of accurate Target 2 trials) was calculated for each of the 96 types of AB trials. Due to the large number of trials and conditions, and the desire to keep the total number of trials to a reasonable level (around 480), the 300ms and 400ms lag times were averaged to get one number for the Target 2 accuracy at Lag 2. Both 300ms and 400ms produce the attentional blink. The same was done for Lag 3, with 500ms and 600ms, which are both outside the attentional blink period. Therefore, Lag 1 was the T2 accuracy at 100ms between targets, Lag 2 was at 300/400ms, and Lag 3 was at 500/600 ms.

Target 2 percent accuracy was analyzed using a repeated measures 4 x 4 x 3 ANOVA with Location (Fovea, Periphery), Emotion (Neutral, Angry), and Lag (100ms, 300/400ms, 500/600ms) as within-subject factors. For location and emotion, factors were coded for all possible combinations of fovea/periphery and neutral/angry for T1 and T2. Combinations for location included (1) Fovea-Fovea, (2) Fovea-Periphery, (3) Periphery-Fovea, (4) Periphery-Periphery. Combinations for emotion included (1) Neutral-Neutral, (2) Neutral-Angry, (3) Angry-Neutral, (4) Angry-Angry. This ANOVA captured the contingency of T1 on T2, as the interest was on the possible effects of variability in T1 and T2 upon T2's accuracy.

There were significant main effects for all possible factors. The first was Location, in which participants were more accurate when T2 occurred in the fovea compared to the periphery, $F = 9.27, p < 0.05, \eta 2 = 0.367$. The second main effect occurred for Emotion, where participants showed a slightly higher accuracy when judging the emotion of neutral faces compared to angry faces; $F = 3.26, p < 0.05, \eta 2 = 0.169$. The last main effect was by far the most significant, and occurred for Lag, $F = 36.97, p < 0.05, \eta 2 = 0.698$. This last finding suggest that the experiment produced the expected attentional blink effect, with a decrease in T2 accuracy during the 200-400 ms time period, and no significant difference between Lags 1 and 3. This trend appeared in both interactions with Emotion and Location, even if not significant (see Fig. 1).

To find which combination of factors was significant in the cases of Emotion and Location, one-way ANOVAS were run. For example, to look at the fovea-fovea Location condition, a 4 x 3 (Emotion x Lag) repeated measures ANOVA was run, where all combinations of emotion by lag in the fovea-fovea were inputted. When collapsed across Emotion, all Location combinations showed a significance in Lag, with the significance always being in Lag 1 x Lag 2 and Lag 2 x Lag 3, never Lag 1 x Lag 3. This reflects the expected attentional blink effect in all location combinations. Lag was most significant (or the difference in means between Lags 1 and 2 and 2 and 3 was greatest) in the periphery-periphery condition, $F = 21.74, p < 0.05, \eta 2 = 0.576$, followed by fovea-fovea, $F = 17.72, p < 0.05, \eta 2 = 0.526$, periphery-fovea $F = 10.61, p < 0.05, \eta 2 = 0.399$, and fovea-periphery $F = 6.46, p < 0.05, \eta 2 = 0.288$. The attentional blink effect proved to be smaller in the location conditions where T2 was placed in the fovea, meaning that T2 accuracy was higher when T2 was located in the fovea, no matter what the positioning of T1.

Regarding Emotion and Location, two locations had significant emotion interactions: fovea-periphery and periphery-periphery. The fovea-periphery condition had a significance difference between neutral-neutral and neutral-angry expressions, $F = 4.58, p < 0.05, \eta 2 = 0.222$. The periphery-periphery condition had a significance difference between neutral-neutral and angry-neutral expressions, $F = 3.14, p < 0.05, \eta 2 = 0.164$. Both conditions showed the neutral-neutral expression condition as reflecting the highest T2 accuracy. Emotion significance is much smaller than the significance with Lag, but does not reflect the predicted result of angry T2 expressions causing higher T2 accuracy, as found in prior studies.

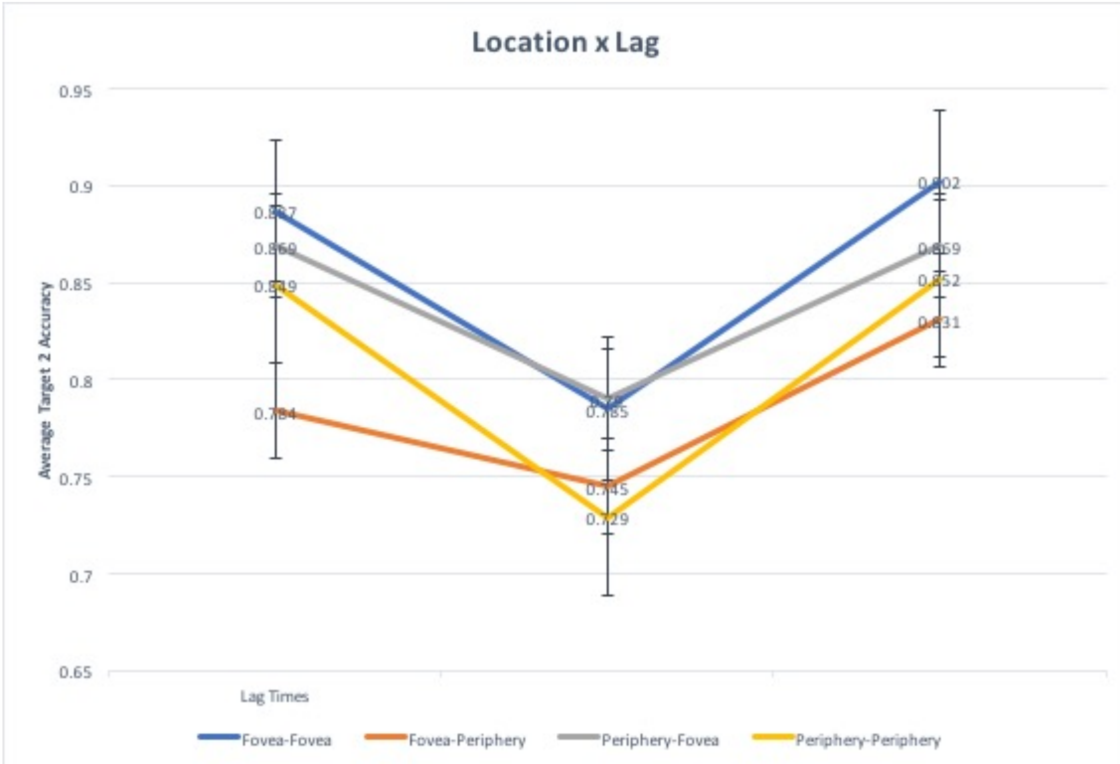

Figure 2. T2 Accuracy by Lag for all possible location combinations, collapsed across emotion

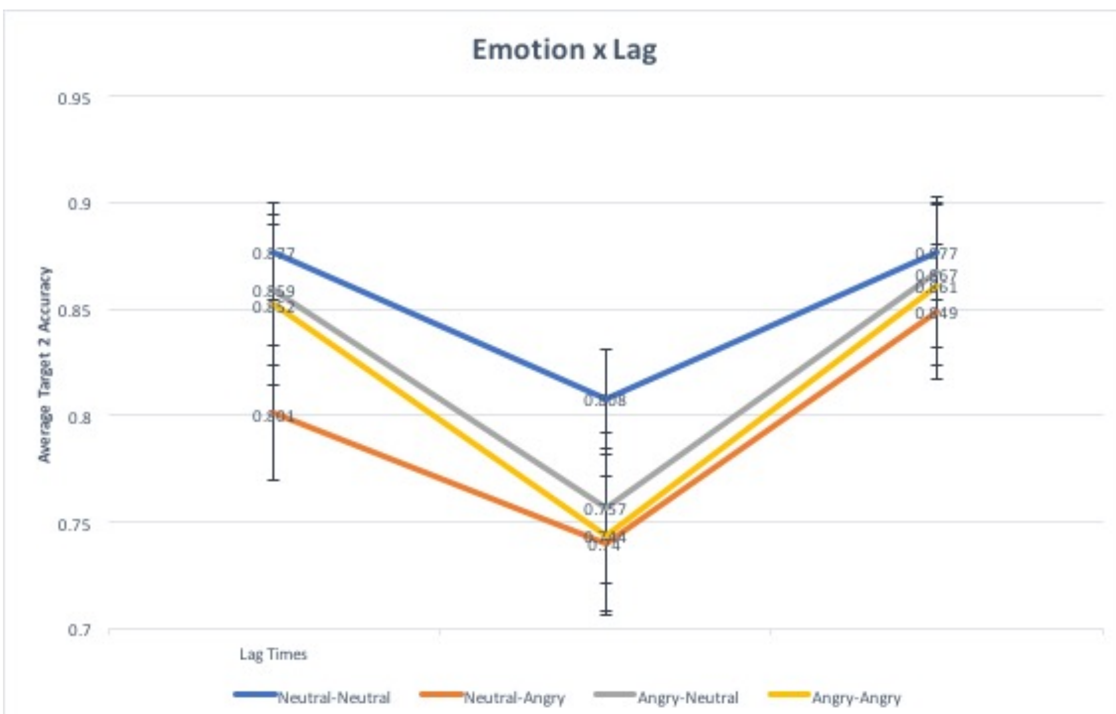

Figure 3. T2 Accuracy by Lag for all possible emotion combinations, collapsed across location

Discussion

This experiment assessed whether emotional faces reduced the attentional blink effect in typically-developed 18-23 year olds, as well as if the placement of the targets either in the fovea or the periphery impacted the results. While a main effect was found in Lag, Location, and Emotion, there was no overall significant interaction between either Emotion or Location with Lag. This suggested that neither factor heavily impacted the AB effect, even though both factors showcased the typical AB trend. Post-hoc analysis showed that while there was no overall Lag interactions, there were Lag effects within individual Locations. When looked at comparatively, there was significantly larger effects in the conditions where T1 and T2 were in the same location. T2 accuracy was also higher for conditions where T2 was placed in the fovea, no matter where T1 was located. Results from the Emotion analysis revealed that while no interaction was significant, neutral faces as T2 actually showed higher T2 accuracy.

As predicted, processing of T2 proved to be easier when T2 was presented in the fovea. The fovea-fovea condition resulted in the highest accuracy for all lags, and the periphery-fovea condition followed it. It was also expected that if a participant looked away towards the periphery at T1 first, and then looked at T2 in the fovea, there would be less accuracy than if the participant just stayed fixated in the fovea. What proved to be interesting was that the lowest accuracy for Lag 1 by a largely significant margin was in the fovea-periphery condition (Figure 2). Periphery-periphery and periphery-fovea both showcased a much larger Lag 1 sparing, even though there was a change in position of eye gaze involved. This suggests that when starting each trial fixated in the fovea, and then presented a Target in the periphery, a possible priming effect takes place where that peripheral stimulation prepares the attentional system for the next target to be in a different location. In the fovea-periphery condition, eye movement is needed, but

T1 being placed in the fovea would not trigger this effect, leading to no increase in performance compared to the other conditions starting in the periphery. This possible peripheral T1 priming effect seems to only be evident at Lag 1 though, as at Lag 2, the periphery-periphery condition's accuracy decreases significantly. It is possible that the 300-400 ms lag is too long, leading to a loss of this priming effect compared to the 100 ms lag.

Questions regarding why the neutral-neutral emotion condition resulted in the highest accuracy came up. One possibility is that the faces were presented too rapidly, making it difficult for the participants to make a distinction and overcome the AB effect. This is a very likely possibility, as across all emotion conditions the T2 accuracies at Lag 3 were much closer in value, suggesting that more time gave more processing time of the emotional faces even when presented extremely quickly. In addition, the basis of angry faces shrinking the AB effect, instead of emotional words as originally proposed by Shapiro, was based on a study done by Yerys et al. with different methods. In their study, participants were shown only pictures in RSVP, with an angry or neutral face as Target 2. Instead of being asked to make a distinction of whether the depicted face was angry or neutral, participants were just asked if they saw a face. Targets that were angry proved to be more likely to be reported than targets that were neutral. With this and our results, which found an overall emotion AB effect as well as higher accuracy of neutral Target 2 faces, angry faces may speed up the process of going through stage one rapid unconscious input processing, but may not have an effect of the actual conscious categorization of the stimuli. This accounts for the found AB effect in all conditions still, but explains why the same angry effect was not found.

The limitations of this study should be noted. The lack of effect regarding emotion as well as lack of obvious trends may be attributed to the small sample sizes, or inadequate power.

17 participant's results were used out of the 22 initially tested due to a lack of completed trials. In addition, possible fatigue effects must be taken into account. Each experiment ran about an hour and a half to two hours, with two mandatory breaks. Extreme decreases in accuracy were not noted throughout the experiment. Trials were also randomized, so no condition should have been more affected than any other by these possible fatigue effects by being presented later in the experiment.

As trials were randomized and not uniform, an uneven amount of trials were run per each condition. Seeing as there were so many different conditions, this lead to problems with certain conditions not having enough trials in order to get an accurate T2 average for that condition. For example, condition 1 may have had eight trials, but condition 2 may have only had two trials. Due to this, lag times had to be combined in order to have enough trials per condition to get a more accurate mean. Conditions with the same location and emotion of T1 and T2 were combined at times 300 and 400ms, and 500 and 600ms. Theoretically, having a lag before the AB (100ms), during the blink (300-400ms), and after the blink (500-600ms) should not affect the results, as the combined time periods fall into distinct categories. However, this is not certain, and if there was a large difference between accuracies at 500 and 600 ms, for example, they would have been combined into one average accuracy, and the difference would not have been reflected.

The locations of T1 and T2 were categorized into either 'fovea' or 'periphery.' This was for simplification of analysis due to already having so many different conditions, but collapses a possible distinction. Studies have reflected differences in processing depending on the positioning of the stimuli, differing in top, bottom, left, or right visual fields. The analysis failed to separate out these different areas in the 'periphery' categorization. Further analysis would allow for further distinction between the locations and separations of visual field besides the general term ‘periphery.’

To further this study, the methods used should be explored. One expected result of angry faces lessening the attentional blink of neutral faces was not achieved, leading to questions as to why. An extension of this study would be to repeat the same methods, but get rid of the location factor, and have all targets presented in the fovea. If the emotional faces are still not proving to lessen the AB, then possibly the stimuli chosen for the targets were not emotional enough, and would not achieve the desired effect.

As mentioned in the introduction, facial processing in the periphery is a particularly interesting subject pertaining to individuals with Autism, as peripheral eye gaze tends to be preferred to direct eye contact. While ASD individuals have been shown to do poorly compared to neurotypicals in some visual processing tasks, one where they have the same performance is during the attentional blink paradigm (Rinehart, 2010; Yerys, 2013). Another way to further this study would be by repeating this attentional blink experiment with an Autistic cohort, as this would provide more insight on the matter. It is possible that individuals with Autism may perform better emotional expression identification of faces presented in the periphery than neurotypicals do.

In summary, Targets presented in the fovea resulted in a greater accuracy and smaller attentional blink effect than when presented in the periphery. In addition, results were inconclusive regarding the effect of emotional faces in an attentional blink task, but possible rationalizations were proposed. These findings have great potential for future studies if compared to other cohort groups, such as ones where peripheral vision is frequently used, such as Autism.

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