The Effects of Fear States from Passive and Active Threats on Breadth of Attention

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The post-encounter and circa-strike fear states define two of the neurological states that can cause changes in cognition, specifically changes in breadth of attention, when in the presence of a threat. Post-encounter represents the neurological and physiological changes that are experienced after the initial detection of a potential threat and aligns with higher activity in forebrain regions including the hippocampus, the amygdala, and the subgenual anterior cingulate cortex (sgACC). Conversely, circa-strike represents the neurological and physiological changes experienced upon interaction with an immediate threat, and results in higher activity in the midbrain and the mid-dorsal ACC, as well as inhibited activity in the sgACC, amygdala, and hippocampus. While certain studies have shown that fear narrows attention, allowing for a smaller range of focus, other studies have suggested the opposite: that fear allows for widened attention and a broader range of focus. We sought to inform this debate by using maze simulations in order to elicit post-encounter and circa-strike fear in subjects. A within-subjects experiment was used in which human participants (N=30) were tasked with navigating throughout 2-dimensional simulated mazes, designed as the game Pac-Man®. Participants were asked to respond to visual stimuli (central and peripheral) within three different maze conditions: a control maze (no threats were present), a passive threat maze (threats were programmed to navigate randomly throughout the maze), and an active threat maze (threats were programmed to constantly pursue participant throughout maze). Results of the study revealed a lower accuracy when responding to peripheral vs central stimuli during the active threat maze, suggesting a narrowed breadth of attention. In addition, there was higher accuracy when responding to peripheral stimuli vs central stimuli during the passive threat maze, suggesting a broadened breadth of attention. These findings support the prediction that post-encounter and circa-strike fear have different effects on attention.

Keywords: passive threat; active threat; post-encounter; circa-strike; fear; visual attention

Introduction

“Passive freezing” is a behavior that takes place when encountering a threat, in which the body freezes all movement in an effort to blend in with its surroundings. This is just one example of the many changes that can occur in the body when activating a self-defense system. Research has shown that there are many effects of fear on behavior and physiology when experiencing fear, including changes in cognition, namely attention. While the ability to recognize and attend to certain sets of visual information is a complex cognitive task, it is one that people complete each day in almost all the things they do. There currently exists a variety of research on the effects of fear on cognition; however, discrepancies exist within some of the existing research. Several studies have explored the effects of fear on different aspects of cognition and attention, with some studies coming to the conclusion that fear has a negative effect on attention (e.g. Hüttermann and Memmert, 2015).
Hüttermann and Memmert (2015) sought to quantify the changes that one experiences in their attentional focus in order to compare their performance when induced into different emotional states. The results indicated that there were systemic differences in the overall scope of attention associated with their different mood states. Their study suggested that the scope of attention was narrowed when participants experienced anxiety. While studies such as this one seem to suggest that attention is narrowed by experiencing fear, other studies have suggested the opposite, going on to show that fear can have a positive effect on attention (e.g. Wegbeit, Franconeri, and Beeman, 2015). Wegbreit et al. (2015) also sought to explore how emotional states affected attention by inducing an anxious state in participants. The results of their study also indicated that when participants were in an anxious mood, they paid more attention to the unimportant features in their periphery, suggesting that their breadth of attention was widened. Discrepancies such as these can raise concerns about the confidence in the current scientific understanding of effects of fear on cognition.

Studies performed by Mobbs et al. (2009) and Fanselow (1986, 1994) have also indicated that fear can be categorized into two different types of fear, determined by the distance of the threat. Fanselow (1986) sought to explore the role of how species-specific defensive responses (SSDRs) define dominant behaviors in different fear evoking environments, such as passive freezing when in a threatening environment. Fanselow (1994) further expanded on the SSDR theory by exploring the neural mechanisms involved in controlling fear and defensive behaviors. This later study explored the existence of three different defensive modes (pre-encounter, post-encounter, and circa-strike). According to Fanselow (1994), pre-encounter becomes activated when entering an area with predatory potential and resulted changes in meal patterns, protection of home/nesting environment, and slowed navigation. Post-encounter activated when a predator or threat is detected in the present environment, resulting in freezing in order to reduce chances of detection. When engaging with the threat becomes inevitable, circa-strike is activated, aligning with behaviors such as defensive fighting and escaping. While the anatomical structures involved in the activation of pre-encounter were not discussed by Fanselow (1994), the study discussed the structures involved in post-encounter (amygdala, ventral periaqueductal gray) and circa-strike (dorsolateral periaqueductal gray, superior colliculus).

Mobbs et al. (2009) also conducted a study in order to test the theory that there are two main defense states in the body (post-encounter and circa-strike). Their theory was that the post-encounter and circa-strike states were organized topographically throughout the medial prefrontal cortex, with inhibitory connections with one another such that the activation of one causes the inhibition of the other; this should allow the brain to be able to rapidly switch between these different defense systems to adjust to rapid changes in their surrounding environment. As such, they concluded that the post-encounter state correlates with increased activity in higher corticolimbic regions such as the ventral medial prefrontal cortex, hippocampus, and amygdala, in order to gather contextual information and prepare for interaction with a threat. Conversely, the activation of the circa-strike state correlates with the inhibition of these forebrain regions, while activity in midbrain regions such as the dorsolateral periaqueductal grey increases, resulting in active defense reactions and “fight or flight” behavior. Their findings align with the findings of Fanselow (1994) suggesting that fear exists in different phases and that these different phases of fear have different neurological effects.

Wieser et al. (2016) and David et al. (2010) proposed two different distinct types of fear which they each coined “phasic fear” and “sustained fear”. Phasic fear is described as a feeling of fear that comes in quickly, then fades soon after the threat is no longer present/imminent, leading to more selective attention. Sustained fear is distinguished as sustained feeling of fear and heightened vigilance do to uncertain danger and coined this “sustained fear”. David et al. (2010) further explain the three defensive stages (pre-encounter, post-encounter, and circa-strike) and
how these defensive behaviors align with threat distance and sustained risk assessment, defining circa-strike as “phasic fear” and post-encounter as “sustained fear”. It appears that Wieser et al. (2016) and David et al. (2010) may have been describing a similar phenomenon to Mobbs et al. (2009) and Fanselow (1986, 1994). This provides further evidence that there may exist different types of fear which are activated differently and have different neurological symptoms, which also suggests that these different fear phases could potentially have different effects on attention.

Perhaps the discrepancies seen in Wegbreit et al.’s (2015) results and Hüttermann & Memmert’s (2015) results are caused by the different physiological and neurological effects of different fear states. This current study was meant to further investigate what the root of these discrepancies in previous studies (e.g. Wegbreit et al. 2015, Hüttermann & Memmert 2015) by building on the prior observations of the neurological effects of post-encounter and circa-strike threats (e.g. Mobbs et al. 2009). Due to the freezing and analytical behavior that appears to be consistent with post-encounter, we predict that post-encounter would lead to a wider breadth of attention. The fight or flight behavior consistent with circa-strike would also suggest that participants are more likely to make physiological and analytical errors when trying to escape the threat, implying a narrowed breadth of attention. The fight or flight behavior consistent with circa-strike would also suggest that participants are more likely to make physiological and analytical errors when trying to escape the threat, implying a narrowed breadth of attention. In this study, we examined how participants’ breadth of attention narrowed when presented with post-encounter vs. circa-strike threats by manipulating threat engagement (active threat vs. passive threat) to induce certain fear states and measuring their responses to visual stimuli (central and peripheral). We predicted that passive threats would invoke the post-encounter fear state and a broader breadth of attention, which would result in a reaction time advantage and accuracy advantage in responding to central stimuli vs peripheral stimuli. This would be indicated by lower accuracy levels when responding to peripheral stimuli and slower reaction times when responding to peripheral stimuli compared to central stimuli.

Material and Methods

Participants
Thirty undergraduate Carnegie Mellon University students (eleven men, nineteen women), aged 18–24, were recruited utilizing the Carnegie Mellon University (CMU) Psychology Department Participant Pool. This study was first approved by the Institutional Review Board at Carnegie Mellon University before being posted on the participant pool website to recruit participants. Participants outside of the required age range were excluded. No pre-study computer literacy or exposure were considered when selecting participants. In addition, the small study population was a result of the limited time available for conducting the study.

Stimulus Design
This study was conducted in an empty lab space on a desktop computer running the Unix operating system. The Pac-Man® (Atari, 1982) style maze was developed using the program Unity; each maze was designed to look like the typical Pac-Man® (Atari, 1982) game, containing 328 dots throughout the maze. Participants were asked to complete three different mazes: a control maze in which no threat was present, a passive threat maze in which the threat was programmed to navigate the maze in random directions (Figure 1), and an active threat maze in which the threat was programmed to actively follow and chase the participant throughout the maze (Figure 2). Participants were shown threat stimuli which were represented as the Pac-Man® ghosts that they are tasked with avoiding. The attentional stimuli are represented with green dots that flash throughout the screen in random locations for a duration of 2 s. The attentional stimuli presented
to the participants are either central, as seen in Figure 1, or peripheral, as seen in Figure 2. Stimuli location was based on the location of the Pac-Man®, utilizing the assumption that participants focus would be on the Pac-Man® as they navigated the maze. A standardized unit of measurement, coined Pac-Man Units, were used to measure the distance from the Pac-Man® to the visual stimuli. Central stimuli were programmed to appear in a random location within a three Pac-Man Unit radius from the location of the Pac-Man®. Peripheral stimuli were programmed to appear in a random location within a fifteen Pac-Man Unit radius of the Pac-Man®.

Procedure

All participants completed three different types of mazes: the control maze, the passive threat maze, and the active threat maze. All participants completed the control maze first, followed by the either the passive threat maze or the active threat maze in an order that was counterbalanced across participants.

Before starting the experiment, participants were told that their task was to complete the maze as quickly as possible by collecting all the dots throughout the maze, while avoiding contact with the ghosts in the maze. Participants were also told that a green dot would flash throughout the maze, and that if they see the dot, they should press the space bar to indicate that they noticed it. They were then told that they would have 4 min to complete each maze. Participants were told that they had three extra “lives” which would allow them to restart the maze if they encountered the ghosts. The maze was considered complete when participants either collected all of the dots, lost all three of their given lives, or reached the 4 min limit. The instructions were presented in verbal form (explained to them by the experimenter).

Control Maze. The participants were given a virtual maze to navigate through, which was used to provide a baseline of their maze performance; this maze did not include any form of a threat. Their objective was to navigate throughout the maze and collect all the dots present. While navigating the maze, there was a series of attentional stimuli that the participant had to respond to. They were shown central attentional stimuli located in their central visual
field, and peripheral attentional stimuli located in their peripheral visual field. The results of the participant’s performance on this maze will be used to determine a baseline of their reaction time and accuracy.

**Passive Threat Maze.** The participants were given a virtual maze to navigate throughout, with the same layout and design, but with four ghosts present. These ghosts are programmed to move throughout the maze in a randomized fashion. Participants were tasked with avoiding these threats while having to respond to both central attentional stimuli and peripheral attentional stimuli.

**Active Threat Maze.** The participants were given a virtual maze to navigate throughout with the same layout and design, and with the same four ghosts present. These ghosts were programmed to follow the participant throughout the maze, at various speeds slower than that of the participant’s speed, allowing the participant to be able to “outrun” the threats. Participants were tasked with avoiding these threats while having to respond to both central attentional stimuli and peripheral attentional stimuli.

Throughout the three trials, information was recorded about the number of stimuli the participant was presented with, the type and location of the stimuli, and the number of times the spacebar was pressed by the participant.

**Post-Study Questionnaire.** The participants were asked to complete a post-study questionnaire in response to their emotions towards participating in and completing the experiment. Participants were asked to describe how they felt while completing the passive and active threat mazes and were given a pre-set list of descriptors (Figure 3). This was used to ensure that participants really did feel more fear in the active threat maze than in the passive threat maze or in the control maze. A chi squared test of association indicated that there was a relationship between the maze condition and the emotional response that participants experienced while completing each maze ($\chi^2 = 7.427$, $p = .024$). Participants were also asked to rate how anxious they felt while completing the active and the passive threat mazes. Figure 4 shows the results of the responses to anxiousness levels during the two mazes, with participants reporting feeling overall higher levels of anxiousness in the active threat maze than the passive threat maze. 20 out of the 30 participants rated feeling an anxiousness level of 4 when completing the active threat maze, and thus any participant who did not rate a level of 4 for the active threat maze anxiousness levels was considered an outlier in the plotting.

**Reaction Time**
A 3x2 repeated measures ANOVA was performed on the reaction time data, with two factors: maze condition (control, passive threat, and active threat) and stimulus location (central and peripheral) (see Table 1). While there was no main effect

![Figure 3. Emotional descriptors were classified in three different categories for users to describe how they felt while completing the experiment.](image-url)
of the maze condition on the reaction time (F (2, 28) = .544, p = 0.584), there was a main effect of the stimulus location on reaction time (F (1, 29) = 12.574, p = .001). Figure 5 shows the comparison of the mean reaction times for the two stimulus locations for each of the three mazes. Overall, the reaction times for the central stimuli were lower than the reaction times for the peripheral stimuli (Figure 5), which was a general trend that would be expected. The ANOVA also indicated that there was not a significant interaction between the maze condition and the stimulus location on reaction time (F (2, 28) = .761, p = .472).

**Accuracy**

A 3x2 repeated measures ANOVA was performed on the accuracy data, with two factors: maze condition (control, passive threat, and active threat) and stimulus location (central and peripheral) (see Table 1). The analysis indicated that there was a main effect of maze condition on accuracy (F (2, 28) = 16.558, p < .001), as well as a main effect of stimulus location on accuracy (F (1, 29) = 49.959, p < .001). In addition, there was a significant interaction found between the effect of both maze condition and stimulus location on accuracy (F (2, 28) = 8.455, p = 0.001). Figure 6 shows the mean accuracy levels of both the central and peripheral stimuli for each of the three maze conditions. In each of the three maze conditions, the accuracy levels were higher for the central stimuli. The accuracy of the peripheral stimuli in the active threat maze was much lower than the accuracy for the central stimuli in the expected threat maze or the central stimuli in either the control maze or the unexpected threat maze.

**Figure 4.** Box and whisker plots show the trend of ratings when participants were asked to rate their level of anxiousness while completing the passive and active threat mazes; active maze plot shows that participants who did not rate the maze as causing anxiousness were outliers.

**Figure 5.** Mean reaction times for the central and peripheral stimuli for each of the three maze conditions.

**Figure 6.** Mean accuracy levels of central stimuli compared to peripheral stimuli for each of the three maze conditions.
Table 1. Summary tables for one factor ANOVAs on reaction time and accuracy in relation to frequency of video game playing.

**RT Anova**

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<td>Most days, typically less than an hour per day</td>
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<td>0.872</td>
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<tr>
<td>Most days, typically one or more house per day</td>
<td>1</td>
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<td>1.1</td>
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<tr>
<td>Typically 1-2 times per week for less than one hour at a time</td>
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<td>4.084</td>
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**ANOVA**

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<td>Within Groups</td>
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<td>Total</td>
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**Accuracy Anova**

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**ANOVA**

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<td>Total</td>
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<td>28</td>
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**Discussion**

The previous studies indicated that there exist different defense systems which become active when in the presence of different threats. We sought to create a maze environment in which the activeness and prominence of the threat could influence the fear state that participants experienced. When responding to visual stimuli, the expectation was that there would be more of an advantage in both reaction time and accuracy when responding central stimuli compared to peripheral stimuli. This would be indicated by faster reaction times in responding to central stimuli and higher accuracy levels. This was confirmed in the control maze, in which the reaction times for the central stimuli were lower than the peripheral stimuli and the accuracy for central stimuli was higher.

The first part of our prediction was that the post-encounter fear state would cause less of an accuracy advantage when responding to central and peripheral stimuli, resulting in similar accuracy levels in responding to central and peripheral stimuli. Our prediction was also
that the circa-strike fear state would cause more of an accuracy advantage, resulting in higher accuracy levels when responding to central stimuli when compared to peripheral stimuli. The observed results also show that participants experienced a much lower accuracy rate when responding to peripheral stimuli compared to the accuracy of responding to the central stimuli in the active threat maze, indicating a larger advantage in responding to the central stimuli. This supported our theory that the active threat maze would result in a narrowed breadth of attention causing them not to notice many of the peripheral stimuli that was presented to them. In addition, the passive threat maze resulted in less of an accuracy advantage when responding to central stimuli compared to peripheral stimuli, indicated by the decreased discrepancy in the accuracy levels. The ANOVA analysis indicated that there was a significant interaction of the stimulus location and maze condition with the response accuracy rate. The decreased accuracy rate in the active threat maze could suggest that while completing the active threat maze, which correlates with the circa-strike fear state, participants experienced a constricted breadth of attention, causing them to neglect many of the peripheral stimuli.

The second part of our prediction was that the post-encounter fear state would cause less of a reaction time advantage and result in less of a discrepancy in the reaction time of responding to central and peripheral stimuli. Our prediction was also that the circa-strike fear state would cause more of an advantage and result in more of a discrepancy in the reaction time when responding to central and peripheral stimuli. The observed results showed that while completing the active threat maze, there was less of a reaction time advantage in responding to central compared to peripheral stimuli. Participants experienced faster reaction times when responding to peripheral stimuli, with little difference between their reaction time in responding to the peripheral stimuli and the central stimuli, which suggests that participants may have experienced a wider breadth of attention, allowing them to be faster at acknowledging the peripheral stimuli. While the reaction time analysis indicates that participants are faster at responding to peripheral stimuli in the active threat maze, this can only be taken into account after considering that participants fail to respond to more than half of the peripheral stimulus presented to them. These results could be explained by participants experiencing some of the physiological effects of being in the circa-strike fear state and higher midbrain activity levels. These side effects, which Mobbs et al. dubbed as “fight or flight behavior” could explain why participants appear so much faster at responding to the peripheral stimuli that they are able to acknowledge in the active threat maze condition. The results also indicate that there does not appear to be much of a discrepancy between the reaction times in the control maze and the passive threat maze. This implies that participants may not be experiencing much difference in the passive threat maze than in the control maze, and that after the initial detection of the threat, participants resort back to the emotional state that they experienced in the control maze when they did not have to interact with any threat at all.

Qualitative data from the post study questionnaire indicated that participants experienced the properly anticipated fear states when completing the mazes. When identifying their levels of anxiousness throughout each of the mazes, participants identified the active maze as causing them to feel overall higher levels of anxiousness than in the passive threat maze, indicating that the active threat maze correctly caused participants to feel more of the emotions related to the circa-strike fear state than the post-encounter fear state.

The results of this study bring about an interesting question about how these fear states interact with one another and the cognitive effects of the post-encounter fear state in comparison to the circa-strike. The hypothesis originally believed that the post-encounter fear state would have effects on cognition and attention that would differ completely from the cognitive effects of the circa-strike fear state, and that they would cause opposing effects on attentions (one would widen attention while the other narrowed attention). The results of this study, however, indicated that the relationship between the two fear states may be more interrelated, and that their effects may not be in
direct opposition of one another. Participants seemed to experience the expected attentional deficits with regards to their accuracy, but also experienced some of the effects of their heightened brain activity in certain regions. This seemed to more strongly affect their reaction time, resulting in a faster reaction time when in a heightened fear state. The results also indicated a relationship between the post-encounter fear state and a person’s standard state of being when completing a cognitive task, and that while the post-encounter state caused behavioral and neurological changes, it did not affect their reaction time as strongly as it affected their accuracy levels.

While it was not possible in this experiment to measure brain activation, the qualitative questionnaire data tells us that participants are in fact experiencing the fear states they are meant to experience in each of the mazes. This then implies that narrowed breadth of attention aligns with higher midbrain cortical activity. With the prefrontal cortex being the region of the brain involved with analytical processing and complex behavior and decision, one must consider why higher prefrontal activity does not seem to cause too much of a difference between the passive threat state and the control state. This also raises the question of whether there are unknown advantages to maintaining the same attentional range when preparing for interaction with a threat, or if there is prefrontal cortical activity involved in completing the cognitive task which could cause confounding results in the control maze performance.

Further elaboration of this study would benefit from tracking the directionality of the participant (i.e. the Pac-Man®) and the threat, in order to determine if there is a relationship between the direction of the participants narrowed attention and the threat. If there is indeed a relationship, then this could provide further explanation to the changes to attentional breadth in the presence of certain threats. In addition, this study would benefit from tracking the participants’ eye movements while completing the task. The current study relied on accuracy and reaction time to determine attention. While these measures do a good job of providing insight on if the participant noticed certain attentional stimuli, a more precise measurement could be obtained by analyzing where the participant was looking throughout the task. While it is apparent that participants appear to miss responding to the peripheral attentional stimuli in the passive threat maze, there is also the possibility that participants noticed the stimuli but made the decision to not respond or responded too late. This study could also benefit from calculating locomotive errors when navigating the maze, which would provide a fair amount of insight on how the participants are interacting with the stimuli and continue to solidify the meaning behind the observed results.

This study suggests that there is a relationship between breadth of attention and fear state, which serves as an explanation for the initial discrepancies noted in previous research on the effect of anxiety and fear on attention. The study implies that these different fear states do have different cognitive implications, and further research into their effects can expose more intricate details about how the brain processes threats and fear.

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