Eye Tracking and PTSD

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Abstract

Eye tracking research in post-traumatic stress disorder (PTSD) is only just emerging, with only a handful of studies completed. The majority of studies have focused on identifying attentional biases toward threat which is proposed as one of the maintaining factors underlying anxiety. At this preliminary stage, current findings reveal evidence for an early attentional bias toward trauma-relevant stimuli in PTSD, with less consistent evidence of subsequent avoidance. However, longitudinal studies are emerging which suggest that attentional avoidance of threat may be a risk factor for developing higher PTSD symptoms in military settings. Eye tracking technology provides significant advances over traditional attentional bias paradigms, as it enables the continuous assessment of visual attention, allowing for both valuable convergent spatial and temporal information. This enables the assessment of both initial attention and avoidance of threatening stimuli. In addition, eye tracking technology may be usefully applied in alternative paradigms assessing social cognition (such as visual scanning of facial expressions) to identify further important aspects of emotional and social processing in PTSD.

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List of Abbreviations

Ms	Milliseconds
MVA	Motor vehicle accidents
PTSD	Post-traumatic stress disorder

Eye movements have been used for decades in cognitive psychology to investigate various aspects of visual attention, perception and spatial processing, motivation, and attentional to emotional aspects of stimuli (Armstrong and Olatunji 2012). Eye tracking research is an emerging field in PTSD, with only a handful of eye tracking studies. Examining eye movements is a rich source of information into visual attention, which extends many other research designs by providing insight into both the temporal and spatial dynamics of attentional processing (Fig. 1).

Eye movement research in PTSD has focused on examining saccadic eye movements and visual fixations to explore attentional biases toward threat. Saccadic eye movements function to direct and change visual fixations. Saccades typically take 50–70 ms, and the average length of visual fixations is 100–200 ms (Olantunji et al. 2013). Common dependent measures from eye tracking studies include the number of visual fixations, the length or duration of fixations, the pattern of subsequent fixations (scan path), and studies often examine concurrent pupil dilation or skin conductance response as an index of sympathetic arousal associated with attention bias.

There is a large body of cognitive research investigating attention biases in PTSD, with a recent meta-analysis of this research finding an attention bias toward threat in PTSD of moderate to large effect size (Bar-Haim et al. 2007). Most studies of attentional bias in PTSD have used emotional Stroop tasks in which patients are required to name the color ink in which trauma-relevant and neutral words are written. In PTSD, it is hypothesized that the hypervigilance to trauma-relevant stimuli captures attentional resources, which leads to interference with the color naming task and a slower response latency (Fig. 2).

While some emotional stroop tasks report slower color naming responses in PTSD which is specific to trauma-relevant words (Bryant and Harvey 1995; McNally et al. 1990; Thrasher et al. 1994), other emotional Stroop tasks found slowed latencies to both trauma-relevant and trauma-irrelevant negative words in PTSD (Litz et al. 1996), and still others found no emotional stroop effect at all in PTSD compared to controls (Devinieni et al. 2004; Bremner et al. 2004; Shin et al. 2001).

Despite these inconsistent findings, it was often assumed that emotional stroop interference effects were robust in PTSD and reflected attentional biases toward threat (Kimble et al. 2003). However, a recent systematic review examined dissertation abstracts (to try to overcome publication biases), and conducted a review of published articles using emotional stroop in PTSD and found that only 8 % of dissertations reported a reliable stroop effect, and only 44 % of published articles

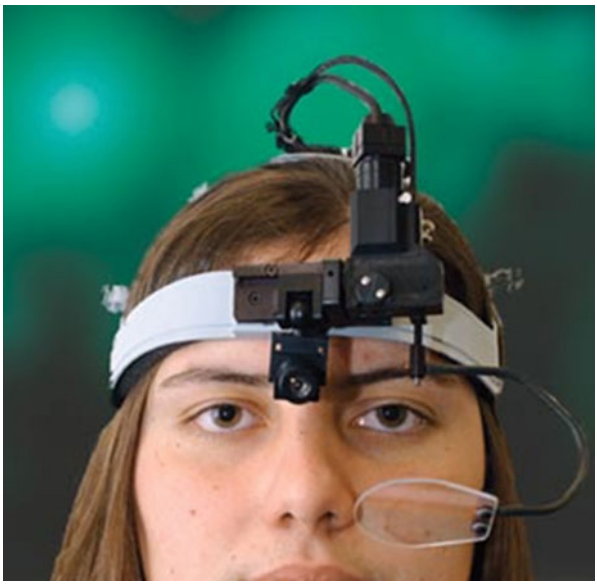

Fig. 1 Example of eye tracking system

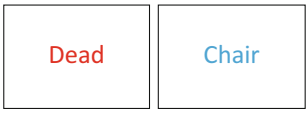

Fig. 2 Example of Stroop color-naming task with trauma-relevant and irrelevant words

(Kimble et al. 2009). Therefore, recent evidence suggests the emotional stroop effect may not be robust or reliable in PTSD.

The stroop effect relies on inferences from response latency measures (reaction time), and the emotional stroop paradigm has been criticized, as it is argued that the longer response latencies may potentially reflect cognitive avoidance, emotional arousal, or attention bias and may be influenced by mood, motivation, and other extraneous variables (De Ruiter and Brosschot 1994; Fox 1994).

A second prominent methodology for examining attentional biases in PTSD has been the modified dot-probe task (MacCleod and Mathews 1988). In this task, the speed of allocation of visual attention to emotionally salient versus neutral spatial location is inferred using reaction time. Typically in this task, a neutral and threat (or trauma-relevant) stimulus are presented simultaneously in different spatial locations. These images are immediately followed by a target image which occurs in the spatial location of the threatening or neutral stimulus. A faster reaction time response to a target on the same side as a threat stimulus is inferred to reflect an attention bias toward the threatening stimulus, as there is an assumption that the threatening stimulus has captured attention leading to more rapid target detection in that spatial location and faster RTs. Conversely, a slower RT to the target behind the threat

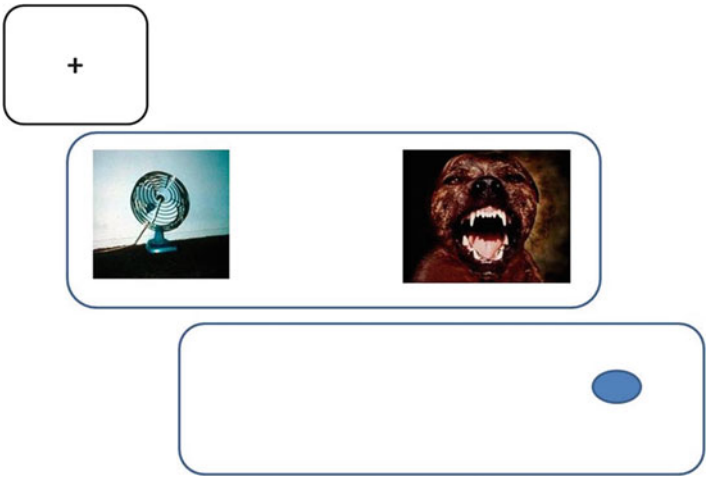

Fig. 3 Example trial from Dot-Probe Task Participants have an initial central fixation for 500 ms, then an affective threat and neutral stimulus are presented simultaneously in different spatial locations for 500 ms. At their offset, a target stimulus is presented in the location of one of the visual stimuli, and the participant is required to button-press on the side at which the target is located

stimulus is thought to reflect an attention bias away from threat (or avoidance) (Fig. 3).

Similar to the emotional stroop effect, dot-probe studies of attentional bias in PTSD have yielded inconsistent findings with some studies reporting attentional biases toward trauma-relevant stimuli in PTSD (Bryant and Harvey 1997; Dalgleish et al. 2001), and others have revealed evidence of an attentional avoidance of threat (Sipos et al. 2014).

Studying attentional biases toward threat is of critical importance as many models of anxiety, and models of PTSD, propose that increased attention to disorder-relevant information is a critical maintaining factor (Chemtob et al. 1988; Ehlers and Clark 2000). Specifically, it is theorized that selective attention to disorder-specific information that is manifested in attentional biases would increase the processing of disorder-relevant stimuli.

Recent theoretical models of attentional biases recognize that there are several key component processes that underlie attentional bias which operate on different time frames (Cisler and Koster 2010). Facilitated attention reflects an initial orienting of attention toward threat, which occurs rapidly and prioritizes the processing of threat stimuli. A second independent process within attentional biases is difficulty disengaging from threatening stimuli, which reflects the degree to which the threat stimulus captures attention and impairs switching to another stimulus. A third process postulated to underlie attentional bias is attentional avoidance (Cisler and Koster 2010). Typically, response-latency-based tasks such as the emotional stroop task and the dot-probe task have considerable limitations in discriminating between

component processes within attentional biases, and particularly between facilitated attention and disengagement (Cisler and Koster 2010).

PTSD has prominent symptoms of both hypervigilance toward threat, distress to trauma-reminders, and avoidance of trauma-reminders. Some models propose that PTSD is characterized by attentional biases toward trauma-relevant stimuli, reflected in automatic orienting of attention to threat accompanied by autonomic arousal (Chemtob et al. 1988), whereas other models suggest a vigilance-avoidance model characteristic of many anxiety disorders may prevail in PTSD (Mogg et al. 2004). The vigilance-avoidance model predicts initial facilitated attention or orienting toward trauma-relevant stimuli, followed by subsequent avoidance of these treat stimuli (Williams et al. 1997).

It is very difficult for emotional stroop and dot-probe tasks to assess these competing models, as the response latency measures of attention at a single moment in time cannot assess temporal changes of attention, that is, the pattern of initial and subsequent visual fixations over time. A further difficulty in dot-probe tasks is that different findings in relation to hypervigilance and vigilance-avoidance models are found depending on the duration of stimuli, with rapidly presented stimuli (500 ms or less) typically not displaying avoidance, where longer stimulus durations (1000 ms) do (Koster, et al. 2005). Finally, these response-latency tasks infer attention engagement from facilitation and interference effects using reaction time as an index, and the reliability of the reaction measures have been questioned in dot-probe tasks (Schmuckle 2005). In contrast, eye movements provide a direct, ecologically valid index of visual attention, which can clearly discriminate the component processes of facilitated attention (via number and location of initial fixations), difficulty with disengagement of attention (via fixation duration time), and attentional avoidance (via location of subsequent fixations). Therefore, to advance understanding of attentional biases in PTSD, more eye movement research is required (Table 1).

Currently there are only a handful of eye tracking studies in PTSD (see Table 2 for a summary of current eye tracking studies). An initial pilot study in motor-vehicle accident survivors (10 had PTSD, 10 were trauma-exposed controls) examined eye movements to an array of four words; some trials contained one trauma-relevant words and three filler words, and other trials contained one neutral word and three filler words (Bryant 1995). All word arrays were presented for 10 s. Skin conductance was recorded concurrently as an index of sympathetic arousal. This preliminary investigation reported significantly greater number of initial fixations to trauma-relevant words in the PTSD group compared to the controls, consistent with an attentional bias toward threat. Interestingly, there was also significantly greater arousal observed in PTSD, signified by an increased number of skin conductance responses (however, these were not tied to initial fixations or threat trials) (Fig. 4).

A second study replicated this design and extended this project in physical assault victims with PTSD (relative to trauma-exposed controls), by examining skin conductance responses specifically associated with initial fixations, and also tested the vigilance-avoidance model by examining fixations following the initial fixation (Felmingham et al. 2011). Using a similar design of presenting four words in a quadrant on each trial (16 trials had trauma-relevant words, and 16 trials had neutral

Table 1 Key facts of eye movements and eye tracking. This table lists the key fact of eye tracking including the types of eye movements, the function of saccades, the type of variables measured in eye tracking such as visual fixations, fixation or dwell time, and pattern of fixation or scan paths, and the types of information provided about visual attention that can be derived from eye tracking

There are four different types of eye movements: saccades, smooth pursuit eye movements, vergence movements and vestibulo-ocular movements
Most eye-tracking research examines saccadic eye movements.
Saccades are rapid eye-movements that function to change the point of fixation.
Saccades can be voluntary or reflexive, they can be on small scale (for example, in reading), or can be large to direct visual fixation at different spatial locations
Eye tracking technology used in research assesses the location and timing of visual fixations to provide a direct and continuous index of visual attention. This provides important spatial information *and* temporal information about where attention is being directed, and how quickly and how long attention remains on different stimuli.
Assessment of initial fixations enables researchers to identify where visual attention is initially directed (to measure orienting and attention biases), and tracking subsequent fixations provides measures of attentional avoidance.
Assessment of fixation time allows researchers to identify how long attention remains in a location or on a particular visual stimulus, and may reflect the extent of attentional capture or difficulty in disengaging from stimulus or location.
Assessment of successive fixations enables researchers to identify the scan path, or patterns of fixations over time, which can provide important information about attentional bias or avoidance of spatial locations or elements of a stimulus (for example, the eyes of a face).

words), this study replicated the findings that there were significantly more initial fixations to trauma-relevant words in the PTSD group compared to controls and there were also significant greater number of SCRs associated with these initial fixations (Felmingham et al. 2011). Interestingly, this study did not find any differences between the groups in terms of subsequent fixations, suggesting there was little evidence for the vigilance-avoidance model (Felmingham et al. 2011). Taken together, these two eye tracking studies suggest there is a facilitated attention or initial orienting toward trauma-relevant stimuli in PTSD, but there is limited evidence of attentional avoidance or for the vigilance-avoidance model.

Other eye-tracking studies in PTSD have employed different methodologies, using visual stimuli rather than words and examining subclinical PTSD samples. Despite these methodological variations, there have been some consistencies reported in these eye tracking studies. The first study to examine eye movements in a military PTSD sample examined eye movements to neutral and negative IAPS images that were presented simultaneously in a parallel visual array for 10 s (Kimble et al. 2010) (Fig. 5).

To assess facilitated attention, these researchers examined the number of initial fixations, and they recorded viewing time and accompanying pupil dilation as an index of sympathetic arousal. They also tested the vigilance-avoidance model by examining subsequent fixation patterns. Finally, they examined how specific the attentional bias was to trauma-relevant images by comparing combat war images (trauma-specific) with general negative images (of car accidents). An important

Table 2 Summary of eye tracking articles in PTSD. This table summarizes the main recent eye tracking articles in PTSD in terms of groups assessed, tasks used, results found, and conclusions drawn

Authors	Study population	Task and measures	Findings	Conclusions
Bryant et al. 1995	MVA survivors – 10 clinical PTSD, 10 controls	4 word quadrants – 1 trauma-relevant or neutral word on each trial (10 s) Number initial fixations Number of SCRs	PTSD ↑ initial fixations to trauma trials PTSD ↑ number SCRs across all trials	Attention bias towards threat in PTSD than trauma controls *Increased facilitated attention*
Kimble et al. 2010	Iraq veterans – high PTSD symptom (subclinical, 2 with diagnostic PTSD), low PTSD symptoms (median split)	20 slides presented with a threat and neutral image side by side for 10 s. 10 slides were trauma-relevant combat pictures, 10 slides had general threat (MVA) pictures. Number initial fixations Subsequent fixations Pupil dilation Fixation time	High PTSD ↑ viewing time and pupil dilation to trauma-relevant and general threat stimuli. Trend high PTSD ↑number initial fixations to trauma-relevant images N.s. difference in subsequent fixations	Evidence consistent with initial attention bias towards trauma-relevant stimuli (but trend level in subclinical sample) Longer view time to all negative – general difficulty disengagement No avoidance evidence
Felmingham et al. 2011	Physical assault survivors – 11 clinical PTSD 10 trauma-exposed controls	32 trials of 4 word quadrants 16 trials – 1 trauma, 3 filler words (10 s duration) 16 trials – 1 neutral, 3 filler words Number initial fixations Subsequent fixations Number of SCRs Pupil dilation	PTSD ↑ initial fixations to trauma trials compared to trauma controls. Increased number of SCR's associated with increased initial fixations No group difference in later fixations	Increased attentional bias and associated autonomic arousal to trauma words in PTSD compared to controls Evidence for facilitated attention No evidence of later avoidance

(*continued*)

Table 2 (continued)

Authors	Study population	Task and measures	Findings	Conclusions
Thomas et al. 2013	Unclear trauma – mixed? 18 clinical PTSD 13 subclinical PTSD 24 non-trauma exposed controls Predominantly female sample	60 trials of 4 image arrays (negative, positive, neutral and trauma-relevant) presented for 6 s First fixations Fixation time overall Temporal analysis (0–2 s, 2–4, 4–6 s)	Overall six second time, no evidence of increased initial fixation to traumatic or general threat trials in PTSD PTSD and sub-threshold had more fixation time to traumatic images For the PTSD group, in 0–2 s timeframe, PTSD had more fixation time to trauma-relevant images than NC, then displayed avoidance in 2–4 s timeframe, then later attention bias towards threat at 4–6 s For subclinical group, no evidence of attention bias in 0–2 s timeframe, then attention bias towards threat in 2–4 s and 4–6 s timeframe. For NC group, no attentional biases.	Evidence consistent with an initial attention bias to trauma-specific stimuli early in processing for the PTSD group, followed by avoidance then later attention bias. For subclinical PTSD, evidence of a later attentional bias towards threat which sustained over time.
Beevers et al. 2011	139 soldiers assessed 3 months before deployment then PTSD and depression symptoms tracked	Matrix of fear, sad, happy and neutral facial expressions presented for 30 s duration Initial fixations Fixation time	War zone stress predicted PTSD and depression symptoms, but this was moderated by eye movements Shorter view time to fearful faces pre-deployment predicted higher PTSD Longer view time of sad faces pre-deployment predicted higher depression symptoms	Attentional avoidance of threat (fearful faces) prior to trauma predicted later PTSD symptoms Attentional bias away from threat appears a vulnerability factor for PTSD in a military context

Dead	Pen
Tree	Tea

Fig. 4 Example of a trauma trial in the word stimuli eye tracking studies

Fig. 5 Example of trial of eye tracking study with visual stimuli (Kimble et al. 2010)

methodological variation in this study was that Iraq veterans were classified into high and low PTSD symptoms using a median split of scores of PTSD severity, but only two individuals of the high-PTSD group met diagnostic criteria for PTSD. Therefore, this study examined a predominantly subclinical PTSD group. Findings revealed evidence of increased pupil dilation (reflecting increased sympathetic arousal) in the high compared to the low PTSD symptom group – this increased pupil dilation was not specific for trauma-relevant combat images but was also seen in response to general threat stimuli. Further, there was a general finding of longer view times to negative stimuli for the high PTSD group who spent more time looking at negative stimuli in general (not just trauma-relevant stimuli). There was a trend for the high PTSD group to have a greater number of initial fixations to threat stimuli (war-related and MVA) and for the high PTSD group to be quicker to look at trauma-relevant images. Similar to previous findings (Felmingham et al. 2011), there was no evidence of avoidance at early or later stages of processing.

The increased arousal and trend for increased initial fixations found in the study by Kimble and colleagues are in line with previous findings (Bryant et al. 1995; Felmingham et al. 2011) and are suggestive of a hypervigilance and early attentional bias toward threat in PTSD. This finding may have failed to reach statistical significance due to the subclinical nature of the majority of the PTSD sample (Kimble et al. 2010). Interestingly, the increased dwell time to all negative stimuli is suggestive of a potential difficulty in disengaging from the threat stimulus which had not been previously examined (Kimble et al. 2010). It is interesting to note that this extended viewing time was not specific to trauma-relevant stimuli but occurred to both war-related and motor vehicle accident-related images. However, as noted by

Kimble, MVA images may have a particular relevance to Iraq veterans as many intermittent explosive devices involve motor vehicles. In contrast, the trend for increased initial fixations reflecting early hypervigilance and orienting was specific to combat-related images.

To examine the effect of subclinical levels of PTSD, a recent eye tracking study compared visual fixations and dwell time to visual images in a clinical PTSD sample, a subclinical PTSD group, and a nontrauma exposed group (Thomas et al. 2013). In this study, eye tracking was recorded to positive and negative stimuli (both general threat and trauma-relevant stimuli) in multiple, four-image arrays (general negative, positive, trauma-relevant, and neutral) that were presented for 6 s. Findings revealed that both the clinical PTSD and subclinical PTSD group attended to trauma-relevant threat images more than the nontraumatized control group, but there were no group differences found to general threat images. While there were no overall group differences across the whole 6 second stimulus presentation time, time-course analysis (0–2 s, 2–4 s, 4–6 s) revealed important differences in temporal attention profiles. The clinical PTSD revealed an early increased attention to trauma-relevant images compared to the nontrauma exposed group in the 0–2 s time bracket; in the subsequent bracket (2–4 s) the clinical PTSD group displayed avoidance of threat images and in the final bracket (4–6 s) showed an increased attention bias. In contrast, the subclinical PTSD did not show attentional bias toward threat in the initial 0–2 s time bracket but displayed increased attention bias toward threat in the 2–4 s time bracket which sustained until 6 s. The nontrauma exposed group did not display significant attentional biases.

In conclusion, this study provided consistent evidence for an initial attention bias toward trauma-specific stimuli in PTSD but is the first study to reveal evidence for subsequent avoidance of threat in the PTSD group as no previous studies have found avoidance within analyses of subsequent fixations. This may be due to the more structured temporal analysis of attentional biases and eye movements employed in this study, and therefore this type of analysis requires replication and further exploration. The attention bias was specific to trauma-relevant stimuli, as there was no evidence of attentional biases toward general negative/threat words in any group. There also appeared to be an attentional bias in nonclinical individuals with subsyndromal PTSD, but this attentional bias was not immediate but occurred after a few seconds of stimulus presentation.

Taken together, the current eye tracking studies in PTSD have assessed attentional biases toward threat using either word or visual stimuli. Most studies report evidence consistent with an initial attention bias toward threatening stimuli, and this appears mostly specific to trauma-relevant words than general threat words. These findings are consistent with a hypervigilance model of PTSD (Chemtob et al. 1988). There is less consistent evidence for attentional avoidance of threat in PTSD, but future studies need to examine the temporal dynamics of attentional biases more closely. As noted, currently there are only a handful of eye tracking studies in PTSD; therefore, these findings can only be considered preliminary rather than conclusive and require further exploration and replication. In addition, most eye tracking studies in PTSD have employed small samples, so future studies need to examine eye tracking and attention bias in larger samples of PTSD patients and across individuals

who have survived different types of traumatic experiences to assess whether these effects generalize.

To further test the hypervigilance model in PTSD, a recent eye tracking study was conducted in nonclinical controls in which hypervigilant states were induced (Kimble et al. 2014). To test the theory that hypervigilance may focus attention on potential threat and induce or maintain a feed-forward loop which increases anxiety (Chemtob et al. 1988), nonclinical students were randomly assigned to either a hypervigilant, pleasant, or control condition (Kimble et al. 2014). To manipulate hypervigilance, those in the hypervigilant condition were instructed to search each picture for threatening targets, and if they didn't find them all then they would hear a loud white noise burst. In the pleasant condition, participants were instructed to search for pleasant targets or they would hear a loud white noise, and those in the control condition were told to look at each image and ignore the loud noise. There were no targets presented in any picture, and no white noise bursts were tied to performance (they simply occurred in a fixed random order). Eye fixations and pupil diameter were recorded. The hypervigilant condition produced a significantly larger number of overall fixations (consistent with a hypervigilant, scanning pattern) than the pleasant or control conditions which did not differ (Kimble et al. 2014). These results suggest that those in the hypervigilant condition had more extensive visual scanning, with significantly more sections of pictures fixated on than in the pleasant or control conditions. The hypervigilant condition was also associated with larger pupil diameters consistent with greater arousal compared to the control condition. However, the hypervigilant group did not report more anxiety than the other groups following the task, as all groups reported increased anxiety at an equivalent level (possibly due to the irregular white noise bursts). Therefore, this analog eye tracking study in nonclinical participants revealed that manipulating hypervigilance resulted in increased sympathetic arousal and increased visual scanning of the environment (Kimble et al. 2014).

A recent meta-analysis has been conducted examining attentional bias studies in affective and anxiety disorders, including PTSD (Armstrong and Olatunji 2012). Findings revealed that anxious individuals (including those with PTSD) showed increased vigilance for threat during free viewing or visual search tasks, and while anxiety disorders showed difficulty disengaging from threat in visual search tasks, only the PTSD group displayed difficulty disengaging from threat in free viewing tasks (Armstrong and Olatunji 2012). This latter specific finding in PTSD was largely driven by the study by Kimble and colleagues (2011) and requires replication in further eye tracking studies.

Longitudinal Studies of Attentional Bias

The eye tracking studies in PTSD that have been reviewed are all cross-sectional and cannot delineate whether attentional bias toward threat is a premorbid vulnerability factor for PTSD or whether it is acquired following the traumatic event and acts to maintain anxiety and PTSD symptoms. Recently, longitudinal studies in large military

samples have examined attentional biases prior to deployment to identify their role in predicting subsequent PTSD symptoms. Initial studies employing the dot-probe paradigm, with reaction time as the dependent measure, have found unexpectedly that attentional avoidance of threat is predictive of later PTSD symptoms (Wald et al. 2011; Bar-Haim et al. 2010). One study revealed a complex pattern, with baseline pretraining attentional biases *toward* threat predicting later PTSD symptoms, but post-training immediately predeployment attentional *avoidance* of threat predicted later PTSD symptoms (Wald et al. 2013). Interestingly, recent studies have also revealed that the imminent nature of the threat in combat environment can influence attentional biases. One study was conducted in Israel during actual combat, and risk of rocket attack revealed that attentional avoidance of threat stimuli using a dot-probe task was associated with greater distress (Bar-Haim et al. 2010). Therefore, it is possible that attentional avoidance may occur during acute or imminent threat. The capacity to be hypervigilant for threat following training may be protective during military combat and trauma exposure (Wald et al. 2013).

These longitudinal studies have used a dot-probe task with response latency dependent measures which has limitations as previously discussed. A recent longitudinal study in a military sample has examined eye tracking indices of attentional bias prior to deployment. Using an eye track task to assess initial fixations to a 2 x 2 matrix of fearful, sad, happy, and neutral faces, 139 soldiers were tested 3 months prior to deployment, and this was followed by a brief self-report measure of PTSD symptoms and a self-report of depressive symptoms during deployment (Beevers et al. 2011). As expected, the amount of war zone stress predicted increased PTSD symptom severity and higher depression during deployment, but notably, the study found that eye movements were a significant moderator of this effect. In soldiers with high levels of war zone stress exposure, reduced mean fixation time to fearful faces (reflecting attentional avoidance) at predeployment predicted higher PTSD symptom severity during deployment (Beevers et al. 2011). This finding is consistent with earlier longitudinal dot-probe studies revealing that predeployment attentional avoidance was a significant predictor of higher PTSD symptoms following deployment (Wald et al. 2013). In addition, Beevers and colleagues (2011) reported that increased fixation time to sad faces at predeployment was a significant predictor of higher depression scores during deployment (Beevers et al. 2011).

In summary, while longitudinal studies of attentional bias have only recently been conducted and are an emerging literature, the most consistent finding is that attentional avoidance prior to military deployment is a significant predictor of later PTSD symptoms. The only longitudinal eye tracking study has found evidence in line with this attentional avoidance effect, consistent with a handful of dot-probe reaction time tasks. These longitudinal studies suggest that attentional biases have differential effects as vulnerability factors and operate differently when promoting risk for PTSD (attentional avoidance of threat is a risk factor for developing PTSD) than once PTSD has been acquired (where attentional bias toward threat is observed).

Further eye movement studies are required to confirm these cross-sectional and longitudinal findings in PTSD, to build a robust set of empirical findings from which conclusions can be reliably drawn. This is of particular importance and clinical

relevance given the recent innovations in treatment approaches that employ attentional bias modifications that are being applied to many anxiety disorders (Kuckertz et al. 2014).

Future Directions for Eye Movement Research in PTSD

Other eye movement paradigms have been used to explore mechanisms underlying other psychiatric disorders, such as examining visual scan paths when looking at complex visual stimuli such as facial expressions or emotional scenes (Toh et al. 2011). Visual scan path studies track the dynamic spatial shift and fixation points in disorder-relevant stimuli. Visual scan path studies of emotional faces have revealed that individuals with social anxiety disorder avoid fixating on the eye region of faces, particularly when confronted with angry facial expressions (Horley et al. 2003). Visual scan path studies have also revealed avoidance of eye regions in schizophrenia (Bestelmeyer et al. 2006) and typically report shorter scanpath lengths and fewer fixations and marked avoidance of salient visual features consistent with avoidance (Toh et al. 2011). The visual scan path literature in anxiety disorders is still emerging with somewhat inconsistent findings and requires replication and further studies in larger samples (Toh et al. 2011). To date, no visual scan path studies have been conducted in PTSD.

Visual scan path analyses of PTSD may be of utility to examine potential attentional biases and avoidance of key aspects of facial emotions or complex scenes. A recent fMRI study has examined the neural correlates of looking at faces with direct versus averted gaze in PTSD, with the assumption that direct gaze represents a more explicit threat than the averted gaze (Steuwe et al. 2014). Brain activity was examined in response to direct eye-to-eye contact in a virtual reality paradigm compared to averted gaze in PTSD patients with a child-sexual abuse history compared to controls. Findings revealed that direct gaze led to increased activity in a cortical network involved in evaluation of top-down social cognition processes (in regions such as dorsomedial prefrontal cortex and right temporoparietal junction), whereas in PTSD direct gaze led to sustained activation of subcortical processing in the superior colliculum, periaqueductal gray, and locus coeruleus which has been associated with an innate fear or alarm system (Liddell et al. 2005; Steuwe et al. 2014).

Conclusion

In summary, although there are only a handful of eye tracking studies in PTSD and replication studies with larger samples of PTSD patients are required before conclusions can be drawn, this methodology provides potentially important insights into differing theoretical models of PTSD in relation to attentional biases. At this preliminary stage, current findings reveal evidence for an early attentional bias toward trauma-relevant stimuli in PTSD, with less consistent evidence of subsequent

avoidance. However, longitudinal studies are emerging which suggest that attentional avoidance of threat may be a risk factor for developing higher PTSD symptoms in military settings. Eye tracking technology provides significant advances over traditional attentional bias paradigms, as it enables the continuous assessment of visual attention, allowing for both valuable convergent spatial and temporal information. This enables the assessment of both initial attention and avoidance of threatening stimuli. In addition, eye tracking technology may be usefully applied in alternative paradigms assessing social cognition (such as visual scanning of facial expressions) to identify further important aspects of emotional and social processing in PTSD.

Summary Points

- Eye tracking research in PTSD is in its infancy, with only a few studies completed. These studies have focused on examining attentional biases toward threat, which are proposed as a key maintaining factor in many anxiety disorders including PTSD.
- Traditional response-latency measures of attentional bias (dot probe and emotional stroop tasks) have provided inconsistent evidence for an attentional bias toward threat in PTSD, but these tasks are subject to the influence of motivation, motor response, emotional arousal, and mood and do not offer a direct measure of attention which can discriminate underlying processes within attention bias.
- The use of eye tracking technologies can significantly advance our understanding of the mechanisms of attentional bias toward threat as they are direct measures of visual attention which do not rely on inference from reaction time data and the continuous nature of the measurement enables discriminating between facilitated attention toward threat (orienting), difficulty disengaging from threat, and avoidance of threat.
- While there are only a handful of eye tracking studies in PTSD, growing evidence suggests that there is a robust attentional bias toward threat in PTSD, which involves facilitated initial attention or orienting. In contrast, there is little evidence for subsequent avoidance of threat.
- This research is more in line with a hypervigilance model of PTSD than the vigilance-avoidance model of threat processing.
- Interestingly, recent longitudinal studies suggest that avoidance of threat is a risk factor for developing PTSD following trauma.
- It is important that more research is conducted in eye tracking to increase the robustness of this literature and to take advantage of the more direct, continuous attentional measures provided by eye movement research.

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