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The Impact of Hypervigilance: Evidence for a Forward Feedback Loop

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Abstract

A number of prominent theories suggest that hypervigilance and attentional bias play a central role in anxiety disorders and PTSD. It is argued that hypervigilance may focus attention on potential threats and precipitate or maintain a forward feedback loop in which anxiety is increased. While there is considerable data to suggest that attentional bias exists, there is little evidence to suggest that it plays this proposed but critical role. This study investigated how manipulating hypervigilance would impact the forward feedback loop via self-reported anxiety, visual scanning, and pupil size. Seventy-one participants were assigned to either a hypervigilant, pleasant, or control condition while looking at a series of neutral pictures. Those in the hypervigilant condition had significantly more fixations than those in the other two groups. These fixations were more spread out and covered a greater percentage of the ambiguous scene. Pupil size was also significantly larger in the hypervigilant condition relative to the control condition. Thus the study provided support for the role of hypervigilance in increasing visual scanning and arousal even to

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neutral stimuli and even when there is no change in self-reported anxiety. Implications for the role this may play in perpetuating a forward feedback loop is discussed.

Introduction

Past and present theories have suggested that attentional bias towards threat plays a central role in anxiety disorders, including posttraumatic stress disorder (Chemtob, Roitblat, Hamada, Carlson, & Twentyman, 1988; Litz & Keane, 1989; Dalgleish, Moradi, Taghavi,, Neshat-Doost, & Yule, 2001; Foa, Steketee, & Rothbaum, 1989; Brewin, Dalgleish, & Joseph 1996; Ehlers & Clark, 2000; Foa & Kozak, 1986; Cisler & Koster, 2010). In many of these models, attentional bias and hypervigilance are thought to play a critical role in the maintenance, and perhaps etiology, of the disorder. Dalgleish et al. (2001) for example, argued that “anxiety leads to increased hypervigilance for threat, a greater level of threat detection leads to increased anxiety which, in turn, leads to increased hypervigilance, and so on in a vicious circle” (p. 541). Beck, Emery, & Greenberg, (2005) later argued that anxiety disorders were associated with a hypervigilance that led them to misinterpret ambiguous situations and exaggerate minor threats, all of which would further increase anxiety. And empirical evidence for attentional bias across a range of anxiety disorders is quite prevalent (Horley, Williams, Gonsalves, & Gordon, 2004; Bogels & Mansell, 2004; Schofield, Johnson, Inhoff, & Coles, 2012; Weeks, Howell, & Golden, 2013). Referring specifically to PTSD, Chemtob and colleagues (1988) argued for a threat detection network that was easily potentiated and could initiate a positive feedback loop. The error in interpretation then provides subjective evidence for threat, thereby increasing threat related arousal. It is argued that this increased arousal facilitates greater attention towards threat and decreases cognitions or behaviors that may inhibit anxiety. Recognizing the critical role of hypervigilance, Conoscenti, Vine, Papa, & Litz (2009) updated the body of work regarding hypervigilance in PTSD and considered the symptom a gateway to posttraumatic disturbance.

Supporting this theory are both long standing clinical evidence for hypervigilance (Kardiner & Spiegel, 1947) as well as ample empirical support for the existence of attentional biases in PTSD. In visual search tasks (Pineles, Shipherd, Welsh, & Yovel, 2007), dot probe tasks (Bryant & Harvey, 1997; Dalgleish et al., 2001), and modified Stroop tasks (McNally, Kaspi, Riemann, & Zeitlen, 1990; Beck, Freeman, Shipherd, Hamblen, & Lacker, 2001), there has been evidence for both facilitation (i.e., increased detection of) as well as an interference (i.e., poor disengagement from) threat related stimuli (for mixed evidence or exceptions see Kimble, Frueh, & Marks, 2009; Pineles et al., 2007; Pollak & Tolley-Schell 2003).

Evidence for facilitation and poor disengagement in PTSD has been bolstered by recent work using eye tracking technology (Bryant, Harvey, Gordon, & Berry, 1995; Kimble, Fleming, Bandy, Kim, & Zambetti, 2010; Felmingham, Rennie, Manor, & Bryant, 2011; Beevers, Marti, Lee, Stote, Ferrel, Hariri, et al., 2011). Eye tracking techniques can assess patterns in eye fixations, fixation durations, and eye movement. In addition, the technology provides continuous, non-invasive indices of attention to visual stimuli. It has a distinct advantage over dot probe, Stroop, visual search, and spatial cueing tasks in that it can directly assess visual attention without the difficulties of interpretation associated with reaction time. This early work in PTSD has shown evidence for increased detection for threat with little avoidance of threatening stimuli after detection (Bryant et al., 1995; Kimble et al., 2010; Felmingham et al., 2011). In a recent study, however, Beevers and colleagues (2011) found that predeployment avoidance of angry faces predicted the development of PTSD when exposed to war zone stressors. The authors argued that avoidance of fear related information prior to deployment may indicate a tendency to avoid thinking about trauma and may later interfere with the extinction and re appraisal processes necessary for recovery (Beevers et al., 2011). Eye gaze was not assessed post-deployment however, and thus it is unclear whether the subsequent PTSD was associated with the facilitation and poor disengagement found in the previous studies.

While there has been a preponderance of evidence for facilitation and poor disengagement in PTSD, no studies have investigated whether these attentional patterns perpetuate a forward feedback loop that results in increased anxiety, increased search for threat, and increased autonomic arousal. The lack of work in this area is partly due to the difficulty of assuring in clinical samples that any changes in anxiety or arousal are actually due to changes in hypervigilance and not some other confounding factor such as trauma type, medication status, or symptom severity. The difficulty is further complicated by ceiling effects in which increasing hypervigilance may be difficult in an already vigilant, clinical sample. However, providing such data in any sample would produce critical evidence in support of the forward feedback loop proposed in PTSD theory. For example, if hypervigilance or attentional bias for threat *does not* produce further anxiety or behavioral change then a forward feedback loop would, in theory, stop at that point.

The goal of this study was to see whether manipulating hypervigilance would affect a forward feedback loop as measured by self-reports of anxiety, impact on visual attention, and influence on autonomic arousal. In order to control for confounding variables and ceiling effects, non-clinical participants were used and were randomly assigned to hypervigilant, pleasant, and control conditions. Hypervigilance was manipulated through an instruction set in which participants were told that they needed to find the threat in a computer presented ambiguous scene in order to avoid an aversive consequence. The impact of this instruction set on anxiety, visual scanning, and pupil dilation was assessed. Consistent with theories that suggest a forward feedback loop in PTSD and anxiety disorders more generally (Dalgeish et al., 2001; Beck et al., 2005; Chemtob et al., 1988; Litz and Keane, 1989), we predicted that the hypervigilant manipulation would result in larger pupil sizes (i.e., greater autonomic arousal), a greater number of fixations (i.e., increased scanning), and higher self-reported anxiety.

In this study, we constrained the stimuli to be most relevant to those with trauma and PTSD. Most pictures were neutral scenes that those with PTSD typically describe as potentially threatening such as railway platforms, busy rooms, empty streets and parking garages, and so forth. The stimuli were purposefully neutral (without any obvious threat) and ambiguous given that those with PTSD aren't necessarily seeing real threats in the environment, but rather perceiving threats that are not there. In addition, given that breadth of stimuli that those with anxiety disorders generally might respond to (i.e., animals vs. faces vs. bridges), we thought it too difficult to produce stimuli that would allow one to conclude a forward feedback loop in anxiety disorders more broadly. However, we feel this study can reasonably serve as a case in point. Specifically, a demonstration of a hypervigilant condition that produces greater visual scanning and autonomic arousal to stimuli that are most relevant to those with PTSD would certainly have implications for understanding hypervigilance in other anxiety disorders. For example, it would be reasonable to conclude that a hypervigilant mindset that produces increased anxiety and visual scanning to stimuli related to PTSD, would do the same for social phobia.

Methods and Materials

2.1 Participants

The participants were 71 students from an undergraduate liberal arts school in the northeast. One student was removed due to poor quality eye tracking data. Participants were recruited from introductory psychology courses and were given research credit for completing the experiment. The average age of participants was 18.4 years; there were 50 females and 21 males; 73% of participants were white, 4% were African American, 11% were Asian American, 1% were American Indian, and 8% reported they were biracial.

2.2 Procedure

Participants were asked to sign an informed consent, and subsequently administered the Spielberger State Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), the Posttrauamtic Stress Scale (Foa et al., 1993), along with a brief demographic survey. Upon completion of the instruments, all participants underwent an eye tracking task in which they were asked to look at 30 pictures on a computer screen for 10 seconds each. The pictures were presented on a Dell 22' monitor and took up the entire screen. Their head was stabilized with a chin rest and their eyes were 57 cm away from the monitor. The pictures were neutral in valence and included an assortment of images such as streets scenes, parking lots, ballparks, forests, stores, and classrooms (See Figure 1 for an example stimulus). All pictures were purposefully neutral but complex in order to simulate situations real-life situations in which those with PTSD often describe as threatening even in the absence of overt threat.

Unknown to the participants, they were randomly assigned to one of three conditions. Participants in the “hypervigilant condition (N=25) were instructed to search each picture for threatening targets. They were instructed that if they did not find all targets, a loud white noise burst (90 dB) would be played. Participants in the “pleasant condition” (N=24) were instructed to search each picture for pleasant targets and were also told that a loud noise would be played if they did not find all of them. Participants in the “control condition” (N=21) were instructed to look at each image for ten seconds and ignore the loud white noise.

The “hypervigilant' condition was designed to emulate the cognitive processes that may underlie hypervigilance, i.e., look for threat (in this case the threatening targets) in order to avoid an aversive consequence (in this case, the loud noise burst). This would be an experimental analog to an individual with PTSD who might look out for danger (i.e., look over their shoulder) in order to avoid a negative consequence (i.e., getting attacked from behind). The pleasant condition was designed to control for valence effects (it was identical except participants were told to find the pleasant stimulus), and the control condition was designed to cover possible effects due to performance anxiety, i.e., hearing the loud noise suggesting that they were failing the task.

2.2.1 Task—In fact, there were no actual targets in the pictures, nor were the noise bursts tied to their performance. All participants were presented all 30 pictures in exactly the same order. Noise bursts were presented in a fixed random order. In all, 30 noise bursts were presented. Four trials had two noise bursts presented during the ten seconds, 14 trials had one, and 12 had none. This pattern of presentation was chosen in order to give the participant the sense that the task was possible, but at times they failed to find the "targets." For any given slide in which a burst was presented, the noise bursts were presented at fixed times. All noise bursts occurred between 2 and 9 seconds after picture onset, were presented at 90 dB, were 1 second long, and were presented through two Altec-Lansing speakers (model BXR1120) placed 24 inches behind the participant. Therefore, picture presentations and noise bursts were identical for all participants, the conditions only differed in their instruction sets.

2.2.2 Eye Tracking—Eye fixations and pupil diameter were measured using an Eyelink 2000 desktop, mirrorless eye tracker (SR Research: Ottowa, Canada). Saccades and fixations were measured using corneal reflection and pupil detection algorithm standard to the Eyelink 2000 system. Data was sampled from the left eye at 2000 Hz. Data Viewer® software was used to overlay fixation and pupil size over the stimuli for later offline analyses. The eye tracking procedure began with a calibration/validation sequence in which participants followed a dot across nine locations on the screen. The eye tracker was calibrated on a per subject basis at the beginning of each experiment and checked for accuracy between each trial. Therefore, the interstimulus interval varied and was usually between 2 and 5 seconds. Dependent measures included the number of fixations during the 10 second trial, pupil size (measured in pixels), and visual scanning (as measured by the percentage of sectors hit out of 88 possible sectors: see Figure 1). The entire eye tracking task typically took 7-8 minutes. When the task was completed, participants filled out the STAI a second time and then were debriefed.

Results

3.1 Demographic Measures

A chi square test indicated that there were no differences between the groups on gender ($x^2(2)=.38$, $p>.05$). A one-way ANOVA revealed no significant differences between groups on age [$F(2,67)=.54$, $p>.05$], pretest anxiety [$F(2,70)=.86$, $p>.05$], or PTSD scores [$F(2,68)= .86$, $p>.05$). See Table 1.

3.2 Self Report Measures

A 3 (Group) × 2 (Time) repeated measures ANOVA indicated a significant main effect of "Time" for the STAI [$F(1,67) = 11.01$, $p<.05$] with all three conditions increasing in STAI scores in the post-task relative to the pretask. There was no significant Group × Time interaction however suggesting the groups did not differ in their self-reported anxiety as a function of group [$F(2,67) = .028$, $p>.05$].

3.3 Behavioral Measures

3.3.1 Fixations—A one-way ANOVA was used to analyze the number of fixations and all physiological variables. A significant difference was found between groups in the average number of fixations to the pictures [$F(2, 69) = 8.06$, $p<.05$]. LSD post hoc analyses indicated that the hypervigilant condition produced significantly more fixations than did the pleasant condition ($p<.05$) or the control condition ($p<.05$). The control condition did not differ significantly from the pleasant condition ($p>.05$).

3.3.2 Visual Scanning—A significant difference was found between groups in percent of sectors hit [$F(2, 69) = 7.15$, p<05]. LSD post hoc analyses indicated that the hypervigilant condition had significantly more sectors hit than did the pleasant condition ($p<.05$) or the control condition ($p<.05$). The pleasant condition did not differ significantly from the control condition ($p>.05$).

3.3.3 Pupil Size—A significant difference was found between the groups in average pupil size [$F(2,69) = 4.34$, $p<0.05$). LSD post hoc analyses indicated that the hypervigilant condition produced significantly larger pupil sizes than the control condition ($p<.01$). The average pupil size for the pleasant condition was between the hypervigilant condition and the control condition but did not differ significantly from either ($p>.05$)

Discussion

4.1. Self-Reports of Anxiety

Contrary to what the forward feedback hypothesis would predict, those in the hypervigilant condition did not report more anxiety after completing the task. Rather, *all* participants experienced an increase in anxiety. Presumably, the aversive noise bursts caused an increase in anxiety regardless of condition. The increased anxiety could not be attributed to performance anxiety as the control group were told simply to look at the pictures and ignore the noise bursts. While there were no condition-related differences in self-reported anxiety, there were differences in pupil size and visual scanning patterns Such a pattern suggests that the hypervigilant-related instruction set produced autonomic and behavioral changes even in the absence of changes in self-reports.

It is also possible that the nature of the stimuli may resulted in a pattern in which we saw increased visual scanning but no increases in self-reported anxiety. In particular, all of the pictures were neutral and did not have any overt threat. It is possible that actual threatening targets (or pictures with high negative valence) may have been needed to produce increases in self-reported anxiety. It seems likely that the inability to find a threat even when "hypervigilant" may have reassured the participants that a threat was really not present, and therefore result in them not *reporting* more anxiety. This would certainly be consistent with some clinical reports that individuals engage in hypervigilance in order to feel safe. In situations in which hypervigilance is engaged in and threats are *not* found, one might expect a reduction (or at least no increase) in reported anxiety. In this sense, hypervigilant behavior would be negatively reinforced through the alleviation of anxiety. For example, a rape survivor who carefully enters her home at night and checks it for signs of illegal entry may significantly reduce her anxiety upon assuring herself that the house is safe. In this study, the presence of only neutral (i.e., safe) visual stimuli may simply not have been sufficient to increase conscious anxiety.

4.2 Pupil Size and Scanning Behavior

While not affecting self-reported anxiety, the hypervigilant condition was associated with differences in pupil size. Pupil dilation is thought to be an index of autonomic, sympathetic arousal and is larger when looking at arousing stimuli (Bradley, Miccoli, Escrig, & Lang, 2008). In PTSD, increased sympathetic arousal is thought to play a role in cueing both reexperiencing and avoidance symptoms. If this is the case, then a hypervigilant mindset, even in the absence of a threatening stimuli, may increase autonomic arousal. However the hypervigilant condition did not differ from the pleasant condition, nor did the pleasant condition differ from the control condition. This suggests that receiving feedback that one was failing at a visual search task was not sufficient to significantly affect autonomic arousal (pleasant versus control), but failing to find a potentially threatening stimulus was (hypervigilance versus control).

The hypervigilant condition had its most robust impact on visual scanning behavior. Those in the hypervigilant condition had significantly more fixations and looked over a broader area than those in either of the other two conditions. These findings contribute to the literature in that most previous studies on attentional bias demonstrate that those with PTSD look first or look longest *at* threatening material. These finding suggest that hypervigilance is also associated with increased efforts *to find* threat. While this is entirely consistent with the clinical presentation of hypervigilance, there has been no previous empirical evidence to this effect. Increasing fixations and doing so over a broader area is likely to increase the odds of finding a possible threat. Consistent with the previous interpretation however, it is also possible that increasing fixations over a broader area may also decrease anxiety if no threat is found. In this sense, hypervigilance may be perceived by an individual as a behavior with few costs. If a threat is found, they are prepared to act; if a threat is not present, they can relax.

4.3 Implications and Limitations

This study used a non-clinical, low in anxiety sample in order to look at the effects of increasing hypervigilance on self-reports and behavior. While this was done purposefully in order minimize confounds and ceiling effects, one cannot be sure whether high levels of hypervigilance play the role in a forward feedback loop in those with PTSD that they played in this non clinical sample. However, hypervigilant behavior in trauma survivors is likely to occur on a continuum that ranges from vigilance to hypervigilance and does not seem to suddenly “appear” in clinical samples with PTSD (Conoscenti, et al., 2009). For example, Kimble and colleagues (2012) found high levels of hypervigilance in civilian settings in all returning veterans, even those without PTSD (Kimble, Fleming, & Bennion, 2013). While those veterans with PTSD had the highest hypervigilance scores (and probably high enough to be functionally problematic), even veterans without PTSD had high hypervigilance scores compared to survivors of other types of traumas. This suggest that hypervigilance is likely a variant of vigilance that differs in frequency and severity, but not kind—suggesting that non-clinical analogs would have much to add.

In addition, one might argue that this analog study is simply a demonstration of a manipulation with little implication for clinical anxiety. The findings, however, understood within the context of anxiety and PTSD theory, suggest two very important points. First, cognitions that mimic hypervigilance led to increased scanning and autonomic arousal. Second, both autonomic arousal and visual scanning has been theoretically linked (Dalgleish et al., 2001; Litz and Keane, 1989) and in some cases has been demonstrated (see Prins, Kaloupek, & Keane, 1995 for review of relevant empirical research) to lead to further symptoms. Therefore, the increased scanning and arousal seen in this sample has important clinical implications. Previous work would suggest that the increased scanning would lead to the finding of more threat and/or negative interpretations of ambiguous stimuli. This would, of course, perpetuate a forward feedback loop.

Our analog for hypervigilance was highly experimental. We tried create an instruction set that mimicked a hypervigilance that might be similar to that experienced by an individual with PTSD. In particular, we tried to generate a “mindset” in the hypervigilant condition that would make the participant alert for possible threat. We did so by setting up experimental conditions in which the participant was told to look for threat in an ambiguous visual stimuli. In addition, they were informed that, if they failed, there would be a negative outcome. This clearly is a mere approximation of what a hypervigilant individual is likely to be experiencing while scanning for threat in the real world. In particular, the largest difference would be in a clinical patient's belief that something catastrophic might occur if they don't identify the threat before it is too late. This could not be mimicked in the lab. However, the fact that our relatively mild hypervigilant condition impacted autonomic arousal and visual scanning in a low anxiety sample suggests that hypervigilance may have at least similar if not larger effects in a clinical sample.

While empirical validation would be critical, we feel it is reasonable to hypothesize that similar patterns may be present in disorders such as social phobia, animal phobia, and panic disorder. Hypervigilance for signs of rejection (i.e., social phobia), a feared stimulus (i.e., snake phobia), or interoceptive abnormalities (i.e., panic disorder), may also lead to increased autonomic arousal and perceptual scanning that maintains a positive feedback loop.

4.4 Conclusions

In summary, this study provided mixed support for the forward feedback hypothesis. Hypervigilance did not impact on self-reported anxiety but did impact on visual scanning and arousal in a manner that could exacerbate other symptoms and result in further threat detection. Therefore, hypervigilance is a candidate to initiate or maintain a positive feedback loop through increased scanning and autonomic arousal and theoretically could potentiate other difficulties even if the behavior does not result in conscious increases in anxiety.

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Highlights

- Hypervigilance is thought to maintain or exacerbate symptoms in anxiety disorders.
- We examine the impact of hypervigilance on anxiety, visual scanning, and autonomic arousal.
- An eye tracker was used to investigate eye movements and pupil size
- The hypervigilance condition resulted in more visual scanning and increased pupil size.

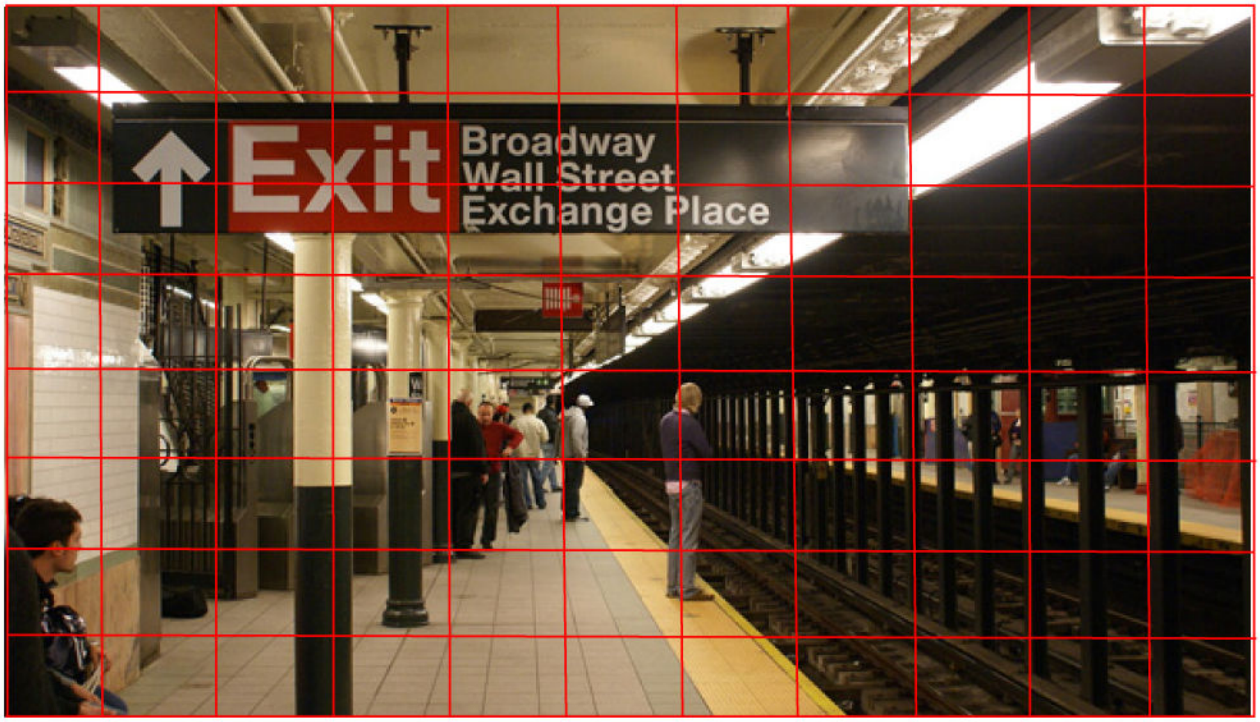

Figure 1. Example visual stimulus with grid overlay

Table 1

Self Report & Physiological Measures

	Control Condition	Pleasant Condition	Hypervig. Condition
Female	N=16	*N=16*	*N=18*
Age	*M* = 18.38	*M* = 18.57	*M* = 18.33
	SD = 1.02	SD =.0.66	*SD* = 0.70
PSS	*M* = 7.05	*M* = 5.48	*M* = 4.08
	SD = 9.17	SD =7.77	*SD* = 5.10
STAI Before	*M* = 38.81	*M* = 35.04	*M* = 37.44
	SD = 9.87	SD = 10.35	*SD* = 9.6
STAI After *	*M* = 42.19	*M* = 38.92	*M* = 41.36
	SD = 12.52	*SD* = 10.00	*SD* = 8.55
Fixations **			
	M = 28.01	*M* = 30.06	*M* = 32.73
	SD = 3.96	*SD* = 4.11	*SD* = 3.95
% Grids Hit **			
	M = 18.90	*M* = 20.68	*M* = 22.56
	SD = 3.24	*SD* = 3.36	*SD* = 3.23
Pupil Size ***			
	M = 1173.6	*M* = 1296.5	*M* = 1447.11
	SD = 235.98	*SD* = 342.53	*SD* = 346.31

* Anxiety scores increased from before to after in all three conditions

** Hypervigilant condition was significantly different from both control and pleasant conditions.

*** Hypervigilant condition was significantly different from control condition.