The Pennsylvania State University

The Graduate School

College of the Liberal Arts

SUSTAINED EMOTIONAL PROCESSING IN INDIVIDUALS SUFFERING FROM CHRONIC WORRY SYMPTOMS

A Thesis in

Psychology

By

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Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

August 2006

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Abstract

Previous findings indicate that worriers avoid particularly upsetting thoughts by worrying and that they have difficulties understanding their own emotions and those of others. At the same time, there is behavioral evidence that worriers are especially attuned to certain distressing emotional stimuli and have difficulty turning off negative emotions once they are initiated. Worriers also report that they express negative emotion readily even though they fear both depressive and anxious experiences. The present study used a variety of emotional stimuli including personally generated relevant materials, normative stimuli from published lists of emotional material, both images and words, and four emotional categories of stimuli (positive, negative, neutral, and threat) to thoroughly examine emotional processing in chronic worriers. Individuals scoring high on a measure of chronic uncontrollable worry (Penn State Worry Questionnaire) were compared to non-worriers (low scorers) on tasks that required valence categorization of emotional stimuli and also on interleaved Stroop color word identification trials to monitor extended effects of emotional stimuli on subsequent cognitive processing. Pupil diameter was assessed as a measure of processing load/arousal. Worriers had larger anticipatory pupil diameters before emotional information was presented to them but had smaller pupils for personally relevant negative information and smaller sustained diameters following emotional material compared to non-worriers. With threatening emotional words, however, worriers had larger sustained pupil sizes relative to the control group. Correlations with self-report symptom scales indicate an independent role for chronic worry symptoms in explaining pupil diameter perseveration above and beyond trait anxiety, depressive rumination, and other symptoms. A model of both emotional avoidance and hypervigilance to threat is supported by the findings with qualifiers for task complexity, temporal dynamics of emotional response, relevance of stimuli, and type of emotional content presented.

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ACKNOWLEDGEMENTS

I would like to thank my adviser, Bill Ray, for allowing me to pursue any and all research ideas that I wanted throughout graduate school. His patience with drafts of my manuscripts that *still* didn't quite "tell a story" was astounding. Talking with him about new research ideas and implications of new data sets were some of my most cherished graduate school experiences. Reading his letter of recommendation that helped me to get a postdoctoral position made me so proud. Bill Ray is my hero.

Tom Borkovec was a major contributor to my professional development, as well. I learned about Generalized Anxiety Disorder and worry from his lab meetings and realized that I share his excitement for research in this area. Tom also read so many drafts of my master's thesis that I lost count. His extensive and thoughtful comments on these drafts were invaluable for my development as a scientific writer. I owe him a great deal.

Clinically, I was very influenced by Aaron Pincus who probably still wishes that I used more psychodynamic terms in talking about clients but who helped me to develop my clinical "voice" through our challenging and fun supervision sessions. This foundation has helped me already in my clinical internship and will no doubt serve me in any future clinical work that I can manage to squeeze into my busy research life.

Deanna Kwan and Evi Behar were good buddies in the lab. Jared Bruce, Srijana Shresta, Jan Pauschardt, and Aref Jabbour were dear friends outside of the lab. Alissa Yamasaki is a friend and labmate who saved me on many occasions. She is one of the sweetest people in the world especially for forgiving me so many times for my

forgetfulness. Brian Sharpless was a wonderful buddy through grad school and life tribulations. To know him is to love him. Everyone needs a friend like him.

My mom always encouraged me to be a psychologist. I bet that she would have been glad to see me helping veterans during my internship. My dad is a super fantastic guy. He kept our family safe and at the same time was a great playmate to me growing up. I hope that he is proud of what he has contributed to my life because I am grateful for it. Thank you, Sharon, for taking such good care of him.

Thanks also to Aunt Sherry, Uncle Tim, Uncle Jay, Aunt Anna, Uncle Darrel, Aunt Peggy and the rest of my "lost family" for welcoming me back and making me feel loved. My gratitude goes to Vera Ginzbourg and her family for helping me to become less of a '*yozhik'* (Russian for 'porcupine'). My brother has my unconditional love. I hope that my hard work will inspire him to set goals and to achieve them.

One benefit of my extended stay (and debt!) at Penn State was that I met a housemate turned friend turned sweetheart in Kelly Krellner. The more I know about her, the more I respect and cherish her.

Chapter 1: Worry Utility and Ubiquity

Worry is a type of anxiety about possible future events that are not immediately present (Molina, Borkovec, Peasley & Person, 1998) but are distressing and unpleasant to think about (Borkovec & Inz, 1990). When people are asked to worry, they report that they feel as if they are trying to solve problems or anticipate and avoid negative future events that have some possibility of occurring (Szabo & Lovibond, 2002). When worry does not become excessive, these qualities are useful for making prepared decisions for the future. However, chronic worry that is difficult to control is the hallmark of Generalized Anxiety Disorder (DSM-IV-TR, 2000). Worry that is excessive and difficult to control has been traditionally measured with the Penn State Worry Questionnaire (PSWQ) which has been shown to have good psychometric properties (validity, internal consistency, test-retest reliability; Meyer, Miller, Metzger & Borkovec, 1990). Though worry is especially relevant to a GAD diagnosis, worry is problematic for individuals with other symptoms of emotional distress. For example, individuals diagnosed with a unipolar mood disorder endorse higher scores on the PSWQ compared to non-psychiatric control participants (Riskind & Williams, 2005). Trait anxiety is also associated with frequent worry about a variety of topics (Eysenck & Van Berkum, 1992). After controlling for both depression and anxiety, worry is associated with over concern with mistakes and perfectionism (Stöber & Joorman, 2001). States of worry, even for non-anxious participants, cause a reduction in cognitive shifts to new topics (Molina, et al., 1998). Though worry often focuses on problem solving, it actually results in solutions on few occasions, especially for individuals with significant symptoms of GAD (Szabo, et al., 2002). For individuals suffering from GAD, their worry topics are less concrete

(Stöber & Borkovec, 2002) which may make concerns more difficult to solve and thus allow worries to persist. Of course, for chronic worriers, the results of worrisome thinking are exacerbated by their frequency and intensity. Frequency and uncontrollability of worry are specifically related to fewer instances of being able to come up with solutions following worry episodes (Szabo, et al., 2002). Problems with worry thus interfere with certain cognitive processes and are associated with a variety of mood and anxiety symptoms. The following sections will build a case for worry as a cognitive activity that is unpleasant and difficult to control, is related to threat assessment in the environment and is related to avoidance of certain types of emotional experience. This rationale will be used to make hypotheses about chronic worriers for the present study. Specifically, it will be hypothesized that chronic worriers will not necessarily show stronger reactions to negative or threatening emotional material compared to non-worriers but will experience residual effects of these stimuli compared to non-worriers as evidenced by pupil diameter. When more central or personally relevant emotional material is presented to worriers, it is hypothesized that they will show tendencies to avoid prolonged processing of this material consistent with endorsements by worriers that they avoid thinking about this type of material. As pupil size fluctuations have been shown to be useful measures of sustained emotional and cognitive processing, we expect that sustained pupil activity will be useful to quantify this avoidance response. Worriers additionally are expected to respond especially quickly to threatening emotional stimuli based on evidence of vigilance associated with chronic worry.

Chapter 2: Structure and Use Differentiate Worriers from Non-worriers

Many of the processes and experiences of worry are similar in chronic worriers and non-chronic worriers. For example, individuals scoring high and low on a measure of excessive uncontrollable worry report worrying about similar topics when they worry (Provencher, Freeston, Dugas, & Ladouceur, 2000). The top three topics endorsed by both groups were interpersonal issues, work/academics, and threats to personal safety. Worriers and non-worriers also similarly report that their worries are negative emotional cognitive states (Borkovec, et al., 1990; Metzger, Miller, Cohen, Sofka, & Borkovec, 1990). There are also some differences between worriers and non-worriers. Chronic worriers not only report more worries, but they also believe the negative outcomes of their worries more and conjure up more severely negative outcomes when they worry (Provencher, et al., 2000). With an analog GAD population, self-reports of negative emotion are greater compared to non-anxious control participants when catastrophizing interviews determine core fears underlying worry topics (Hazlett-Stevens & Craske, 2003). Though the GAD group did not rate their final feared outcome generated by this method as more likely compared to the control group, they did provide more layers of abstraction for their worry topics as indicated by steps in the catastrophic interviews. This suggests that the core fear underlying worry is more difficult to access in a group suffering from chronic worry symptoms. Those with GAD also report using worry more often as a strategy to deal with unpleasant or unwanted thoughts compared to control participants (Coles & Heimberg, 2005). Thus, despite a number of similarities in the experience of worry for worriers and non-worriers, for the chronic worrier, their worries are more abstract, have more underlying negativity, are more believable to them and are

chosen more often as a method to regulate mental contents. These factors likely contribute to the chronic negative impacts of worry states for individuals suffering from frequent worry episodes. Worry is additionally associated with certain types of emotional experience and not associated with others.

Chapter 3: Worry is Not the Same as Fear

For the most part, physiological evidence does not support a state of emotional arousal similar to fear during worry states (Borkovec, et al., 1990; Borkovec, Lyonsfields, Wiser, & Diehl, 1993) and one prominent theory suggests that worry may actually be useful as an emotional avoidance strategy (Borkovec, Alcaine, & Behar, 2004). At the same time, there is evidence that individuals with chronic worry have difficulty ignoring negative emotional information or inhibiting negative emotional processing once it starts (MacLeod, Mathews, & Tata, 1986; Becker, Rink, Margraf & Roth, 2001). Specifically, individuals suffering from GAD (by definition chronic worriers) are hypersensitive to threat cues in the environment (MacLeod, et al., 1986) and are especially distracted by emotional information when concurrently engaging in an unrelated cognitive task (Emotional Stroop; Becker, et al., 2001). Also, individuals asked to worry report approximately equal amounts of anxiety and depressed mood (Andrews & Borkovec, 1988). These emotional reactions are not necessarily synonymous with bodily arousal as in a fear state. Even when worry increases subjective reports of anxiety, physiological systems may not be preparing for fight/flight reactions (Borkovec, et al., 1990). In fact, worrisome thinking tendencies (rather than imagery) are related to less cardiovascular responses to phobic images in speech phobic individuals (Borkovec, et al., 1993). Also, chronic worriers do not exhibit increased anticipatory startle responses relative to non-worriers before viewing affect laden pictures (Nitschke, et al., 2002). Thus, worry is a type of anxiety distinct from traditional fear responses. Worry is associated with negative affect (Borkovec, et al., 1990; Metzger, et al., 1990) but negative affect does not necessarily coincide with an immediate arousal state. Instead, negative affect has been

shown to have a special relationship with emotional arousal. In a non-psychiatric participant group, assessments made each hour over an 8 hour period showed correlations between emotional arousal and heart rate as well as physical activity and heart rate (Brosschot & Thayer, 2003). Negatively valenced thought, on the other hand, was not correlated with heart rate at those assessments but did predict prolonged activation in heart rate assessed 5 minutes later. Neither emotional arousal nor physical activity levels successfully predicted prolonged activation in heart rate. The results stress the importance of negatively valenced thoughts in predicting perseverations of emotional processing despite the lack of relationship between negative valenced thought and direct emotional reactivity.

Worry is linked to persistent threat processing

It has been suggested that anxiety and fear differ in that fear is an active coping mechanism and anxiety results when threats are resistant to coping (Öhman, Flykt, & Lundquist, 2000). If threats are resistant to coping, they might reasonably be expected to continue to influence cognition. In partial support of a connection between anxiety and persistent threat processing is a positive correlation between trait anxiety scores and a measure of threat bias in implicit memory (Mathews, Mogg, May, & Eysenck, 1989). Certainly, in the case of worry, there is a prolonged cognitive state of threat processing separate from active coping with a proximal threat. For example, GAD and non-anxious control participants show a different pattern of responses on a test of visual attention following presentations of words intended to yield threatening interpretations (MacLeod, et al., 1986). Those suffering from GAD respond faster to probes in the position where a threat word was previously shown. Non-anxious control participants alternatively

respond faster to probes in the area where a threatening word was not shown previously. The authors interpret these findings as hypervigilance to threatening information associated with GAD compared to a threat avoidance strategy in the non-anxious group. There may be a special relationship between worriers and threat processing. Individuals with GAD generate more threat words in word-stem completion tasks of implicit memory compared to non-anxious control participants (Mathews, et al., 1989). Those suffering from GAD were also primed better for threat words while non-anxious control participants were primed better for non-threat words. The connection between worry and threat predicts that worriers in the present study will experience persistence in processing threatening emotional stimuli.

Chapter 4: Worry Has a Complex Relationship with Emotionality

Excessive responsiveness to threat may be something that worriers have in common with other anxious groups. For example, EEG recorded from midline electrode sites suggest that high anxious individuals deploy more attentional resources (larger amplitude N100 and P400 event-related potentials) to threatening information relative to low anxious individuals (Weinstein, 1995). However, individuals with GAD may be especially general in their assessments of threat even compared with individuals suffering from other anxiety disorders. For example, those suffering from GAD are distracted by a wider variety of emotional information compared to individuals with social phobia who are only distracted by words related to their phobia (Becker, et al., 2001). Despite this general hypervigilance, there is some evidence that worriers avoid certain emotional experiences. Chronic worriers diagnosed with Generalized Anxiety Disorder are more likely than control participants to endorse items on a questionnaire such as "worrying about most of the things I worry about is a way to distract myself from worrying about even more emotional things, things that I don't want to think about" (Borkovec & Roemer, 1995). Those scoring high on a scale of GAD symptoms also endorse higher levels of thought suppression compared to individuals with low scores (Riskind, et al., 2005). This would suggest that chronic worriers suppress unwanted thoughts and avoid unwanted emotions. Suppression is a relatively ineffective long term emotion regulation strategy (Gross, 2002) which may partially explain the maintenance of negative mood symptoms in groups suffering from chronic worry. Chronic worriers are hypervigilant to threatening information in the environment (MacLeod, et al., 1986), are especially distracted by emotional information (Becker, et al., 2001), and tend to express negative

emotionality to a greater extent as a function of their degree of chronic worry symptoms (Turk, Heimberg, Luterek, Mennin, & Fresco, 2005). Thus, it is likely an oversimplification to categorize chronic worriers as either emotionally blunted or excessively emotionally aroused. Responses to emotion illuminate important aspects of the emotional lives of chronic worriers. Though individuals diagnosed with GAD report that they attend to their emotions as much as non-anxious controls participants, higher scores on the PSWQ are associated with less emotional clarity and difficulty both describing and identifying emotion (Turk, et al., 2005). Individuals with anxiety disorders in that study also reported more difficulty in repairing negative mood states compared to control participants. These reports are consistent with emotional (especially negative) perseverations associated with anxiety. These perseverations are experienced as inabilities to inhibit unwanted emotional experiences. The resulting negatively valenced cognitive state of worry would thus be expected to perseverate. Also, as in the present study, worriers asked to make judgments about the emotionality of presented information would have difficulty with this task because of reports of reduced emotional clarity and difficulties identifying emotion (Turk, et al., 2005). At the same time, they report more emotional intensity and willingness to express negative emotion. It is possible that the perfectionism of worriers (Stöber, et al., 2000) would ensure that they respond accurately to emotional judgments and that their subjective feelings of intensity for these stimuli might also facilitate performance. However, their perceived confusion with emotional material could oppositely predict problems in emotion identification. The results of the present study will be useful to support one or another connection to emotional processing.

Worry may predict the return of negative affect following avoidance

Though individuals with GAD are especially vigilant to visually presented threat words (MacLeod, et al., 1986) and report that they regularly experience the negative affect associated with their worry states (Borkovec, et al., 1990; Szabo, et al., 2002), they admit to avoiding core emotions (Borkovec, et al., 1995). Chronic worriers are highly reactive to certain types of emotional information even while attempting to avoid certain deep emotional experiences, as reviewed above. If worry is a strategy often chosen by individuals with GAD to deal with unpleasant or unwanted thoughts (Coles, et al., 2005) though they know that they are avoiding more personally vulnerable topics by worrying (Borkovec, et al., 1995), they may be regularly engaging in threat appraisals but never attenuating the source of their negative thought streams. The avoidance of core emotions may allow for perseverations in threat processing and hypervigilance tendencies to perpetuate. Accessing deep or central feared material has been suggested to be essential for anxiety reduction (Foa & Kozak, 1986) and the ability to re-assess or reappraise the emotional significance of emotional reactions has been shown to be an especially effective technique for adaptive emotion regulation (Gross, 2002). The marrying of these emotional processing theories suggests that individuals with dishinhibited emotional states may especially benefit from the experience of core affective material in conjunction with critical evaluations of one's initial assessments of this material (i.e. "reappraisal"; Oathes, pending publication). In the case of chronic worriers, evaluation and prolonged appraisal of emotional material (especially threat assessments) are synonymous with worry as a cognitive state. However, without accessing core emotional material concurrently with these processing states, the underlying cause of catastrophic

uncontrollable worry does not abate. Thus, an underlying source of anxiety that might normally be processed and rendered impotent is disinhibited in the sense that it is allowed to continue to influence cognitive and emotional experience.

Chapter 5: Perseveration Links Worry to Depressive Rumination

This disinhibition or perseveration explanation for the link between chronic worry and negative emotional states has been used to explain emotional dysregulation with a number of psychiatric symptom categories. Other symptom categories described in terms of disinhibition or perseveration include ADHD and conduct problems (Hinshaw, 2003), as well as impulsivity and aggression (Davidson, Putnam, & Larson, 2000). The most common symptom category related to cognitive and emotional perseveration is depression and a cognitive process referred to as rumination. People who tend to respond to stress by ruminating think repetitively about negative emotions and focus their attention on symptoms of distress while also worrying about future outcomes of their symptoms (Lyubomirsky, Caldwell, & Nolen-Hoeksema, 1998; Nolen-Hoeksema, 1991). Rumination is typical of depression in that those diagnosed with a major depressive disorder endorse more tendencies to ruminate compared to those not diagnosed with the disorder (Nolen-Hoeksema, 2000). Rumination is also linked to anxiety. For example, rumination tendencies are correlated with both depression and anxiety self-reports (Nolen-Hoeksema, 2000). Rumination scores were also higher in that study for a mixed anxiety/depression group compared to a depressed only or anxious only group. Both the anxiety and depression only groups had higher rumination scores compared to a group without either type of symptom. Following experimental induction of anxiety, engaging in rumination prolongs both anxiety and negative mood compared to engaging in distraction (Blagden & Craske, 1996). When asked to worry, more than 10% of the time individuals will engage in rumination (Szabo, et al., 2002). Scores on rumination and worry questionnaires were also positively correlated in that study. Rumination was

additionally related positively to the frequency of worry reported. The overlap between anxiety and depression in terms of rumination tendencies may be part of a more global tendency to have distressing cognitions that are difficult to control and that persist despite efforts to control them. Repetitive thought has been theorized to be the link between both worry and rumination to negative moods associated with each (Segerstrom, Tsao, Alden, & Craske, 2000). Repetitive thought including worry, global rumination and depressive rumination was positively correlated in that study with anxiety and depressive symptoms for both a student population and a patient population. Rumination was also specifically correlated with depression in a clinical sample. Each factor contributing to the conglomerate measure (worry, global rumination and depressive rumination) was each correlated with the other factors suggesting that there is significant overlap in what these measures assess. Consistent with the idea that perseverative thinking allows emotional distress to persist, the conglomerate repetitive thought factor in that study partially predicted the maintenance of anxiety symptoms. The result of perseverating negative cognitive states is a rigid focus on one's internal states and over reliance on this information for the interpretation of new information. The nature of perseverative, inflexible, negatively valenced cognitive states associated with rumination and worry requires an internal focus of attention. A greater self-focus is positively correlated with diagnostic severity among clinically depressed and anxious individuals (Woodruff-Borden, Brothers, & Lister, 2001). Greater self-focus was also positively correlated with depression and anxiety symptoms and negatively related to problem solving. This is further support for the idea that strategies including worry and rumination that involve a rigid negative self-focus may not be ideal coping or problem solving strategies.

Cognitive control problems may co-occur with emotional disinhibition associated with worry and rumination

An explanation for the link between inflexible cognitive states, such as rumination, and failures to adequately process emotional material comes from a study that assessed a measure of executive functioning (Wisconsin Card Sort Task) that requires cognitive set shifts (Davis & Nolen-Hoeksema, 2000). The study found that ruminators committed significantly more perseverative errors and failed to maintain cognitive sets more than non ruminators. The authors suggested that their results support a theory that people who are cognitively inflexible may tend to ruminate when feeling sad because alternative coping strategies are difficult for them to generate. Thus, when a coping strategy associated with depression and that induces negative emotion is used in place of a more effective strategy, negative emotion persists. Chronic worriers similarly show evidence of cognitive inflexibility that may partially explain perseverations of negative thoughts. For example, chronic worriers persist on insoluble tasks longer than non-worriers though their persistence is not productive (Thompson, Webber, & Montgomery, 2002). When worriers failed, they also continued to make more subsequent failures compared to non-worriers. Higher scores on the PSWQ are also related to more negative affect in response to exam scores in university students regardless of actual scores (Meyer, et al., 1990). Worrying about a negative emotionally arousing film clip after watching it leads to more subsequent thought intrusions about the film clip over three days following the session compared to a condition in which participants are asked to "settle down" after watching (Wells & Papageorgiou, 1995). Chronic worriers react to challenging cognitive tasks with more anxiety and experience more than the usual cognitive interference following

task failures compared to non-worriers (Thompson, et al., 2002). This disruption causes more subsequent task failures and longer response latencies suggestive of more evidence for perseveration of a maladaptive cognitive set with negative self implications. In other words, worry is associated with being overly influenced by previous experiences in terms of subsequent task performance and emotional states. This may also explain why individuals with high scores on a measure of GAD symptoms report elevated levels of impaired mental control and fear of losing control over their thought processes and impulses (Riskind, et al, 2005). These examples are all consistent with cognitive and emotional concerns persisting combined with a sense of lack of control experienced by individuals suffering from chronic worry. These results support a hypothesis that some of the presented emotional material will evoke emotional processing that will be difficult for the worriers to inhibit. They also permit the idea that worriers may be actively engaged in trying to exert control over what they perceive to be a disinhibited process. Though behavioral data will be used to support these claims, response times and self-report questionnaires are not the only methods that have been used to index cognitive and emotional disinhibition. The following section will discuss a physiological measure, pupil diameter, which is expected to be well suited to measure the type of negative emotional processing expected to be evinced in chronic worriers assessed in the present study.

Chapter 6: History and Background of Pupillometry

Though task evoked pupil responses have been shown to be sensitive indicators of cognitive fluctuations and central nervous system processing allocation to a task (Granhold & Steinhauer, 2004), the fact that they are used less often than other psychophysiological indicators of these fluctuations may rest in the fact that the pupil is a less face valid measure of brain function (Beatty & Lucero-Wagoner, 2000). The authors also point out that more than a century ago pupil diameter fluctuations were linked to cognitive fluctuations in labs in Germany but these findings were not communicated to the American scientific community until the 1960s. The authors suggest that an only now diminishing reticence to use pupil diameter fluctuations in psychophysiological experiments again likely rested on the lack of face validity for the measure. An increasing number of studies are now being published using pupillometry as a psychophysiological measure and methods for quantifying pupil diameter responses to cognitive and emotional demands have greatly improved over the last 50 years. In the latter half of this century, electronic systems for recording pupil diameter, including video monitoring, were integrated with emerging computer technology to increase the accuracy of pupil monitoring over less temporally accurate still photo frames. Resolutions of better than 0.025 mm and changes in the order of hundredths of a millimeter in average pupillary responses can now be attained with proper signal averaging techniques (reviewed in Granholm & Steinhauer, 2004). Small-scale rapid changes in pupil diameter corresponding to central nervous system activity and reflective of cognitive fluctuations vary on the scale of half millimeters and so are only recently reliably detected (Beatty & Lucero-Wagoner, 2000). The methods are more convenient

and less expensive than other measures of cognition and emotion (e.g. fMRI, PET, etc.). Also, more labs are currently cross validating fMRI with concurrent pupil dilation so the neural relationships between brain and pupil activity during cognitive and emotional demands will be further elucidated in the near future.

Chapter 7: Pupil Sizes Are Well Suited to Measure Emotional Response and Subsequent Processing

Pupil size fluctuations have been used in a variety of cognitive experiments as an index of processing capacities and attentional resource allocation. Within working memory limits, pupil size shows incremental increases consistent with cognitive load increases (Granholm, Asarnow, Sarkin, & Dykes, 1996). However, when processing demands exceed available resources, the pupil can actually show constriction as a function of overtaxing cognitive load. Pupil dilation has been shown to index prefrontal working memory engagement and to follow BOLD fMRI increases in prefrontal and parietal activations associated with increases in task difficulty (Siegle, Steinhauer, Stenger, Konecky, & Carter, 2003). As an index of processing demands, the pupil has been extended to the study of emotional processing. With non-psychiatric individuals, dilation of the pupil has been related to the intensity of emotional material but was not found to be a useful discriminator of valence (positivity/negativity; Janisse, 1974). One recent study used pupil diameter as an addition to response time recordings in the assessment of emotional processing and perseveration in individuals suffering from unipolar depression (Siegle, Granholm, Ingram, & Matt, 2001). For non-personally relevant words, depressed individuals were faster to respond to negative compared to positive stimuli on a valence identification task. Non-depressed individuals, on the other hand, were faster to respond to positive compared to neutral words. A late peak in pupil dilation approximately four seconds post-response was larger for depressed compared to non-depressed participants across valence categories. Both groups showed larger responses to negative information compared to positive at one second following their

responses. At this time, non-depressed individuals also showed greater responses for personally relevant negative compared to non-relevant positive words relative to depressed subjects. Depressed individuals also had smaller peaks in pupil diameter time locked to the actual responses. At one second pre-response, depressed individuals showed larger pupil diameters likely reflecting stimulus identification or preparatory processes, according to the authors. The sustained dilation factor for personal positive words was correlated with the rumination scale from a widely used measure of how people deal with distressing or unwanted emotion (Response Styles Questionnaire; Nolen-Hoeksema, Morrow, & Frederickson, 1993). Depressed individuals also mistakenly judged non-negative stimuli as negative more often than non-depressed participants. In another study, depressed individuals again showed more sustained dilations in response to stimuli in emotional processing tasks (Siegle, Steinhauer, Carter, Ramel, & Thase, 2003). The depressed individuals showed sustained dilations especially to negative and personally relevant emotional information. Further, there were multiple moderate correlations between the sustained pupillary response and measures of rumination for personally relevant negative words in the depressed group. Overall, the results suggest that depressed individuals perseverate in their emotional responses to negative emotional stimuli similar to what is expected for chronic worriers in the present study. Another analysis showed that rumination scores on the RSQ were related to delays in naming positively valenced words even after controlling for depression severity in clinically depressed individuals (Siegle, Steinhauer, Carter, & Thase, 2000). Only one depressed participant in that study showed a relationship between sustained pupil dilation and the normative arousal rating for the emotional words presented. Further, the valence

and valence by diameter interaction accounted for more pupil size in basic memory trials following affective word presentations for depressed individuals compared to never depressed control participants. These findings suggest that sustained pupil dilations are related to emotional information processing but in ways that are not effectively assessed by traditional emotional reactivity measures. Sustained activation of the amygdala has also been shown to exhibit findings similar to those of sustained pupil dilation with emotion identification tasks similar to those utilized in the present study (Siegle, Steinhauer, Thase, Stenger, & Carter, 2002). Sustained amygdala activity was negatively correlated with dorsolateral prefrontal activation for negative words and positively related to rumination tendencies (Siegle, Steinhauer, Thase, Stenger, & Carter, 2002). Increases in regional cerebral blood flow (rCBF) using Positron Emission Tomography (PET) show decreases in activity in the amygdala (and other areas) as well as a negative relationship between left orbitofrontal activation and bi-lateral amygdala activity during worry episodes (Hoehn-Saric, Lee, McLeod, & Wong, 2005). The overlap in brain areas associated with rumination and worry thus strengthen the case for utilizing pupil diameter for the assessment of emotional processing in chronic worriers as has been done thoroughly with depressive ruminators. Further theoretical basis for this point is described below.

Worry should be well suited to the methods previously used to assess depressive rumination and emotional perseveration

Though depressive and anxious thoughts show a number of similarities, anxiety is associated with a number of factors consistent with difficulties stopping the anxious thoughts even beyond relationships with depressive symptoms (Papageorgiou & Wells,

1999). In that study, anxious thoughts also resulted in self reports of greater emotional intensity compared to depressive thoughts. This suggests that reactions to and following negative affective stimuli in the present study should be at least as strong in the chronic worrier group as compared to previous research with depressive ruminators. After controlling for highly co-morbid depressive symptoms, anxious symptoms are additionally associated with less dissmissability of, greater distraction by, and greater attention to anxious thoughts as well as more worry about worry ("meta-worry"; Papageorgiou, et al., 1999). All of these characteristics are consistent with lasting effects of negative cognitive processes associated with anxiety. One criticism of many cognitive assessments of vigilance to threat or emotional distraction in dual attention tasks is that the tasks give only a brief snapshot of attentional allocation to emotional information in psychiatric participant groups (Mogg & Bradley, 2005). One advantage of the study by Siegle, et al. (2005) is that the direct response to emotional stimuli was measured as well as a significant time window following the required response by participants in order to monitor reactivity and arousal attenuation once the emotional stimuli were no longer present. This method of assessing emotional responding seems ideal to target initial emotional responses as well as subsequent elaborative processes which are both theoretically linked to anxiety etiology and maintenance (Beck & Clark, 1997). Therefore, emotional information processing is assessed at extended periods post-stimulus in the present study and in subsequent basic cognitive task trials as a function of the emotionality of the preceding stimulus.

Chapter 8: Perseveration May Depend on Which Emotion is Assessed

Predictions in the present study for relationships between chronic worry and emotion may depend on contributions from depressive symptoms and anxiety symptoms in the worrier group as well as the valence (positivity/negativity) of the emotional processes impacted by worry symptoms. One study contrasted emotional valence, subjective feelings of emotion and both anxious and depressive symptoms in a Generalized Anxiety Disorder group and a non-clinical sample (Roemer, Salters, Raffa, & Orsillo, 2005). A measure of GAD severity (including distress and interference) was correlated with scores on the PSWQ and, for the most part, showed similar relationships with emotionality assessments. Both GAD severity and PSWQ scores correlated with fear and avoidance of emotional experience. Also, relationships to fear of emotion depended on the type of emotion assessed. GAD severity and PSWQ scores were more correlated with fear of depression, fear of anxiety, and experiential avoidance compared to fear of anger or fear of positive emotion. There were also overlapping but partially independent contributions from fears of emotion depending on whether they were anxiety or depression related. After controlling for fear of anxiety, GAD severity and PSWQ scores remained correlated with fear of depression. After controlling for fear of depression, there was a negative relationship between PSWQ scores and fear of positive emotions. Thus, chronic worriers do not fear emotion, in general, but instead show partially orthogonal relationships to fears for depression and anxiety. Consistent with a lack of general emotional fear, high scores on the PSWQ were linked to less fear of having positive emotional experiences. In summary, chronic worriers are not afraid of positive emotion but are afraid of depression and anxiety symptoms. It therefore becomes apparent that a

simple assessment of threat or negative emotional reactivity in chronic worriers is not enough to encapsulate a complex relationship between chronic worry and emotionality. The present study assessed positive, negative, threat-related and neutral stimuli in a valence identification task to understand how worriers respond behaviorally and physiologically to the emotional stimuli according to the type of emotion presented.

Broader categories of mood symptoms may explain overlaps in rumination and worry

Results suggesting perseverations of emotional processing may be related to overlaps in depressive rumination and worry, overlaps in co-morbidity between anxious and depressive symptoms and general categories, such as trait anxiety, that are related to worry as a more general super ordinate category. Those higher on measures of trait anxiety experience a greater frequency of worry compared to those low on trait anxiety (Eysenck, et al., 1992). Trait anxious individuals also worry significantly more often about a variety of topics including social evaluation, personal relationships and personal fulfillment. In fact, anxious individuals worried more about 8 out of 10 topics assessed in that study compared to low anxious individuals. Also, at 500 millisecond delays, neutral and threat related words successfully prime semantic activation in a lexical decision task for both high and low anxious individuals (Richards & French, 1992). At longer delays (750 ms), however, the only significant priming effect in that experiment was for threat words for high anxious individuals. The authors suggest that high anxious individuals "lock on" to threatening interpretations by automatic spreading semantic activation induced by the previous threat related information. This interpretation is not unlike a perseverative thinking explanation for carryover effects of emotional processing on subsequent arousal and cognitive states that were used to explain maintenance of anxiety

symptoms above. Thus, several contributing elements related to overlaps with trait anxiety, depressive rumination, negative affect, depressive symptoms and cognitive inflexibility may explain a perseverative emotional response in chronic worriers. High scores on the PSWQ may be especially related to other symptoms of emotional disturbance in individuals who do not carry a diagnosis of GAD (Meyers, et al., 1990). Therefore, an additional exploratory analysis was conducted in the present study to assess the degree to which individuals symptoms including rumination, depression, worry and trait anxiety independently related to pupillary response group differences for the individual tasks.

Images and verbal material with chronic worry

Research has shown that worry is associated with verbal linguistic activity in a greater proportion to imagery over relaxation inductions (Borkovec, et al., 1990). Also, anxious thoughts have more verbal content compared to depressive thoughts (Papageorgiou, et al, 1999). Based on the affinity between anxious worry thoughts and the verbal modality, it was hypothesized that words would have additional emotional effects compared to images in the present study.

Chapter 9: Rationale

Worry inductions cause increases in anxiety but no corresponding increase in heart rate (Borkovec, et al., 1990). Thus, though we expect that worriers may report negative affect in response to negatively valenced emotional stimuli, we do not necessarily expect that measures of emotional arousal will differentiate worriers from non-worriers during these tasks. Instead, as pupil responses have reliably indexed group differences between individuals with and without mood symptoms according to personal relevance and valence (Siegle, et al., 2001; Siegle, et al., 2003), we expected the difference in sustained pupil diameter between worriers and non-worriers to be most pronounced for personally relevant negative stimuli. Worriers may avoid negative emotion but, once they experience it, the negatively valenced cognitive state is expected to persist and interfere with subsequent processing. With a basic cognitive task (Stroop color naming), depressed individuals show less sustained activity compared to non-depressed individuals (Siegle, Steinhauer, & Thase, 2004). As a potential measure of general cognitive inflexibility, the present study also included the Stroop task for worriers and non-worriers. Additionally, it has been shown that when alternating between basic cognitive and emotional valence determination tasks, sustained pupil responses continuing from the emotion identification tasks into the subsequent cognitive tasks are related to the emotional valence of the preceding tasks especially in depressed individuals (Siegle, et al., 2000). As a replication of the design of that study, the present study alternates a valence identification task with basic Stroop trials in order to test the hypothesis that chronic worriers will exhibit a pupillary response to cognitive tasks, in anticipation of

them, or following them according to the positivity or negativity and the personal relevance of the preceding emotional identification task.

In the present study, we included words with emotional content from a list with normative averages based on emotional arousal ratings (Affective Norms for English Words; Bradley & Lang, 1999). The word list also included items that were generated by each research participant according to personally relevant negative, positive and neutral categories. We included a list of emotional pictures (International Affective Picture System; Lang, Bradley, & Cuthbert, 2005) varying by emotional valence and arousal ratings for similar comparisons between worriers and non-worriers. Though we expected group pupil diameter differences to be especially prominent for words, we also expected that pictures would arouse emotions of importance for chronic worriers. We expected sustained pupil size to differentiate worriers from non-worriers especially for personally relevant and negative stimuli. A smaller relative sustained pupil diameter following emotional stimuli would support and avoidance theory of worry (Borkovec, et al., 2004) while a larger sustained pupil size would highlight the overlap between worry and rumination as forms of perseverative thinking (Segerstrom, et al., 2004). We expected that, since worry is especially related to threat processing (e.g. MacLeod, et al., 1986; Mathews, et al., 1989) that a word list previously used to discriminate GAD from non-anxious participant performance (Mathews, et al., 1989) would be useful to assess vigilance and threat processing in contrast to positive, negative and neutral words from Bradley, et al., (1999).

Hypotheses

1) Sustained pupil size following emotional word presentations will be critical in differentiating worriers from non worriers.
    a) Support for an emotional avoidance theory of worry would be supported if worriers have smaller sustained pupil responses.
    b) Support for a perseverative thinking process similar to rumination would be supported if worriers have larger sustained responses.
2) Based on previous research showing a special connection between threat processing and chronic worry, it is hypothesized that worriers will have larger pupil responses to threat words and that these will be hard to turn off once they start (i.e. will perseverate into subsequent cognitive tasks).
3) Worriers will have different behavioral performance profiles (response times and accuracy) for emotional information relative to non-worriers.
    a) Facilitated performance will support an emotional vigilance model of chronic worry.
    b) Decrements in performance will support avoidance and/or difficulty understanding emotion endorsed by chronic worriers.
4) Exploratory analyses will test whether effects are especially strong for words relative to images in worriers and whether sustained pupil diameter is related to worry symptoms above and beyond trait anxiety, depression and rumination scales.

Chapter 10: Methods

Participants

Participants were drawn from introductory psychology courses for class credit. The initial screening phase of the study invited participants to fill out mood and anxiety questionnaires. These included the Penn State Worry Questionnaire (PSWQ), the Trait version of the State-Trait Anxiety Inventory (STAI-Trait) and the Beck Depression Inventory (BDI). Inclusion in the "worrier" group required a score of 56 or greater on the PSWQ and inclusion in the "non-worrier" group required a score of 55 or less.

At the actual experimental session, participants filled in the Response Styles Questionnaire (RSQ), Thought Control Questionnaire (TCQ) and filled out a word list of personally relevant words between 3 and 8 letters long with 10 being personally positive words, 10 personally negative and 10 personally relevant but neutral words. Participants then were asked to sit in a chair in front of the computer screen at a fixed distance of 29 cm from the participant's nasion to the screen. A headband with the sensor for the head tracker was placed on each participant and the computer keyboard was placed in his/her lap before starting the tasks presented on the computer.

Stimuli and Sequence

Participants were first shown instructions on the computer screen on performing the Stroop task. They were encouraged to respond to the color that the words were displayed in rather than to the words themselves. For example if the word "RED" was displayed in green, participants were requested to respond to the green coloring while ignoring the word "RED." Before the first color word presentation, a "mask" was presented for 2 seconds consisting of 4 black plus symbols centered horizontally and vertically on the

screen. Color words for the Stroop were presented for 6 seconds in the same location followed by a 300 millisecond inter-stimulus interval and then the mask for 2 seconds before another 300 ms ISI and another Stroop. Participants were asked to use the number pad 1, 2 and 3 buttons to make their responses with the index, middle and ring finger, respectively. Pairings of the red, blue and green colors to the 1 (index finger), 2 (middle finger) and 3 (ring finger) keys was counterbalanced across worrier and non-worrier groups such that each group had equal numbers of participants with each of the three fingers being used to indicate red, blue or green. Stroop tasks presented throughout the experiment included 66% incongruent (color of word did not match printed word) and 33% congruent (color and word matched) trials. Participants practiced a 12 trial block of the Stroop, with feedback on accuracy, until 80% accuracy was reached before being allowed to continue with the experiment (demonstrating understanding of the task and visual/color acuity). All participants were able to achieve this level of accuracy within 3 blocks of the 12 practice trials. After achieving the appropriate level of accuracy on the practice trials, participants completed 18 trials of the Stroop task without feedback.

Next, participants were given instructions to rate emotional words according to "positive," "negative," or "neutral" on the same computer keys (1, 2, and 3) with button assignments for emotional category counterbalanced as colors were for the Stroop task. The emotional words included 10 words of each category (positive, negative and neutral) from a word list based on normative response data (ANEW). It also included a fourth category of 10 "threat" words taken from a list that has been previously used to contrast anxious from non-anxious individuals (Mathews, et al., 1989). Accuracy for threat words was based on correctly identifying these words as "negative" on the response keys. Also

included were the 10 personally relevant words for each emotional category generated by each participant (total of 30 additional words). Emotional words were presented in random order. A practice block of all 70 trials were run, with feedback, and all participants reached 80% accuracy or higher by the end of the first practice session. The timing and duration for the emotion identification task was identical to the Stroop task in that the words were on the screen for 6 seconds and the same mask as used with the Stroops stayed on the screen for 2 seconds with 300 ms ISI's. Words were .5 cm high and approximately 1.25 cm wide (slight variations by word length). Words subtended approximately .98 degrees of visual angle.

After the practice session, an experimental block was run in which affective words were interspersed with Stroop trials. The full block of emotional words from the practice session was presented with each word followed by three Stroop trials and masks presented before and after each emotional word or Stroop. The exception was that the last color word in each three Stroop sequence was followed by a reminder screen indicating the finger assignments for color and emotion for 3 seconds. A new mask then came on the screen to start the next 4 part trial (emotional word judgment and three Stroops). All timing for Stroops and words were identical to the practice trials.

The session with words was followed by affective judgments of IAPS pictures interspersed with Stroop trials identical to the format for emotional words. IAPS pictures for the positive, negative and neutral categories were chosen to be strongly represented according to valence along those dimensions but also to have high arousal ratings. Ten pictures from each of the three emotional categories were presented in random order for a total of 30 pictures. As with the emotional word judgment task, pictures were presented

with three Stroop trials after each affective picture judgment. The masks, finger assignment reminders and all other timing for the picture segment was identical to the emotional word judgment task. IAPS words and masks were 5.75 cm high and 7 cm wide, subtending 11.22 degrees of visual angle. The mask for the picture judgment task was derived from applying Gaussian filters and "smearing" an existing photo from the IAPS picture set until the picture was unrecognizable but provided similar levels of contrast and luminance to the IAPS pictures used in the rest of the experiment. The mask was presented for 2 seconds before each IAPS picture was presented and then was replaced by the IAPS picture requiring a participant response. Following each IAPS picture presentation, the mask was again presented but with Stroop color words superimposed on the larger mask.

Luminance values across emotional categories for words along with Stroop trials were equated (within 1 SD and not significantly different by category; all *p*'s>.05). Luminance values were also equated between the emotional categories of IAPS pictures and the mask between picture trials. To facilitate equating the luminance values of IAPS pictures, some of the borders of the original pictures were trimmed to be more similar to the rest of the pictures and all pictures were converted to black and white from the original color photos. All stimuli throughout the experiment were presented on dark gray backgrounds to assist in luminance deflection measurement according to stimulus categories.

Apparatus

An ASL Eye Tracker, Model 504 running an E5000 control program and equipped with a magnetic head tracker to account for head position changes when tracking the eye

location and calibrating gaze locations (Applied Science Laboratories, Bedford, MA) was used throughout the experiment. Pupil size and gaze direction was sampled at 60 Hz. Calibration for gaze direction was calculated for each participant along with an eye tracker/magnetic head tracker position offset calibration. The room lighting was approximately 29.42 lux as determined by the average of three readings by a light meter held at the position of the participant and aimed in the direction of the computer screen. Signals from the pupillometer and magnetic head tracker were passed electronically to an acquisition computer. The acquisition computer also integrated into one data file event markers signaling the start and stop of individual trials from the stimulus display computer.

Chapter 11: Results

Analyses

Differences in pupil diameter waveform were assessed following Guthrie & Buchwald's (1991) strategy for significance testing of electrophysiological potentials. This method is ideal for testing group differences in that it is insensitive to the magnitude of difference at any one point that might confound an average across the entire waveform. It also yields a temporal quantification of waveform differences that has been already successful in differentiating depressed from non-depressed individuals according to sustained pupil responses (Siegle, et al., 2003).

Trials comprised of over 70% blink data were removed from analysis. Linear interpolations replaced blinks for trials that were kept. For each task and each participant, graphical examinations were conducted to ensure that interpolations were reasonably representative of the waveform surrounding the interpolated data. Pupil data were smoothed using a 5-point weighted average filter and linear trends over blocks of trials were removed to eliminate slow drift in pupil measurement. Otherwise, implementation of the significance testing strategy followed previous successes with depressed patients (Siegle, et al., 2004). Within and between group contrasts were assessed, point by point, along pupil diameter waveforms re-sampled at 10 Hz. Consecutive points in periods of waveform differences were used as replications to control for Type I error with $p<.05$. Seventeen points consecutively different at $p<.1$ correspond to a difference for the waveforms at $p<.05$ based on previous findings with Monte Carlo simulations (Siegle, et al., 2004). A sustained difference at least 0.28 seconds in length was considered significant based on these previous results and the 60

Hz pupil sampling rate. All pupil diameters were assessed as differences from diameter over one second preceding stimulus onset (pupil "response" to stimuli) and thus analyzed data included negative pupil diameter values (as seen in figures).

Differences in self-report symptom scales were analyzed using two-tailed independent samples t-tests with corrections for violations of variance homogeneity following Levene's test, where indicated. Effect sizes are reported for group comparisons (Cohen, 1998). For categorical comparisons, Fisher's exact test is reported for cases when expected cell counts counterindicated Pearson's Chi-square. In the interest to reduce Type I error, only pupil response components and behavioral data that significantly differentiated worriers from non-worriers were followed up and tested for correlation with self-report symptom scales.

Separate analyses were conducted for pupil diameters as well as for response times to valence identification and Stroop trials. The pupil and response time dependent measures were assessed for picture and for word stimuli as well as for personally relevant and non-personally relevant words as a function of the emotionality of the preceding stimulus.

Demographics. Mean ages between groups were within one year (non-worriers: M=18.2, SD=.422; worriers: M=19.06, SD=.998) and ranged from 18-19 years in non-worriers and 18-21 years in worriers. The group of 11 non-worriers included 10 white and one Hispanic individual; five were male. Four had one finger to emotion and color assignment, three had another assignment, and four had the third assignment. The worrier group of 17 individuals included 13 white, one Asian, one Hispanic, and one non-responder for ethnicity; four were male. Six individuals had the first finger assignment, five had the second assignment, and six had the third assignment. There was no

relationship between gender and group status (worrier/non-worrier, $p>.05$) by Fisher's exact test. There was no relationship between ethnicity (white vs. non-white) and group status (worrier/non-worrier, $p>.05$) by Fisher's exact test. There was also no relationship between finger assignment and group status by Pearson's Chi-square test ($\chi^2=0.015$, df=2, $p>.05$).

Self-report. Compared to non-worriers, worriers reported higher scores on the Penn State Worry Questionnaire (PSWQ; $t(26)=-6.547$, $p<.001$, $d=-2.56$; worrier: M=64.44, SD=12.88; non-worrier: M=32.55, SD=11.73), higher scores on the trait version of the State-Trait Anxiety Inventory (STAI-T; $t(26)=-2.566$, $p<.05$, $d=-0.99$; worrier: M=47.65, SD=7.43; non-worrier: M=39.45, SD=9.417), higher scores on the Beck Depression Inventory (BDI; $t(23.31)=-2.243$, $p<.05$, $d=-0.75$; worrier: M=14.06, SD=11.32; non-worrier: M=7.09, SD=4.83), and higher scores on the rumination index of the Response Styles Questionnaire (RSQ-RUM; $t(26)=-2.364$, $p<.05$, $d=-0.91$; worrier: M=47.24, SD=9.21; non-worrier: M=38.55, SD=9.94). The groups did not differ according to the distraction index on the Thought Control Questionnaire (TCQ-DIS; $t(26)=-0.94$, $p>.05$, $d=-0.10$), did not differ on the worry index from the Thought Control Questionnaire (TCQ-WRY; $t(26)=-1.96$, $p>.05$, $d=-0.25$), and did not differ on the distraction scale of the Response Styles Questionnaire (RSQ-DIS; $t(26)=1.19$, $p>.05$, $d=0.46$). Across groups, two-tailed bivariate Pearson Correlation coefficients revealed significant relationships between self-report scales. There were significant positive relationships between the PSWQ and STAI-T ($r=.434$, $p<.05$) as well as between the PSWQ and RSQ rumination scale ($r=.449$, $p<.05$). The STAI-T was additionally positively correlated with the TCQ worry scale ($r=.494$, $p<.01$), positively correlated with the BDI ($r=.604$,

$p<.005$), positively correlated with the RSQ-RUM scale ($r=.478$, $p<.05$), and negatively correlated with the RSQ distraction scale ($r=-.501$, $p<.01$). The BDI was additionally positively correlated with the TCQ worry scale ($r=.456$, $p<.05$) and with the RSQ rumination scale ($r=.566$, $p<.005$). The distraction scales from the RSQ and TCQ were positively correlated with each other ($r=.617$, $p<.001$). No other correlations were significant ($ps>.05$).

Tasks. The emotion identification tasks and Stroop tasks caused appropriate elevations in pupil diameter (see Figure 1A & 1B) but there were no overall periods of significant valence or Stroop congruency effects in pupil response collapsed across worrier and non-worrier groups (all $ps>.05$). Personal relevance was also not a significant discriminator of pupil response waveforms collapsed across groups in word valence identification tasks (all $ps>.05$; see Figure 2). Valences did not significantly differ from one another collapsed across groups for the Word task alone (see Figure 3B), for the Word task mixed with Stroop trials (see Figure 3C), or for the IAPS pictures interleaved with Stroop trials (see Figure 3D; all $ps>.05$). Congruent (matched word and color) Stroop trial pupil response did not significantly differ from incongruent trials (unmatched word and color) as seen in Figure 3A (all $ps>.05$).

Group Pupil. There were group differences in several tasks which were significant. The figures show areas where there were significant differences at $p<.05$ as indicated by gray bars below the two waveforms. The periods of significant difference between groups were followed up on for further analysis. There was a significant group difference for incongruent Stroop trials (color and name of color were unmatched) for an extended period at the tail end of the Stroop trial and fully through the next fixation

period (see Figure 4; 3.68 to 6.00s: $t(26)=3.79$, $p<0.005$, D=0.11 mm, $d=1.47$). There were no differences for the word valence identification task by itself (see Figure 5). During the fixation period about one half second before word valence identification in a task interspersed with Stroop trials (WordStroop), worriers had larger pupil responses (see Figure 6; 1.20 to 1.63s: $t(26)=-2.18$, $p=0.04$, D=-0.02 mm, $d=-0.84$). Similarly, when IAPS pictures were interspersed with Stroop trials, worriers also had a short period of greater anticipatory dilation compared to non-worriers in the fixation period immediately before the IAPS picture was presented (see Figure 7; 1.30 to 1.92s: $t(26)=-3.08$, $p<0.005$, D=-0.02 mm, $d=-1.19$).

When personal relevance was used to discriminate worriers from non-worriers, there was no difference for the word valence task (without Stroop) collapsed across emotional categories (all ps$>.05$; same waveform as Figure 5). For the WordStroop task, worriers had an early dip in pupil diameter when non-worriers were experiencing a sharp dilation for personally relevant words in the first second of being exposed to the word (see Figure 8), causing a significant difference between the groups (2.08 to 2.88s: $t(26)=2.35$, $p<0.05$, D=0.03, $d=0.91$). When non-worriers showed a steady rise in anticipation of the first Stroop task following personally relevant word valence identification, worriers maintained a relatively flat pupil size profile until the actual onset of the Stroop trial, yielding a significant group difference (8.95 to 10.08s: $t(26)=2.11$, $p<0.05$, D=0.08, $d=0.82$). At the end of that first Stroop trial, through the next fixation, and into the second post-valence identification Stroop trial, worriers had smaller diameters relative to non-worriers (12.12 to 15.50s: $t(26)=2.30$, $p<0.05$, D=0.08, $d=0.89$). The response to this Stroop trial and subsequent recovery in pupil size followed a similar profile for both

groups (see figure). However, the worriers did not reach the same level of dilation to the first Stroop trial after personally relevant valence identification and subsequently had diameters smaller than their own pre-valence identification levels (shown as negative values in Figure 8). By the end of the third Stroop trial post-valence identification, graphs show worriers "catching up" to their non-worrier cohort before the next task is initiated.

To replicate past research with depressive ruminators (Siegle, et al., 2003), we used a difference score between the personally relevant negative words and normed neutral words to test for a group effect. For the word valence identification task, alone, there were no significant group differences (see Figure 9). For the combined task (Wordstroop), immediately after presentation of the emotional word, worriers had a sharp drop-off in pupil diameter for negative personal words relative to normed neutral words yielding a marginally significant group difference (see Figure 10; 2.30 to 2.85s: $t(26)=2.07$, $p=0.05$, D=0.05 mm, $d=0.80$). The graph shows that worriers continued to show smaller pupil dilations for negative personal words relative to neutral normed words throughout the time period when the words were on the screen (negative values in figure). In the first half of the fixation period post-valence identification and into the first Stroop trial, worriers show a delay in the effect of negative personal words to increase pupil dilations yielding another group difference (9.02 to 11.72s: $t(26)=2.49$, $p<0.05$, D=0.13 mm, $d=0.96$). At the period of this group difference, worriers again show a relative decrease in pupil diameter for personally relevant negative words compared to neutral normed words (though not nearly as much as during exposure to the words) as indicated by negative values on the graph. Worriers also generally show less effect from

valence and relevance in the Stroop trials following valence identification as indicated by the graph.

Threat words were also analyzed separately as being especially relevant to previous behavioral experiments with chronic worriers (e.g. Mathews, et al., 1989). For the valence discrimination task alone, there were no differences between worriers and non-worriers (all *p*s>.05). When intermingled with Stroop trials, worriers had a direct response to the threat words that paralleled non-worriers. However, after the first Stroop trial, worriers maintained a significantly higher level of pupil dilation compared to non-worriers (see Figure 11; 12.22 to 12.65s: $t(26)=-2.20$, $p<0.05$, D=-0.08 mm, $d=-0.85$).

Since not many studies with worriers have examined positive emotion, an exploratory analysis was done for positively valenced words in the Wordstroop task but there were no group differences in pupil response (all *p*s>.05).

Pupil response individual variability. For pupil diameter segments that differentiated worriers from non-worriers, each individual participant score within the worrier group was assessed relative to the non-worrier group average. For the late Stroop component that differentiated worriers from non-worriers (see Figure 4), 16 out of 17 worriers had smaller pupil diameters compared to the non-worrier group average. For the WordStroop segment group difference (see Figure 6), 12 out of 17 worriers had larger pupil diameters compared to non-worriers. For the PicStroop segment (see Figure 7), 13 out of 17 worriers had larger pupil dilations compared to non-worriers. At the three intervals for which worriers had smaller pupil diameters during personally relevant WordStroop trials (see Figure 8), 11 of 17 worriers had smaller pupils for the first interval, 12 of 17 worriers had smaller pupils for the second interval, and 9 of 17 had smaller pupils for the

third interval. The number of individuals in the worrier group that followed the pattern of group comparisons was high indicating that the group differences listed above for pupil diameter were generally useful for describing worriers on an individual basis.

Blink data. Also, since blink data were used to determine whether or not individual trials were used for analysis, the number of trials dropped for excessive blinks was analyzed to test whether any of the tasks differed according to group status. None of the worrier vs. non-worrier differences in blink data for the tasks approached significance (all *p*s>.05).

Correlation pupil and self-report. For the components that differentiated worriers from non-worriers, two tailed correlations were run with a subset of self-report data most relevant to perseverative thinking, depression, and anxiety. These included the rumination scale from the Response-Styles Questionnaire, the distraction scales from the RSQ and the Thought Control Questionnaires, the PSWQ, trait anxiety (STAI-T), and depression (BDI). For the components in response to personal words during the WordStroop task, there was a significant correlation between the second component (See Table 1; PWS2) and both the distraction scale from the RSQ (r=-.481, p<.01) and the distraction scale from the TCQ (r=-.506, p<.01). None of the other correlations with this component or with the other components from the WordStroop task with personally relevant words were significant (see table; all *p*s>.05). As the difference between negative personal and normative neutral word pupil diameters increased for the first component (NEGWS1), trait anxiety decreased (r=-.415, p<.05) and distraction on the RSQ increased (r=.437, p<.05). Neither of the other negative/neutral differences for WordStroop were correlated with self report (see table; all *p*s>.05). For the incongruent

Stroop difference (ISTRP), the direction of response of the worriers was associated with elevations in the PSWQ (r=-.605, p<.01), the BDI (r=-.416, p<.05), trait anxiety (r=-.566, p<.01), RSQ rumination (r=-.393, p<.05), and decreases in RSQ distraction scores (r=.419, p<.05). Since a number of these symptom scales were correlated with each other, each was correlated separately with the Stroop component while partialing out the variance of the other factors. The remaining correlation with the PSWQ (r=-.469, p<.05) was the only relationship that held up statistically to this rigorous analysis and remained significant even after partialing out age, which was also correlated with the Stroop component (r=-.605, p<.005).

Response time/accuracy. For the word valence identification task by itself, worriers were faster (t(18.024)=2.704, p<.05, d=1.07; worrier: M=1127.31, SD=176.34; non-worrier: M=1398.03, SD=321.47) and more accurate than non-worriers (t(26)=-2.135, p<.05, d=-0.81; worrier: M=92%, SD=4.3%; non-worrier: M=87%, SD=6.7%). For the same task intermingled with Stroop trials, the worriers were faster (t(18.582)=2.127, p<.05, d=0.84; worrier: M=996.28, SD=159.06; non-worrier: M=1181.03, SD=276.00) and marginally more accurate (worrier: 95%; non-worrier: 91%, p=.064). Examining independently the threat stimuli, worriers were faster than non-worriers (t(18.565)=2.111, p<.05, d=0.83; worrier: M=925.65, SD=118.69; non-worrier: M=1062.67, SD=206.26) but not more accurate (worrier: 97%; non-worrier: 98%, p>.05). For personally relevant words in the WordStroop task, worriers were faster (t(17.528)=2.525, p<.05, d=0.81 worrier: M=1007.05, SD=185.64; non-worrier: M=1283.38, SD=354.69) and more accurate (t(26)=-2.084, p<.05, d=-0.79; worrier: M=95%, SD=7.3%; non-worrier: M=89%, SD=9.2%). For personally relevant negative words, the worriers were again

faster (t(17.806)=2.453, p<.05, d=0.97; worrier: M=1005.38, SD=232.95; non-worrier: M=1335.11, SD=433.37) and more accurate (t(14.559)=-2.500, p<.05, d=-1.00; worrier: M=97%, SD=6.2%; non-worrier: M=84%, SD=17.6%). Descriptively, worriers were faster for personal negative words compared to neutral words from the normed list while non-worriers showed the opposite pattern: they were slower for personal negative words compared to neutral words from the normative list.

Correlation behavioral data and self-report. Two-tailed correlations between symptom self-report and behavioral data showed that with increases in scores on the PSWQ, response times decreased (r=-.407, p<.05) and accuracy increased (r=.472, p<.05) for the word valence discrimination task. Accuracy was also positively correlated with the PSWQ for the word valence task mixed with Stroops (r=.467, p<.05), for personal words in that task (r=.510, p<.01), and for personally relevant negative words in that task (r=.412, p<.05).

The BDI was negatively correlated with accuracy for threat words on the WordStroop task (r=-.580, p<.005). The worry scale from the TCQ was positively correlated with response times for the word valence task, alone (r=.427, p<.05), the word task mixed with Stroops (r=.380, p<.05), personally relevant words from the word task mixed with Stroops (r=-.481, p<.05), and negatively related to accuracy for threat words on the WordStroop task (r=-.416, p<.05). The relationships with this worry scale are clearly different from those between the PSWQ and both response times and accuracy for valence identification tasks. No relationships were significant between response time or accuracy and rumination, distraction, or trait anxiety measures (all ps>.05).

Chapter 12: Discussion

The present study sought to better understand the complex emotional experiences of chronic worriers who, on the one hand, report difficulties understanding emotion (Turk, et al., 2005) and preferences to avoid particularly distressing emotion (Borkovec, et al., 1995) while, at the same time, showing evidence of vigilance for distressing emotional material (MacLeod, et al., 1986; Becker, et al., 2001) and a willingness to express negative emotion (Turk, et al., 2005). It was thought that exploring a variety of emotional stimuli and looking across the time course of emotional responding would help to support either an emotional avoidance theory of chronic worry or a hypervigilance model. The results from the present study show evidence for both vigilance to emotional tasks and avoidance of certain emotional materials. With threatening content, worriers show perseverations of processing indicating disinhibition. Worriers also show evidence of being especially efficient processors of emotional information across categories. A variety of symptom scales were related to pupil response waveforms that separated worriers from non-worriers including independent relationships between pupil diameter and worry symptoms assessed by the Penn State Worry Questionnaire. The complex relationship between chronic worry and emotionality depends on the complexity of the task (mixed with Stroop trials or not), the type of emotion associated with the stimuli presented, the personal relevance of the stimuli presented, and the time course of emotional processing (temporal dynamics).

The present study shows that worriers have anticipatory pupil dilation relative to non-worries just before an emotional word or picture is presented in a valence identification task when intermingled with several successive Stroop trials. In contrast to predictions,

there were no clear differences between responses to pictures and words in that the responses to IAPS pictures were also found with ANEW words. However, the word tasks highlighted a number of differences that were not found with pictures consistent with descriptions of worry as more verbal-linguistic relative to other mental states (Borkovec, et al., 1990). The results from both anticipating pictures and anticipating words are consistent with a "vigilance" model for describing anxious individuals with problematic worry symptoms (MacLeod, et al., 1986). The ambiguity of not knowing the emotional valence of the subsequent stimulus and perhaps switching from several preceding trials of Stroop stimuli likely contributed to this effect as previous research has not shown an anticipatory arousal response when the valence of the stimulus to be presented in known and no other cognitive tasks were presented (Nitschke, et al., 2002). Subsequent effects of the stimuli depended on the valence and relevance of information presented.

Sustained pupil responses were anticipated to be useful in the present study to differentiate worriers from non-worriers based on overlaps between ruminators and worriers in perseverative thinking. For the most part, measures of sustained pupil activity indicated that worriers had less trouble than non-worriers in shutting off pupil dilation responses once they occurred. Following personally relevant words, worriers did not show pupil dilation responses in anticipation of the first Stroop trial, unlike non-worriers. This blunted pupil response before the Stroop trial was significantly and negatively correlated with two separate self-report scales of distraction suggesting that a worrier-like lack of anticipatory Stroop dilation may be achieved via distraction or related tendencies. Across the three significant differences associated with presentations of personally

relevant words, worriers had smaller pupil responses relative to non-worriers. During the first second in which participants are exposed to the emotional word in the Wordstroop task, worriers had a sharp decrease in pupil diameter for the personal negative words compared to the neutral words. Both groups after several more seconds exhibited greater arousal for the negative personal words but worriers never showed this effect to the same degree as non-worriers as indicated by a second period of significant blunting of the personal/negative effect for worriers compared to non-worriers as the Stroop stimulus was presented. Worriers had blunted responses directly to personally relevant words (smaller pupil diameter compared to baseline) and this blunting continued into cognitive tasks following valence identification. This blunting happened only for personally relevant words. Though pupil constriction has been shown to correspond to processing demands that exceed capacity (Granholm, et al., 1996), this explanation is not likely the cause of the group differences in the present study based on the fact that worriers perform the tasks behaviorally exceptionally well and so were not likely to have been exceeding their processing capacities. Instead, these results are consistent with the idea that worriers are in some respects emotionally avoidant (Borkovec, et al., 2004) and with their admissions to using worrying as a means to avoid thinking of distressing emotional topics (Borkovec, et al., 1995). The results are also consistent with endorsements of high levels of thought suppression by individuals with elevations of GAD symptoms (Riskind, et al., 2005). Despite adequate performance on these tasks, tendencies to avoid thinking about emotional material may reflect ineffective long term regulation strategies (Gross, 2002). To the extent that personally relevant self-generated words used in the present study reflect avoided emotional topics, these results support an avoidance theory of chronic

worry (Borkovec, et al., 2004) and are consistent with reports by individuals suffering from GAD that they are afraid of certain emotions (Turk, et al., 2005).

An important exception to the trend for less sustained processing of emotional material in chronic worriers were the results for threatening emotional words to which worriers had perseverations of pupil dilation following their presentation. Just after the first Stroop trial was completed following threat word valence identification, non-worriers had pupil diameters below their baselines while worriers failed to show this dramatic reduction in pupil size. Graphically, the worriers maintained this persistent dilation until the last Stroop trial was finished (see Figure 11). It is thus clear that the after-effects of identifying the emotional content of threatening words differ for worriers and non-worriers. The same threat word list used in the present study was used to show the influence of threat exposure on implicit memory in chronic worriers (Mathews, et al., 1989) which is consistent with findings using the present protocol that threat stimuli influence subsequent processing for worriers. The extended influence of threat has been previously shown to be associated with individuals endorsing high levels of anxiety symptoms (Richards, et al., 1992). The special case of threat stimuli to show this response is consistent with a theory that "anxiety" happens when threats are resistant to coping as opposed to "fear" which has more to do with direct response mechanisms (Öhman, et al., 2000).

Though there was a prediction that threat words would also cause greater immediate responses for worriers, this did not prove to be the case. However, a vigilance connection to chronic worry was supported by anticipatory responses to emotional word valence identification trials. This effect may have been related to reports that worriers fear

experiences of negative emotion (Roemer, et al., 2005) thus causing a dilation of the pupil before a potentially negative stimulus. Speeded response times in worriers for many of the group comparisons support the hypothesis that worriers are especially ready to quickly deal with emotional material and are inclined to anticipate its occurrence. With most material, even negative personally relevant material, worriers were then able to successfully blunt their emotional responses relative to non-worriers. With threatening emotional words, however, the material may have overtaxed the avoidant tendencies of worriers to allow for the perpetuation of processing indicated by the residual pupil dilation. The biological imperative of the threat content may have been the necessary component that broke through the defenses of worriers. A number of other findings from the present study support the combination vigilance and avoidance evidence associated with chronic worry.

The relative differences between self-generated personally relevant negative words and those with neutral valence from a normative list may also be interpreted to support a theory of emotional avoidance in the worrier group. It is noteworthy that despite a proclivity of individuals suffering from GAD to respond to a wider variety of stimuli as if they were threat words even compared to another anxious group (Becker, et al., 2001), chronic worriers' reactions to threat words did not generalize even to personally relevant negative information. A simple model of emotional blunting and avoidance is counterindicated by anticipatory dilations for words and pictures with affective significance already mentioned. The simple model is further weakened by the results from the Wordstroop task when words of threat value were presented and which were specifically taken from a list of words known to affect chronic worriers (Mathews, et al.,

1989). The results suggest that emotional processing in chronic worriers depends on the type of emotional stimulus presented, the relevance of the stimuli, and the time course relative to the onset of the emotional information. Different symptom elevations within our chronic worry group were also important in further understanding group differences in pupil response.

It has been suggested that perseverative thinking is a common thread between depressive ruminators and chronic worriers (Segerstrom, et al., 2000). In support of this connection, chronic worriers had a slower return to baseline in pupil responses following valence discrimination tasks for at least one category of emotional stimulus similar to depressive ruminators exposed to personally relevant negative information (Siegle, et al., 2003; Siegle, et al., 2001). It is also the case that, within our sample, a measure of depressive rumination (RSQ-Rum) was highly correlated with the worry scale of primary interest (PSWQ) supporting a link between these tendencies. However, there are also clear differences between the present results and those with ruminators and some independence in relationships between pupil diameter and symptom scales. The specific measure that most clearly has shown perseverative dilation with ruminators (Siegle, et al., 2003; Siegle, et al., 2001) showed the opposite pattern with worriers in the present study: Instead of prolonged dilation as with ruminators, worriers had several clear periods of blunted pupil responses for personally relevant negative words compared to neutral normed words when contrasted with the control group. This significant group difference in pupil diameter was correlated with the PSWQ indicating that worry accounts for its own profile of pupil responses. A non-emotional cognitive task also showed noteworthy relationships between physiology and self-report symptom endorsements.

Worriers had smaller pupil responses for an extended period at the tail end of the first Stroop similar to depressive ruminators (Siegle, et al., 2004) and through the next fixation period. This difference was correlated with a variety of self-report scales including rumination but with the exception of the TCQ. This supports an overlap in depressive symptoms, trait anxiety symptoms, worry (PSWQ), distraction, and rumination as indicators of physiological recovery from task demands. With the exception of distraction, elevations on all of these scales indicated a greater decrease in pupil diameter following Stroop presentations and these scales were highly correlated with each other. However, only the correlation between this pupil waveform and PSWQ worry scores survived when controlling for all of the other factors. Thus, worry is a strong independent indicator of less pupil response following a cognitive task suggesting reduced processing. If not specifically indicative of emotional avoidance (it is unclear if participants felt an emotional reaction to incongruent Stroop stimuli), the results are not inconsistent with this theory and in the least are synchronous with tendencies to reduce task related elaboration associated with either cognitive load and/or emotionality.

The group difference profiles in pupil diameter don't necessarily reflect "failures" in processing for the worrier group relative to the non-worriers at least not in terms of response times or accuracy for the tasks used in the present study. In fact, worriers had faster response times and better accuracy than non-worriers for most tasks and did not have slower times or worse accuracy for any of the tasks compared. Worriers have more pupil dilation anticipating an upcoming valence identification task and they perform better than non-worriers. Also, worriers exhibit blunted responses to personally relevant words but again do better than non-worriers. The performance differences are small

given the ease of the task but still significant and never in the opposite direction. Scores on the PSWQ were positively correlated with accuracy and negatively correlated with response times for several tasks including the Wordstroop for personally relevant stimuli and for personally relevant negative stimuli, specifically. Though the PSWQ and BDI were positively correlated, their individual correlations with task performance were in opposite directions. Tendencies towards chronic worry symptoms and related perfectionism (Stöber, et al., 2001) may have helped to counteract decrements in performance associated with depressive symptoms that co-exist with worry elevations. Despite having co-morbid depressive symptoms, tendencies to worry have unique relationships with responding to emotional material. Based on their superior performance, worriers are clearly adept at differentiating emotional information according to valence despite reports that emotions are difficult for them to understand (Turk, et al., 2005).

The differences highlighted in the present study between worriers and non-worriers only partially support the idea that worriers have a difficult time turning off emotional processing when it starts, as hypothesized in the introduction to this study. The partial support lies in that the perseveration of pupil dilation following emotional processing only happened following words specifically related to threat. The sustained pupil dilation also did not happen directly following the threat word processing but, instead, emerged following a subsequent cognitively demanding task which also caused a pupillary response. Though the interpretation is similar and suggests that worriers suffer intrusions or bouts of cognitive rigidity in the seconds following exposure to threat words, the delayed effects on pupil diameter perpetuation should be stressed. Worriers also show a

lack of intrusions as exemplified by instances of blunting in pupil responses throughout Stroop and fixation trials following personally relevant words and in direct response to personally relevant negative words. By whatever strategic or automatic process, the worriers reduce processing of these personal words without decrements in performance. Consistent with an emotional avoidance theory (Borkovec, et al., 2004), worriers blunt direct physiological responses to personally relevant negative information and prevent personal emotional information from affecting their reactions to subsequent cognitive tasks. At the same time, speeded responses to threat stimuli and subsequent re-emergence of pupil dilation for subsequent tasks mirrors the facilitating effects of threat word presentations for subsequent response times to neutral probes on the dot-probe task for chronic worriers (Generalized Anxiety Disorder patients; MacLeod, et al., 1986). The simultaneous threat vigilance and emotional avoidance findings with chronic worriers are dually supported with the present results with qualifiers for temporal dynamics of the emotional response (i.e. anticipatory effects, reactivity, or prolonged activation) and according to the type of emotional information used (i.e. personal relevance and threat content). All group differences were found when alternating emotion valence identification tasks with several Stroop trials. The added capacity demands of switching tasks were apparently necessary to bring out the group differences and qualify both vigilance and avoidance interpretations.

One of the drawbacks to the present study is the lack of online emotion monitoring, by self-report, for comparison with pupil diameter. Pupil dilation reflects cognitive load in tasks that do not have explicit emotional content (e.g. Granhold, et al., 1996). Though many of the results presented here vary by emotional category, it would be useful to

know if subjective affective experiences might have corresponded to pupil diameter differences. In the case of the incongruent Stroop task which yielded a prolonged and sizeable correlation with worry self-report as well as with a host of other anxiety and depressive symptom endorsements, it would be especially interesting to know whether or not participants felt as if they were "upset" following the Stroop trials. Also, though there were group effects for personal relevance, it is unclear whether or not worriers listed personal negative words that were consistent with topics that they specifically might be worried about. It may be the case that since worriers think of especially severe negative outcomes to their worries relative to non-worriers (Provencher, et al., 2002) that the threat words might have actually been closer to the topics of their worries. Future research with additional stimuli implemented in a design similar to that used in the present study could help to answer these content specific questions. Additional physiological measurements would also be advantageous for future research to better understand mechanisms responsible for group differences in the present study.

With depressive ruminators, measuring BOLD dependent activations using fMRI has yielded results supplementary to the understanding gained from pupil diameters alone (Siegle, et al., 2002). Since the same participants were used in the sustained pupil response study, the authors were able to conclude that the dorsolateral prefrontal and amygdala activations accounted for additional variability in the valence related effect compared to pupil diameter (Siegle, et al., 2002). Left orbitofrontal cortex activity has been implicated in the reduction of amygdala activity during worry episodes (Hoehn-Saric, et al., 2005). Also, dorsolateral prefrontal activity has been shown to relate negatively to sustained amygdala activity in a task also shown to cause sustained pupil

dilation (Siegle, et al., 2002). Thus, the activation of frontal regions associated with cognitive influence on emotional arousal could have played a role in the anticipation, blunting, and sustained processing associated with chronic worriers in the present study. Future research might help to elucidate the neural mechanisms responsible for up and down-regulating pupil diameter differentially for the groups in the present study and to discover the degree to which these areas correspond to those implicated in the cognitive control of emotion or with areas shown to be active during worry induction (Hoehn-Saric, et al., 2005).

The present study highlights the importance of understanding the emotionality of chronic uncontrollable worry not only as a discrete response or as an anticipation of possible future negative events (Szabo, et al., 2002) but as a set of manifestations that must necessarily include personally relevant emotional reactions; the effect of emotional information on subsequent cognitive processing; anticipatory, reactive, and prolonged physiological responses; behavioral performance data; and a variety of reported mood and anxiety symptoms. With all of these factors included in the present study, a comprehensive assessment of chronic worriers both in terms of emotional avoidance and vigilance to threatening emotional material was made. According to the present results, worriers are efficient at processing emotional material of all types. At the same time, knowing that emotional information will be forthcoming and will need to be processed causes an anticipatory physiological reaction in worriers. For most types of emotional information, worriers then blunt any carryover effects from that emotional material. Threatening emotional information, however, has a special reaction for the chronic worriers who show a resurgence of their pupil dilation responses to that information as a

bleed over into subsequent cognitive processing. The general relevance of these findings suggests that emotion should not be measured only as a discrete event and that subtypes of negative emotional material can have different effects on anxious individuals.

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Appendix A: Tables and Figures

Table 1

Correlations between Self-Report Scales and Pupil Response Diameters

Correlations	PSWQ	BDI	STAI-T	RSQ-RUM	RSQ-DIST	TCQ-DIST	TCQ-WRY
PWS1	.025	.097	-.008	.131	.042	-.002	.078
PWS2	.023	.290	.231	.074	-.481**	-.506**	.078
PWS3	.265	.248	.124	.023	-.337	-.180	.241
NEGWS1	-.175	-.031	-.415*	-.126	.437*	.370	-.004
NEGWS2	-.354	-.170	-.294	-.230	-.138	-.192	-.033
ISTRP	-.605**	-.416*	-.566**	-.393*	.419*	.034	-.224

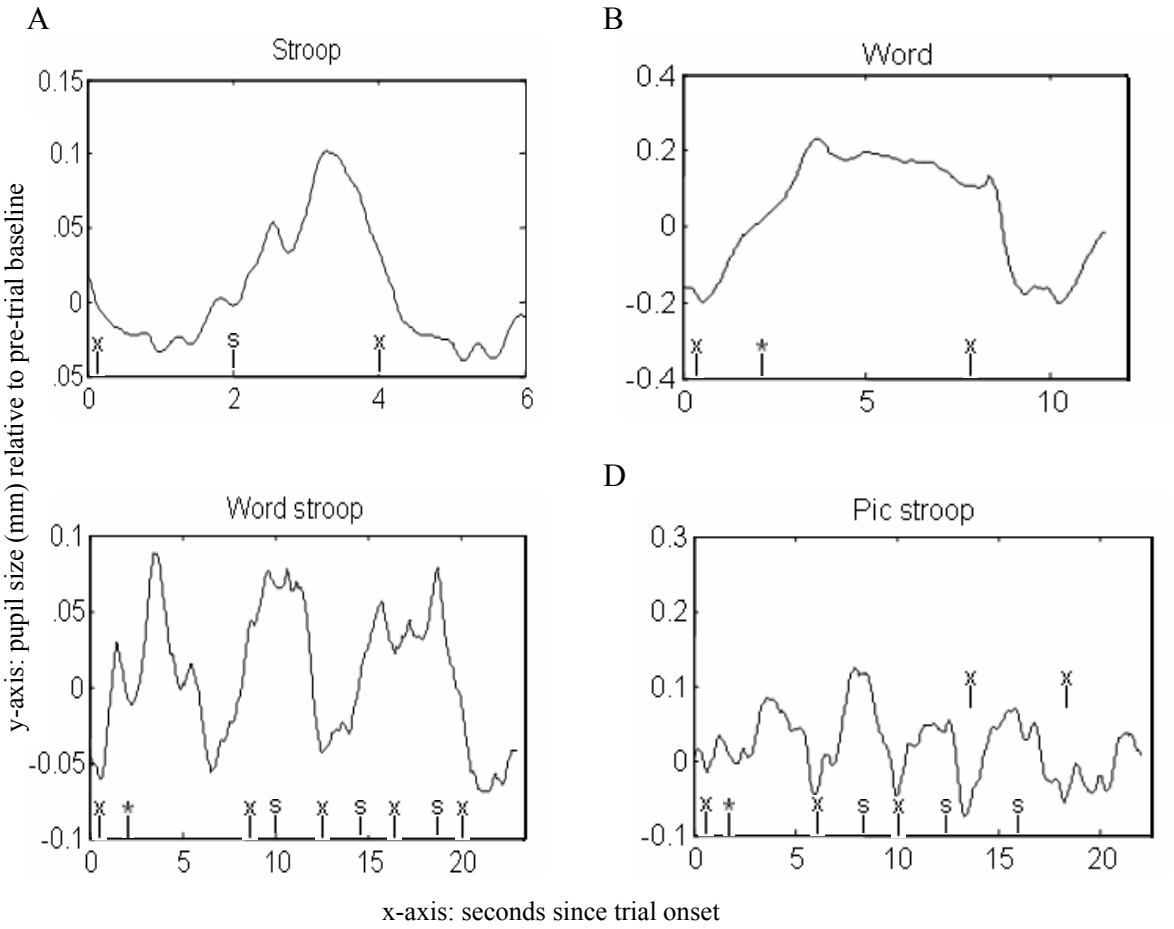
*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

PWS1 refers to the first significant group difference in the pupil waveform for the Wordstroop task with personally relevant words. PWS2 and 3 are the 2nd and 3rd significant differences. NEGWS1 and 2 are the first and second significant group differences in the pupil waveform for the Wordstroop task for negative words. ISTRP refers to the significant group difference for the Stroop task alone (incongruent stimuli). Abbreviations for symptom scales are reported in the Method section.

Figure 1

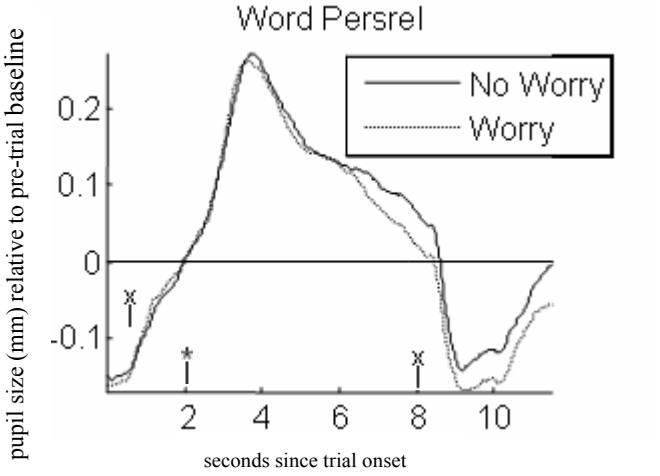
Task Pupil Responses Collapsed across Groups



Stroop is the task where only colorword identification trials were presented. Word is the task where only word valence identification was required. Word Stroop combined both word valence identification and Stroop trials. Pic Stroop combined both picture valence identification and Stroop trials. Pupil dilation as deviation from pre-trial baseline in millimeters listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. '*' refers to an emotional stimulus presented for valence identification. 's' marks the onset of a Stroop trial. 'x' indicates that a mask was presented.

Figure 2

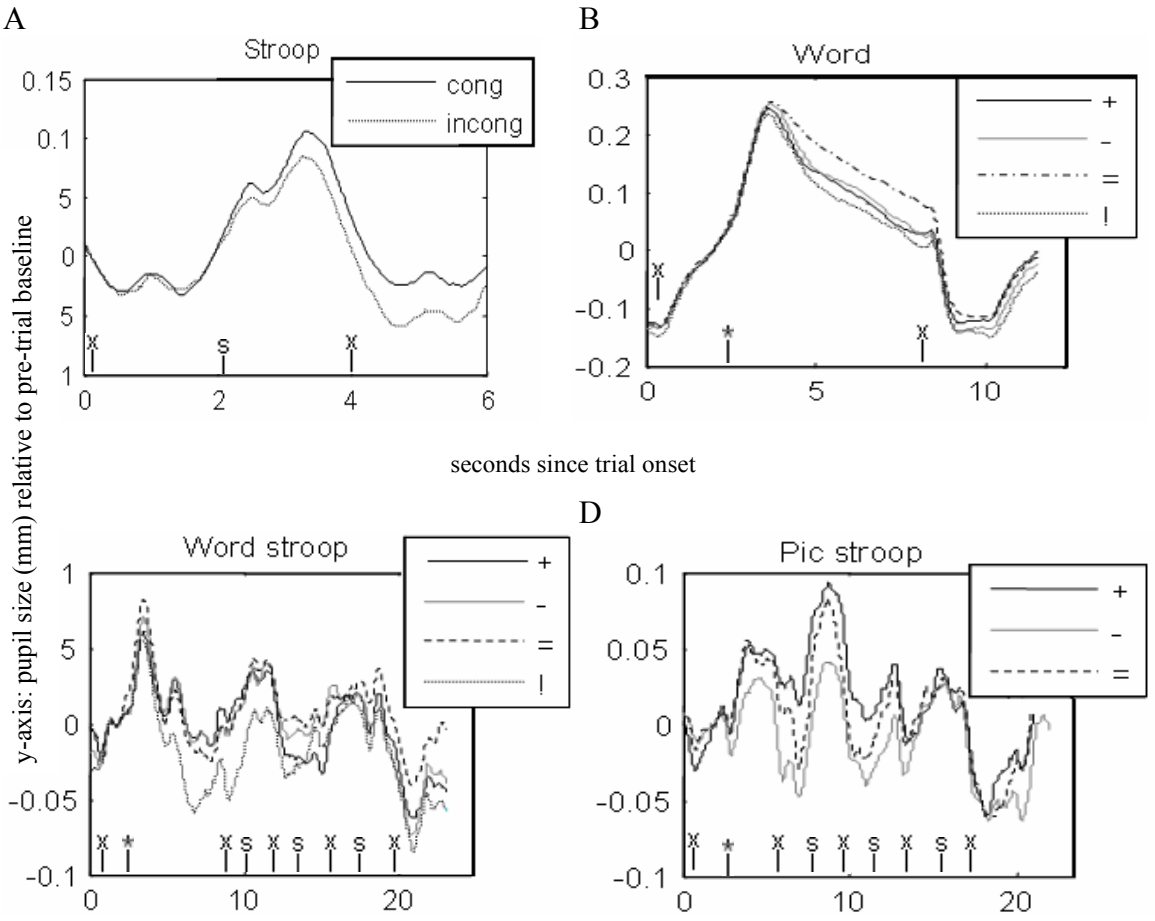
Task Pupil Responses Collapsed across Groups



Word is the task where only word valence identification was required. "Persrel" refers to personally relevant words (generated by participants). Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. "No Worry" refers to non-worrier group; "Worry" refers to worrier group. '*' refers to an emotional stimulus presented for valence identification. 'x' indicates that a mask was presented.

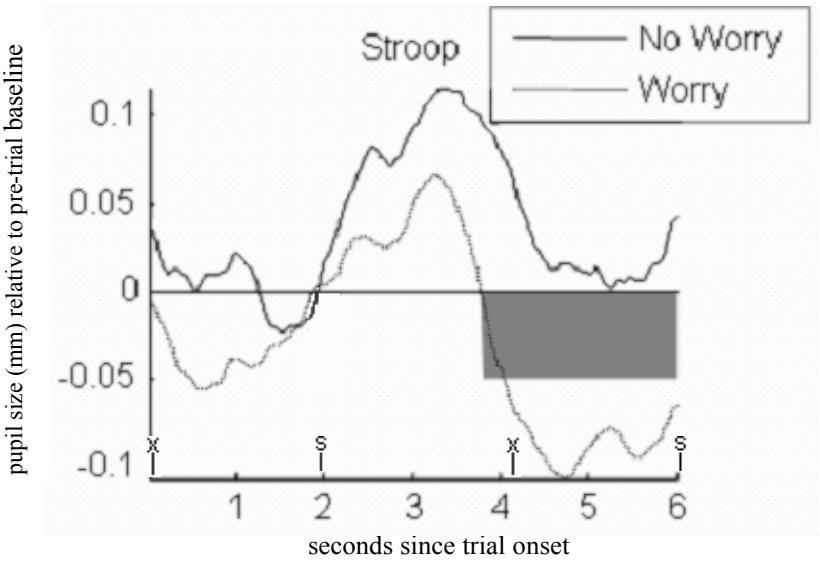
Figure 3

Task Pupil Responses Collapsed across Groups



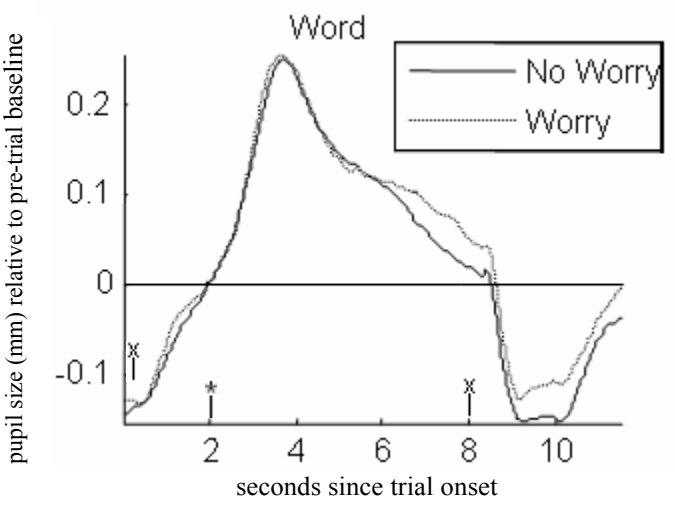
Stroop is the task where only colorword identification trials were used. "Cong" refers to congruent Stroop trials (color and word matched) and "incong" refers to incongruent Stroop trials (color and word were different). Word is the task where only word valence identification was required. Word Stroop combined both word valence identification and Stroop trials. Pic Stroop combined both picture valence identification and Stroop trials. '+' refers to positively valenced stimuli; '-' refers to negative valence; '=' for neutral stimuli; '!' for threat words. '*' refers to an emotional stimulus presented for valence identification. 's' marks the onset of a Stroop trial. 'x' indicates that a mask was presented. Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa.

Figure 4



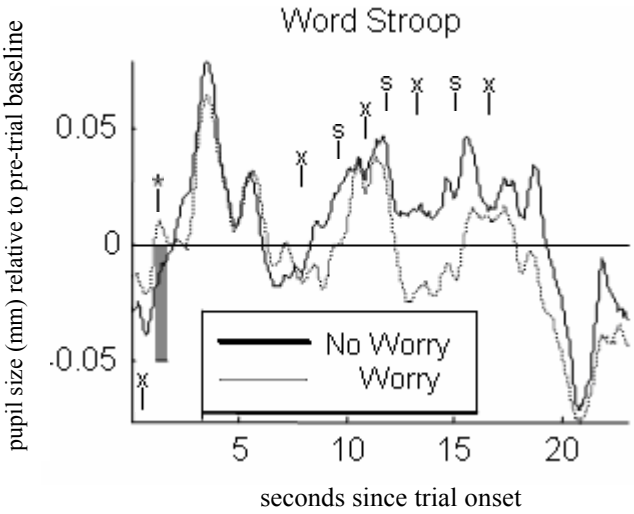
Stroop is the task where only colorword identification trials were used. Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. "No Worry" refers to non-worrier group; "Worry" refers to worrier group. Shaded grey areas represent significant group differences in pupil dilation at least 0.28 seconds in length. 's' marks the onset of a Stroop trial. 'x' indicates that a mask was presented.

Figure 5



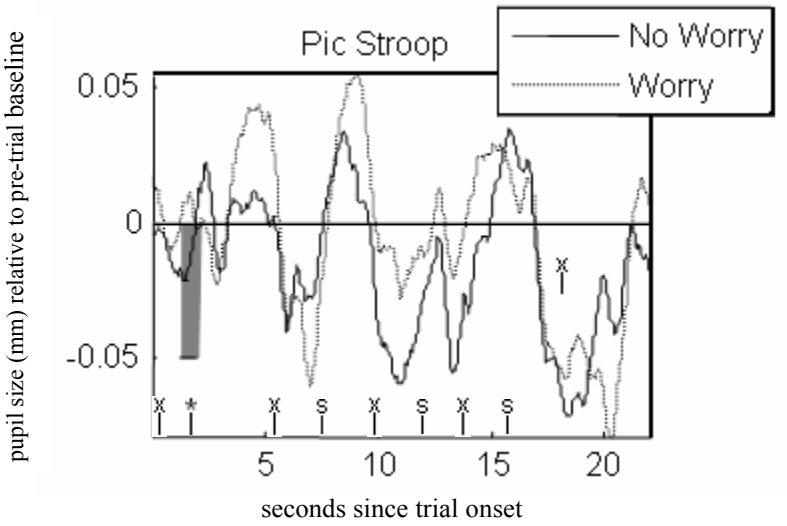
Word is the task where only word valence identification was required. Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. "No Worry" refers to non-worrier group; "Worry" refers to worrier group. '*' refers to an emotional stimulus presented for valence identification. 'x' indicates that a mask was presented.

Figure 6



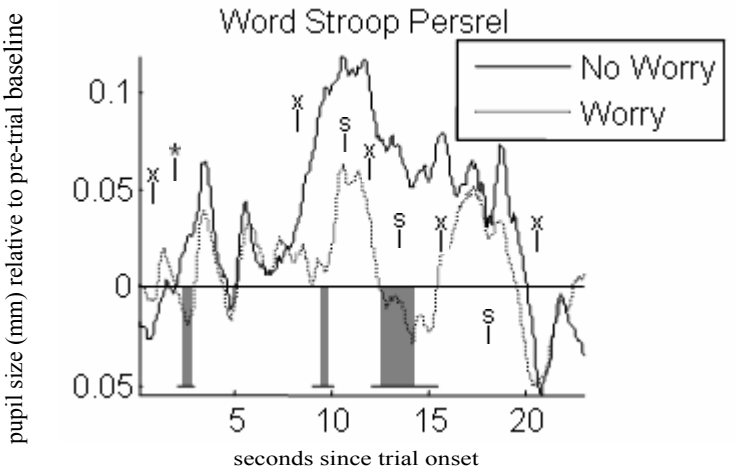
Word Stroop combined both word valence identification and Stroop trials. Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. "No Worry" refers to non-worrier group; "Worry" refers to worrier group. '*' refers to an emotional stimulus presented for valence identification. 's' marks the onset of a Stroop trial. 'x' indicates that a mask was presented. Shaded grey areas represent significant group differences in pupil dilation at least 0.28 seconds in length.

Figure 7



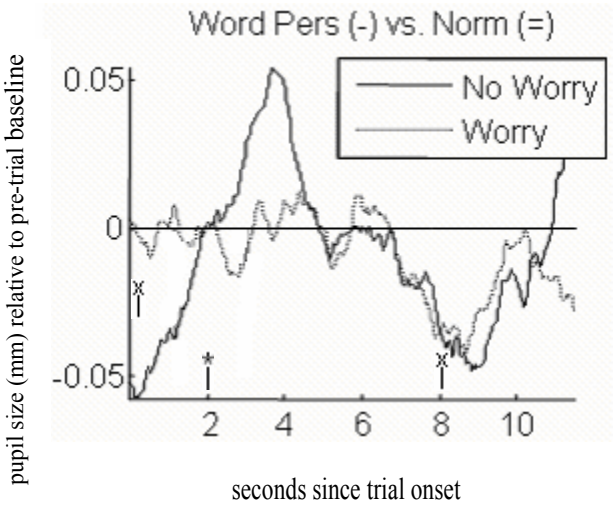
Pic Stroop combined both picture valence identification and Stroop trials. Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. "No Worry" refers to non-worrier group; "Worry" refers to worrier group. '*' refers to an emotional stimulus presented for valence identification. 's' marks the onset of a Stroop trial. 'x' indicates that a mask was presented. Shaded grey areas represent significant group differences in pupil dilation at least 0.28 seconds in length.

Figure 8



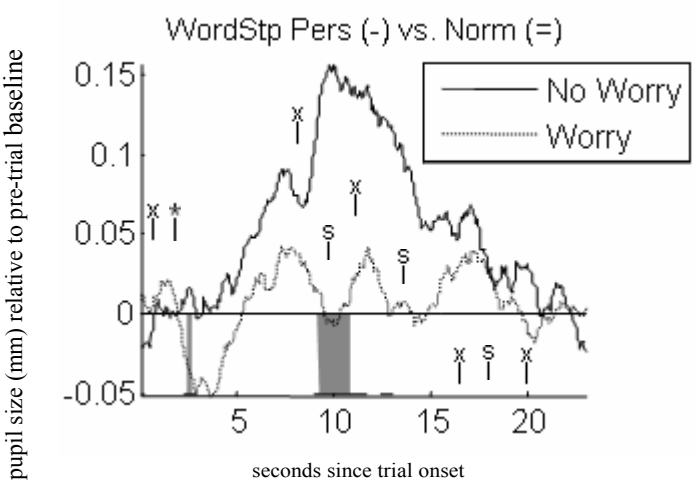
Word Stroop combined both word valence identification and Stroop trials. "Persrel" refers to personally relevant words (generated by participants). Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. "No Worry" refers to non-worrier group; "Worry" refers to worrier group. '*' refers to an emotional stimulus presented for valence identification. 's' marks the onset of a Stroop trial. 'x' indicates that a mask was presented. Shaded grey areas represent significant group differences in pupil dilation at least 0.28 seconds in length.

Figure 9



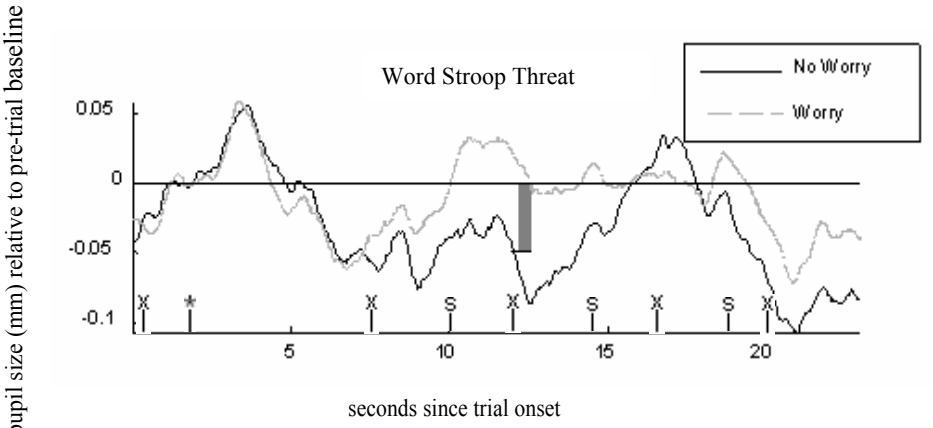
Word is the task where only word valence identification was required. Lines on graph represent a difference between personally relevant negative words ("Word Pers (-)") and neutral words from a normative list ("Norm(=)"). Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. "No Worry" refers to non-worrier group; "Worry" refers to worrier group. '*' refers to an emotional stimulus presented for valence identification. 'x' indicates that a mask was presented. Shaded grey areas represent significant group differences in pupil dilation at least 0.28 seconds in length.

Figure 10



Word Stroop combines word valence identification and Stroop trials. Lines on graph represent a difference between personally relevant negative words ("Word Pers (-)") and neutral words from a normative list ("Norm(=)"). Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. "No Worry" refers to non-worrier group; "Worry" refers to worrier group. '*' refers to an emotional stimulus presented for valence identification. 'x' indicates that a mask was presented. Shaded grey areas represent significant group differences in pupil dilation at least 0.28 seconds in length.

Figure 11



Word Stroop combines word valence identification and Stroop trials. Threat refers to words intended to convey threatening emotional content. Pupil dilations as deviation from pre-trial baseline in millimeters are listed along the ordinate of each graph. Seconds elapsed from the start of the trial for each graph are listed along the abscissa. "No Worry" refers to non-worrier group; "Worry" refers to worrier group. '*' refers to an emotional stimulus presented for valence identification. 'x' indicates that a mask was presented. Shaded grey areas represent significant group differences in pupil dilation at least 0.28 seconds in length.

Desmond J. Oathes
Curriculum Vitae

Education

1999 - 2006	Pennsylvania State University Ph.D. Clinical Psychology minor in Psychophysiology
2005-2006	V.A. Western New York Healthcare System, Clinical Internship
Aug, 2002	Pennsylvania State University, M.S. Psychology
June, 1999	California State University, Hayward B.A. magna cum laude, Psychology

Selected Awards and Distinctions

Tursky Student Poster Award, 43rd Annual Meeting of the Society for Psychophysiological Research (Chicago, October 2003)

Neuroscience Fellowship (National Institute of Neurological Disorders & Stroke, NIH, Summer 2003)

Outstanding Psychology Student Award 1999, Cal State Hayward

Selected Publications

Oathes, D.J. & Ray, W.J. (2006). Depressed mood, index finger force and motor cortex stimulation: A transcranial magnetic stimulation (TMS) study. *Biological Psychology*, 72(3), 271-277.

Ray, W.J. & **Oathes, D.J.** (2003). Brain imaging techniques. International Journal of Clinical and Experimental Hypnosis, 51(2), 97-104.

Oathes, D.J., Ray, W.J., Yamasaki, A.S., Borkovec, T.D., Newman, M.G., & Castonguay, L.G. (submitted). Worry, generalized anxiety disorder, and negative affect: Evidence from the EEG gamma band before and after psychotherapy.

Oathes, D.J. & Squillante, C.M. (submitted). Worry states and induced preferential responding to threatening emotional words.

Oathes, D.J. & Bruce, J.M. (submitted). Worry influences motor activation induced by transcranial magnetic stimulation.

Ray, W.J. & **Oathes, D.J.** (in preparation) Dissociative tendencies facilitate speeded emotional processing of graphical and semantic stimuli.

Quirin, M., **Oathes, D.J.**, & Kuhl, J. (in preparation) Self-access and parasympathetic reactivity: Only if you feel your emotions can you regulate them.