**Part 2: Experimental Work**

2.1 Unconscious Threat Extinction Using CSF

**Introduction**

The most common intervention for anxiety disorders is treatment with exposure to a feared situation or object (Deacon & Abramowitz, 2004). The goal of exposure is to facilitate threat extinction – that is, to reduce the conditioned threat response to the triggering stimuli (Abramowitz, 2013). Although effective psychological and pharmacological treatments exist for anxiety disorders (Alonso et al., 2004), most people with such disorders never seek treatment (Wittchen et al., 2011). A possible explanation for the low rate of treatment-seeking is that patients consider confronting feared objects or situations as overly demanding. Accordingly, novel interventions that will help patients minimize their encounter with aversive stimuli are needed (Pearson, 2012). A possible advancement toward this goal may be found in the field of consciousness studies.

Studies show that a stimulus or image can be processed by the visual system and affect the person seeing it, even if the person is not aware of the stimulus. This has been observed, for example, in reading and processing different words (Abrams, Klinger, & Greenwald, 2002; Armstrong & Dienes, 2013; Lamy, Mudrik, & Deouell, 2008), performing arithmetic operations (Ric & Muller, 2012), doing memory-related tasks (Liu et al., 2016), and distinguishing inconsistencies in visual scenes (Mudrik, Breska, Lamy, & Deouell, 2011) or written sentences (Sklar et al., 2012).

The above-mentioned studies are based on a technique called Continuous Flash Suppression (CFS), which was developed on the basis of the Binocular Rivalry technique (Tsuchiya & Koch, 2005). It has the potential to be a reliable measure of early autonomic biases. In this method, different stimuli are presented to each of the two eyes. One eye is presented with a static stimulus, while the other eye is presented with a dynamic and powerful visual stimulus that causes the static stimulus to be invisible for up to several seconds. The observer is only able to process the dynamic stimulus, despite the static representation of the target stimulus, since the CFS is so strong.

Studies using this paradigm have found that high-contrast stimuli break into the consciousness faster (Tsuchiya & Koch, 2005), as do familiar stimuli (Jiang, Costello, & He, 2007), and stimuli with threatening emotional content (Yang, Zald, & Blake, 2007). Other studies have found that stimuli that are seen during the CFS procedure may affect the observer's behavior and various physiological metrics. For example, one study recorded amygdala activity in response to images of fearful-looking faces that were presented using CFS. Research has shown that fearful faces break into the observer’s consciousness more rapidly than neutral or happy faces. These studies demonstrate the potential of learning fear through CFS. Two studies demonstrated an increase in skin conductance as reported through Skin Conductance Response (SCR) to conditioned stimuli of fearful faces (Raio, Carmel, Carasco, & Phelps, 2012) and unconditioned fearful faces presented using CFS (Lapate, Bokers, Li, & Davidson, 2013). It has been found that even an update of an acquired conditional stimulus can be made unconsciously via the CFS technique (Homan et al., 2021).

If a threat can be acquired and experimentally evoked outside of a person’s consciousness, it is plausible that a conditioned threat could also be extinguished under similar conditions. However, previous literature does not provide clear and compelling evidence for threat extinction provoked by invisible stimuli. Several behavioral studies tested whether subliminal exposure to images of spiders affects one’s willingness to approach them among people who are afraid of spiders (Siegel & Weinberger, 2009; Weinberger et al., 2011). To examine long-term effects of this form of exposure, participants in these studies completed a behavioral avoidance test (BAT) one week after exposure to masked images of spiders. They were then presented again with images of spiders, either masked or unmasked. Participants in the masked condition were more willing to approach a spider than those who were consciously exposed to pictures of spiders. These findings were replicated with two-week and one-year follow-up measurements (Siegel & Warren, 2013; Siegel & Weinberger, 2009; Weinberger et al., 2011). Importantly however, in these studies no online measures of awareness were taken using either subjective or objective measures (see Reingold & Merikle, 1988). Instead, the premise that participants were not aware of the stimuli was based on a preliminary masking experiment with a different sample (Siegel & Weinberger, 2009; Weinberger et al., 2011), in which participants were unable to identify the masked images. In another study, participants completed an identification questionnaire evaluating awareness only at the end of the experiment, so no online tracking of participants’ awareness of the stimuli was performed (Siegel et al., 2018). In addition, these studies focused on behavioral effects, which have yet to be corroborated by physiological responses.

Only two studies measured participants’ skin conductance in response to exposure. Siegel et al. (2018) concluded that masked exposure is not associated with increased physiological responses in the threat-extinction process. Although participants in the masked condition did have greater success in the BAT, no evidence for reduced physiological responses was obtained. Another study (Oyarzún et al., 2019) showed the potential benefit of unconscious exposure using CFS. Fear reduction was manifested by a measure of threat-potentiated startle responses, but not by SCR. Furthermore, that study lacked a control group for which no threat extinction took place.

Given these gaps in the research, our goal was to investigate the effectiveness of unconscious exposure to aversive stimuli, when awareness is properly controlled using the CFS paradigm. To assess the threat response, we relied on SCR, a commonly used autonomic measure of threat conditioning (Boucsein, 2012). Studies have demonstrated that this measure contributes to the understanding of anxiety disorders when used in fear conditioning experiments (Esteves et al., 1994).

The present research aimed at evaluating the feasibility and robustness of threat extinction evoked by unconsciously perceived stimuli. This was done by: (a) testing for threat extinction while carefully assessing conscious experience of the suppressed stimuli; and (b) testing for the robustness and generalizability of unconscious threat extinction with CFS, in which a stimulus is presented to the non-dominant eye but rendered invisible by presenting colored dynamic patterns to the dominant eye. The experiment included measurements of changes in SCR, while viewing a pre-installed computer presentation on a monitor.

The study started with an acquisition phase, in which participants were presented with the Conditioned Stimuli (CS+ and CS-): a fearful male or female face. While the CS were presented, participants received mild electric shocks at a level which they determined to be “aversive” and “uncomfortable but not painful”. Subsequently, participants underwent a threat-extinction phase, during which they were presented with the same stimuli again, without receiving the electric shocks.

Next, participants were divided into three groups: (1) Unaware (2) Aware and (3) No Extinction. The Unaware group was presented with the CS+/CS- stimuli under CFS; the Aware group was presented with the CS+/CS- stimuli without CFS; and the No Extinction control group was presented with scrambled versions of the CS+/CS- stimuli under CFS. In the Unaware and the No Extinction groups, participants’ awareness of the suppressed stimuli was carefully assessed using both objective and subjective measures. Finally, in the testing phase, all participants were presented with the CS+/CS- stimuli, to assess the effects of conscious and unconscious extinction relative to the No Extinction group.

**Discussion**

The aim of the current study was to investigate whether threat extinction can be accomplished without conscious awareness. Despite our expectations, we found that threat extinction did not occur when using the CFS method to suppress stimuli from entering individuals’ awareness. As expected, all experimental groups showed a comparable threat response in the acquisition process, with higher SCR to the CS+ relative to the CS- stimuli. In the later phase of threat extinction, the Aware group showed decreased SCR, while the Unaware group showed only a marginally significant decrease in SCR. Furthermore, regarding the RI measure, although there was a decrease in SCR in the Unaware group, it did not reach the level of significance. Thus, in the CFS paradigm, with stringent trial-by-trial measures of awareness, no effect was found for unconscious exposure.

Several studies have demonstrated that acquiring fears can also take place outside of consciousness (Homan et al, 2021; Raio et al, 2012). Weinberger and Siegel’s series of studies demonstrated, using the Visual Masking (VM) technique, that unconscious threat extinction can be performed among subjects with symptoms of spider phobia. Oyarzún et al. (2019) demonstrated unconscious extinction via the CFS technique, assessed by the startle response index. Therefore, there is a basis to assume that threat acquisition and extinction can be created under laboratory conditions using the CFS technique. Nevertheless, no evidence for unconscious threat extinction using CFS was found.

This finding is consistent with previous research demonstrating limited unconscious processing with CFS as compared to other methods (Almeida et al., 2010; Faivre et al., 2012, 2014; Izatt et al., 2014). For instance, Almeida et al. (2010) found that backward-masked primes elicited category-specific and identity-specific priming with stimuli representing both tools and animals, whereas CFS-suppressed primes only elicited limited category-specific priming with tool stimuli.

Other studies examined perceptions of processing and facial recognition. It was found that CFS impairs high-level face recognition, implying that unconscious face recognition in CFS could be due to a mechanism involving lower-level facial features (Barbot & Kouider 2012; Izatt et al., 2014).

The studies presented here are supported by literature on brain imaging studies, which demonstrate that nerve activity in response to stimuli that are suppressed by CFS are limited to the primary vision areas (Hesselmann & Malach, 2011; Sterzer, Stein, Ludwig, Rothkirch, & Hesselmann, 2014; Yuval-Greenberg & Heeger, 2013). These studies provide evidence that processing with CFS is limited (Moors, Hesselmann, Wagemans, & van Ee, 2017).

At first, the results of Experiment 1 appear to be inconsistent with the findings of Siegel et al. (2011, 2013, 2018), which suggest that threat extinction does occur in the absence of awareness when using VM. However, the lack of evidence for the effect can be explained by the limited processing ability inherent in the CFS technique. Additionally, there are various properties underlying this technique that may affect the extent to which stimuli will penetrate awareness. Studies that examined the mechanisms underlying the CFS technique found that this paradigm is highly sensitive to the spatiotemporal properties of stimuli. Improper stimulus control may weaken suppression, increase the impact of response biases and demand characteristics, and even influence the conclusions that can be drawn from the procedure (Blake et al., 2014; Hedger et al., 2016; Hesselmann & Moors, 2015). According to literature on the spatial aspect of both the stimuli and the mask pattern, low-level properties such as contrast can affect whether a stimulus is perceived by the participant (Gray et al., 2013; Yang et al., 2007).

Other studies show that not only spatial characteristics affect how the stimulus is processed, but also the frequency and rate of masked stimuli. Several studies have examined the extent of the effect of flash frequency on stimulus visibility (Zhan, 2019; Zhu, 2016). A study that compared multiple frequencies found that while many CFS studies use a frequency of 10 HZ for the masked stimuli, the highest suppression effect actually occurs at a frequency of 6 HZ (Zhu, 2016). This finding is supported by another study, which found that suppression capabilities are better at frequencies of 4, 6, and 8 HZ than they are at 10 HZ (Zhan, 2019). The existing research thus suggest that this issue should be taken into account in other studies using CFS in order to get the most out of this technique (Zhan, 2019).

It is possible that in the present experiment different characteristics, in terms of the contrast and frequency of the masked stimulus, could have yielded different results.

As stated, this experiment yielded no evidence of unconscious threat extinction. Decreases in SCR were found only among participants in the Aware group. This might cast doubt on the very existence of unconscious threat extinction, when proper measures are taken to assure that the stimuli are indeed invisible. Alternatively, this might suggest that CFS does not allow for sufficient processing to induce unconscious threat extinction. To arbitrate between these two explanations, Experiment 2 was conducted using a larger sample and the VM paradigm, for which previous studies did find an effect (Siegel et al., 2011; Siegel & Warren, 2013; Siegel et al., 2018; Siegel & Weinberger, 2009, 2012; Weinberger et al., 2011).

**2.2 Unconscious Threat Extinction Using VM and the Role of Anxiety**

**Introduction**

Considering the results of our CSF experiment, together with those of Oyarzún et al., (2019), we might conclude that there is a lack of evidence for unconscious threat extinction using CFS. However, previous studies have relied on two kinds of manipulations in order to prevent conscious processing, CFS and VM (Faivre, 2012); therefore, it is still possible that unconscious threat extinction is possible under VM paradigm. This chapter describes our tests regarding this research question.

It is important to consider whether some people may respond better to unconscious exposure. From the literature, it emerges that some subjects show effects of unconscious exposure while others do not. This could be a matter of some personal attribute that makes some subjects more prone to internalize unconscious information and be affected by it. We will delve into this question later on in this chapter.

### *Unconscious Threat Extinction Using VM*

Visual Masking is an experimental paradigm commonly used in cognitive research to investigate preconscious processes (e.g., priming), neural correlates of consciousness, spatiotemporal limits of visual discrimination, perception-related endophenotypes linked to psychopathology, and more (Bachmann & Francis, 2013). In this method, the target stimulus is presented, and after a very short time covered with a mask stimulus, the purpose of which is to prevent the subject from recognizing the target stimulus. Currently, it is commonly thought that masked stimulation inhibits the processing of the target stimulus because it is likely to shorten the duration of the target stimulus’s effectiveness (Kim & Blake, 2005). Another theory claims that the masked stimulus interferes with feedback signals related to the target stimulus, and therefore interferes with its conscious perception (Enns & Di Lollo, 2000).

This technique presents quite a few benefits in comparison to CFS, including increased therapeutic potential, processing ability, and procedural simplicity.

There is evidence that affective reactions to target stimuli can occur despite a lack of conscious awareness. In addition to measurable behavioral changes (Winkielman & Berridge 2004); facial muscle reactions to masked expressions have also been reported (Dimberg et al., 2000). VM techniques can be used to affect behavioral processes as well as unconscious, affective processing in general (Dimberg et al., 2000; Öhman 2002; Öhman & Soares, 1994; Whalen et al., 1998; Wong & Root, 2003). It can be argued that the latter overlaps with the functional domain of psychotherapy to some extent (Hassin et al., 2005).

Öhman and Soares (1994) used the technique of backward masking in their study and found that both phobic and non-phobic subjects were unable to identify the target images of frightening stimuli that were presented for a short time and followed immediately by the masked stimuli. Although the subjects did not identify the target images, in the same experiment it was found that subjects with phobias showed a high SCR, regardless of whether masking had been performed or not. High cutaneous conductivity response is known to be associated with anxiety (e.g., Lader, 1967), therefore, this finding indicates that phobic subjects experienced fear even when they did not consciously detect the stimulus of the thing they feared. This finding formed the basis for further studies using the technique of backward masking in combination with exposure as part of behavioral therapy for subjects with specific phobic disorders (Siegel & Weinberger, 2009 add more years). However, these studies did not use online measures of awareness. In the present experiment, unconscious exposure was performed using the VM technique, with awareness properly controlled.

There is some evidence suggesting that VM and CFS may involve different underlying mechanisms and may evoke different types of unconscious processing (Breitmeyer, 2004; Fogelson et al., 2014; Kim & Blake, 2006). Several studies indicate that the suppressed stimuli are processed differently in CFS and VM, even at the neural level (Dehaene et al., 2001; Fang & He, 2006). Some of the differences may be explained by the different areas activated in the brain, and the intensity of the activation that takes place in these brain areas, depending on the masking technique. Almeida (2013) examined how a masked image of a face, whether smiling, angry, or neutral, would affect a classification task. When the images were presented using a CFS technique, displaying an angry stimulus affected the classification task. When the images were presented using the VM technique, both the masked angry stimulus and the smiling stimulus affected the classification task (Almeida, 2013). The explanation given is that VM is a less selective processing method, and its lack of selectivity allows for a more general and powerful effect. Moreover, although the duration of stimulus presentation via VM is significantly shorter relative to the CFS technique, more information is likely conveyed given the more lenient suppression under the VM technique. Moreover, conducting an experiment with the VM technique, which is simple to operate, may lead to the development of a tool that can be applied in the clinical field. Since few studies have compared CFS to VM using the same task and stimuli (28-31), doing so might also shed light on their underlying mechanisms. The applicability of this methodology, which does not require equipment beyond a computer screen or a cellular phone, means that it can be easily used in exposure therapy.

### *The Role of Anxiety*

Humans have the ability to quickly detect threatening stimuli. Studies have shown that snakes and spiders are quickly identified not only by adults but also by children, toddlers and even monkeys (Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2003; Shibasaki & Kawai, 2009). The ability to quickly identify threats is not limited to snakes and spiders – humans quickly detect other threats on a perceptual and visual level. Visual threat stimuli such as frightening faces, negative words, animal attacks, and neutral stimuli for which conditioning has been performed through use of electric shock, may physically and mentally affect the observer. There is evidence that these stimuli evoke a wide range of defensive psychological responses, including an effect on access to conscious awareness.

The degree to which emotional content of stimuli modulates sensory perception and attention, varies with level of anxiety. Anxious individuals are more likely to notice probes replacing threating faces (Bradley, Mogg, Falla, & Hamilton, 1998; Capitão & Yang, 2014).

Thus, it seems that the ability to quickly detect a threatening and potentially dangerous stimulus, an ostensibly adaptive ability at the evolutionary level, is, in reality, closely related to abnormality. In fact, attentional bias is considered one of the hallmarks of anxiety, along with other factors such as a tendency to interpret vague messages as threatening and difficulty in diverting attention from threatening stimuli (Eysenck, Mogg, May, Richards, & Mathews, 1991; Fox, Russo, Bowles, & Dutton, 2001). Some researchers even consider attentional bias as a contributing factor to the development and perpetuation of anxiety disorders (Bishop, 2007; Matthews & Macleod, 2005).

As opposed to low-anxiety individuals, highly anxious individuals display an increased attentional bias toward subliminal negative words, which is consistent with their responses to consciously perceived stimuli (Mogg, Bradley, & Williams, 1995). This is a crucial topic, with significant consequences for both cognitive and clinical anxiety studies. If such biases are proven to occur unconsciously, it may support the theory that anxiety-related selective biases occur at an early stage of processing.

Despite this, there is still controversy in the literature regarding the degree to which the prioritized processing of threats present in anxiety disorders occurs in an automatic and unconscious manner. In this study, which will form the basis for a therapeutic tool, it is essential to understand and investigate how anxiety affects the ability to subliminally detect and eradicate stimuli.

To address this issue in the current study, high and low trait anxious subjects participated in fear acquisition and unconscious threat extinction tasks. Participants first underwent fear acquisition in which a neutral stimulus – an image of a man or a woman – was associated with an electrical shock. In the second phase, they were presented with the same stimulus again, but without the electrical shock. Finally, all participants underwent a testing phase to assess the effects of conscious and unconscious threat extinction, relative to the control group who did not undergo a process of threat extinction. The second experiment assessed whether threat extinction can occur unconsciously using VM, and whether symptoms of anxiety affect unconscious fear acquisition and threat extinction processes.

## Discussion

Using the VM method to suppress stimuli from the observers’ awareness, we demonstrated that threat extinction can occur even when the CS are presented unconsciously. As expected, all experimental groups showed a comparable threat response in the acquisition process, with higher SCR to the CS+ relative to the CS- stimulus. In the late threat-extinction phase, only the Aware and Unaware groups showed significant decreased SCR, while in the No Extinction group, the responses did not differ between early and late threat extinction.

This result was strengthened by the RI measure, demonstrating that the recovery of threat responses occurred only among participants who did not undergo threat extinction; no recovery was evident among participants in the Aware or Unaware groups. This constitutes a clear demonstration of unconscious threat extinction obtained in the VM paradigm with stringent trial-by-trial measures of awareness. Of particular interest to the current experiment is whether an individual’s level of anxiety influenced susceptibility to unconscious threat extinction. Consistent with reports by other researchers (Bradley, Mogg, Falla, & Hamilton, 1998; Capitão & Yang, 2014), we found that according to the RI measure, anxious participants in the Unaware group showed a decrease in SCR compare to the non-anxious participants. In contrast, in the Aware group, the non-anxious participants showed decreased SCR compared to the anxious participants. The results will be discussed below.

Findings from the VM technique suggest that both conscious and unconscious exposure are effective in reducing the conditioned response via non-reinforced presentations. These findings could pave the way for establishing a new therapeutic protocol, which relies on unconscious exposure. Such a protocol has never been clinically implemented; however, some studies suggest that threat extinction through unconscious exposure may be effective, which is in line with our findings. There is a growing body of research on a novel brain imaging approach called decoded fMRI neurofeedback (36-38). This technique is based on rewarding unconscious neural representations of feared stimuli in order to counter-condition the feared representation. This approach has demonstrated promise in decreasing fear responses to laboratory-conditioned fears (39). Both approaches show that threat extinction can occur unconsciously. It should be noted however, that the method employed in the present research is much easier to implement and does not require the complex infrastructure involved in the decoded fMRI neurofeedback procedure.

Our finding that threat extinction might be independent of awareness has interesting theoretical implications. One of the predominant theories of exposure therapy is the inhibitory learning model (40). This model suggests that the relationship between the CS and the aversive stimulus is not eradicated during threat-extinction processes. Rather, a new inhibitory connection is created, whereby the conditioned stimulus no longer predicts the aversive stimulus (thereby inhibiting the fear response). The inhibitory connection then “competes” with the previously learned fear.

It has been suggested that one of the core processes underlying inhibitory learning is expectancy violation. This is based on the premise that a gap between expectations and actual outcomes is critical for acquiring new inhibitory expectations, which would compete with existing expectations. However, given that learned threat extinction is based on the formation of non-coincidental relationships between conditioned and unconditioned stimuli, awareness of the stimuli and the non-occurrence of the unconditioned stimulus are deemed essential (41). The present findings, however, indicate that threat extinction can also occur outside of conscious awareness, which goes against this assumption. Future research may indicate whether unconscious exposure involves expectancy violation or other mechanisms (e.g., habituation). Another avenue for future studies would be to utilize a 3-day study design, in which the fear acquisition phase would be separated from the threat-extinction phase by at least 24 hours. That would complete the picture obtained here, since we used immediate exposure, so that consolidation of the previously acquired fear memory was not possible.

In the present experiment, we used VM techniques to render stimuli invisible. In the VM technique, the target stimulus is displayed for several dozen milliseconds, immediately preceded and followed by a masked stimulus (23). In the previous experiment described above (2.1), we used the CFS technique, in which each eye is presented with a different stimulus. One eye is presented with a series of flashing high-contrast images, while the other eye is presented with a stationary, often low-contrast stimulus (24). The CFS technique is based on the fact that the visual system is not able to handle incompatible inputs to both eyes. As a result, only one stimulus is able to reach awareness, while the other stimulus remains invisible, until it overcomes the suppression (11). In contrast, in the VM technique, the masked stimuli tamper with the feedback sweep that typically follows feedforward processing of the target stimulus (23). As such, the differences between the two techniques also influence the amount of information that is received and processed (42).

In the current experiment, VM outperformed CFS, highlighting the differences between the techniques (27, 43), and strengthening claims that CFS might not allow for higher-level processing (44). This is in line with previous studies indicating that unconscious processing under CFS is more limited than VM in presenting unconscious semantic effects (45, 46). Accordingly, some researchers have suggested that backward masking might be a more sensitive way of measuring unconscious high-level processing than interocular suppression (20). Our findings support that claim, though more research is needed to determine whether this is indeed the case.

Studies show that anxiety can affect how a stimulus with emotional content modulates sensory perception and attention. Anxious subjects exhibit increased sensitivity to threat-related cues, presumably as a result of increased unconscious vigilance. When doing research that could potentially serve as an infrastructure for developing therapeutic tools for anxiety sufferers, it is important to understand whether this population tends to respond more to unconscious threat extinction than does a population that does not suffer from anxiety. The results of this study show no evidence that anxiety affects the threat response recovery index in a broad and significant way. However, when we examined the various groups in the experiment, it appears that the level of anxiety had different effects on subjects who were exposed to stimuli openly, as compared to subjects who were exposed to subliminal stimuli. These findings are consistent with behavioral studies that have found that the capture of observers’ attention using threat-related facial stimuli is most successful during unconscious rather than conscious processing (Fox, 2002; Mogg & Bradley, 1999). The current study may be underpowered; yet it still has important implications for our understanding of anxiety because it highlights the automatic and possibly preconscious existence of the early cognitive processes that underpin anxiety responses. Such processes may be central to the behavioral symptoms of anxiety, making them an important target for cognitive and psychiatric treatments.

In conclusion, the present study demonstrated unconscious exposure using VM. Its findings may facilitate the development of novel treatments integrating unconscious exposure with various psychopathologies, populations, and therapeutic doses, which will be discussed in the next chapter.