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# An Effect of Fear on Auditory and Olfactory Perception.

Erika Hansen Siegel
*College of William and Mary*

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Erika Hansen Siegel

Redondo Beach, California

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Erika Hansen Siegel

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Committee Chair
Assistant Professor, Jeanine K. Stefanucci, Department of Psychology
College of William and Mary

Associate Professor, Peter M. Vishton, Department of Psychology
College of William and Mary

Assistant Professor, Catherine A. Forestell, Department of Psychology
College of William and Mary

# ABSTRACT PAGE

Previous research has shown that fear and arousal can influence visual perception. However, scant research to date has investigated whether fear can affect other perceptions. The current research investigated the relationship between fear and the perception of smells (Experiments 1 and 2) and tones (Experiment 3). Participants in all three experiments were randomly assigned to either a fear or neutral/control condition. Participants in the fear condition wrote about a frightening experience in their past. Participants in the neutral/control group wrote about what they do to get ready in the morning. In Experiment 1, participants then judged the intensity and pleasantness of five different odors (strawberry, bubble gum, tuna, pyridine, and mineral oil which was chosen as a no odor control) that varied in pleasantness and intensity (a weak and a strong version of each odor) on a scale from 0 to 100. Participants in the fear group judged the mineral oil as significantly more intense and more pleasant than participants in the neutral/control group, suggesting that perhaps fear affects the perception of neutral or weak odors. In Experiment 2, we directly tested this hypothesis. Participants wrote about a frightening or neutral experience and rated the intensity and pleasantness of 5 weak and neutral odors (mineral oil, green tea, cola, strawberry, and tuna) on a scale from 0 to 100. Fearful participants in this experiment rated the odors as less intense than participants who were not afraid, suggesting that fear may affect olfactory sensitivity. In Experiment 3, the auditory study, participants wrote about a frightening or neutral experience and then rated the loudness and duration of 10 tones (which ranged in frequency from 1000-5000 Hz) at two durations (320 milliseconds and 640 milliseconds) and rated each tone on a scale from 0 to 100. Participants in the fear group estimated that the tones were significantly louder than participants in the neutral/control group. However, there were no significant differences in their estimates of duration. Because there were significant differences in loudness but not in duration, this indicates that these data were not the result of a response bias (a general increase in responses overall). These data are interesting because they suggest that fear changes what we see hear and, to a lesser extent, what we smell. Taken as a whole, these studies show that emotion may qualitatively change the way we perceive and interact with the world.

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An Effect of Fear on Auditory and Olfactory Perception

**Introduction**

*"Whilst part of what we perceive comes through our senses from the object before us, another part (and it may be the larger part) always comes out of our own mind."*

— *William James* (1892, p. 329)

In this quotation, James voices an interesting notion. He suggests that what we perceive in the world may consist of more than just the input from our senses. What we perceive in the world, at least in part, may be determined by our current mental state. This thesis will examine the role of one mental state, emotion, on auditory and olfactory perception. Psychological research has found that the emotional state of the observer, especially a fearful state, plays a role in visual perception. Scant research to date, however, has examined whether the perceptual changes related to fear extend into other perceptual modalities like audition and olfaction. This thesis is the first to investigate the role of fear on basic, low-level auditory and olfactory perception and will support the hypothesis that what we perceive in the world is different when we are afraid.

There are four relevant areas which contribute to this hypothesis and will be reviewed herein. The first concerns the nature of emotion and how it might affect perception. The next section will examine previously reported effects of fear on visual perception, as well as possible neural correlates for that relationship. The third literature involves olfaction and will focus on the relationship between emotion and olfaction as well as neural substrates which may underlie that relationship. The final section will review the relationship between emotion and audition as well as possible neural correlates of that relationship.

**Emotion and Sensory Perception**

Experiencing emotion is commonplace and is considered universal in humankind (Ekman & Friesen, 1971). The empirical study of emotion, on the other hand, can be perplexing and difficult. The difficulty in studying emotion stems from the diffuse and amorphous nature of emotion and emotional experience (for reviews see Barrett, 2006; LeDoux, 1995; and Ortony, Clore & Collins, 1988). While a full and complete review of emotion is beyond the scope of this work, it seems appropriate to discuss the nature and utility of emotional reactions, particularly as they relate to changes in sensory perception.

Most researchers use the term *affect* to refer to the group of psychological and physiological components which combine to form emotions, feelings, and moods. Affect, in general, is composed of simple feelings of pleasure or displeasure, called *valence*, with some degree of activation or physiological *arousal* (Russell & Barrett, 1999; Russell, 1980) (see Figure 1). Within Russell's framework, called the circumplex model of affect, differing levels of arousal and valence produce different emotions. Taken as whole, the different combinations of arousal and valence comprise the full range of human emotions. Fear, the emotion of interest in this work, is a highly arousing and negatively valenced emotion.

Affect can be experienced as free floating (a sad mood) or can be attributed to some cause (anger at a person) (Russell, 2003). It is free floating, core affective experience that is most often associated with changes in cognition and perception (Russell, 2003; Stefanucci & Storbeck, 2009; Storbeck & Clore, 2008). In this work, I use the term fear with regard to our manipulation because we asked participants to write about a frightening experience in their past. However, I do not propose that fear, per se, changes perception. Rather, as the literature would suggest (Lindquist & Barrett, 2008), I suspect that it is unpleasant, arousing core affect that influences perception.

## Emotional Influences on Visual Processes

### *Behavioral Research*

Arousal and unpleasant affect have been shown to affect visual attention and perception (Becker, 2009; Phelps, Ling & Carrasco, 2005; Stefanucci & Storbeck, 2009). Emotional arousal, in particular, may alter perception in audition and olfaction because arousal cues, which usually accompany a fear response, are generally nonspecific and can be easily transferred from one arousing source to another (Stefanucci & Storbeck, 2009). In addition, the emotional activation associated with highly arousing emotions, such as fear and excitement, has been found to affect attention and perception (Phelps, Ling & Carrasco, 2005; Storbeck & Clore, 2006). Negative valence, without arousal, has also been associated with changes in attention and perception. People in sad moods are less likely to process visual information globally and tend to focus on specific, localized visual information (Gasper & Clore, 2002). Further, people in sad moods who are standing at the bottom of a hill tend perceive the hill as steeper than people in happy moods (Riener, Stefanucci, Proffitt, & Clore, 2008). When combined, negative and arousing core affect can lead to pervasive changes in attention and perception. These changes have been studied extensively in visual perception and a review of that literature follows.

Of particular interest for this work is the effect of a current emotional state, particularly fear, on incoming perceptual information; in other words the way that the emotional state of the perceiver influences perception. In general, a substantial body of behavioral research has begun to amass which indicates emotion, particularly low level affective states like fear, can alter visual perception. Additionally, neurological data suggests that two brain structures, the amygdala and the orbitofrontal cortex, are involved in the processing of basic emotions and aspects of visual perception.

Behavioral research indicates that emotion, particularly fear, affects visual perception. Fear changes lower level visual processes like visual search as well as higher order visual processes like spatial layout. Specifically, fear improves visual search for non-threatening objects (Becker, 2009) and enhances contrast sensitivity (Phelps, Ling, & Carrasco, 2005). Fear makes slants look steeper (Stefanucci, Proffitt, Clore, & Parekh, 2008) and heights look higher (Stefanucci & Proffitt, 2009; Stefanucci & Storbeck, 2009; Teachman, Stefanucci, Clerkin, Cody, & Proffitt, 2008).

Becker (2009), for example, shows that the presentation of a frightened face can increase visual search efficiency, even when the object of the search is neutral. People searched arrays of images for the presence of neutral (non-affective) target images. Each array was preceded by the presentation of a frightened, happy, or neutral face. Participants who saw the frightened faces took less time to locate the task-relevant objects. As predicted, the benefit was specific to threat-relevant emotional expressions; it did not occur with the happy or neutral faces.

Phelps, Ling, and Carrasco (2005) found a similar relationship between fear and contrast sensitivity. They showed participants fearful or neutral faces and then assessed contrast thresholds on a subsequent discrimination task. They found that observers were more sensitive to contrast when the faces had a fearful expression than when they had a neutral expression. In other words, the mere presence of a fearful face heightened contrast sensitivity. In a subsequent study, the authors manipulated covert attention and found that the effect of fear on contrast sensitivity was magnified with transient, covert attention.

Stefanucci, Proffitt, Clore, and Parekh (2008) demonstrated a relationship between fear and higher order visual perception, the perception of spatial layout. They had people stand on a skateboard at the top of a hill and imagine rolling down the hill on the board. Compared with a control group who stood on a box of the same height as the skateboard, the participants on the skateboard overestimated the steepness of the hill. Previous work hypothesized that individuals would be more likely to overestimate steep hills when viewing them from the top because it is more difficult and dangerous to descend a steep hill than to ascend one (Proffitt, Bhalla, Gossweiler, & Midgett, 1995). Stefanucci et al. (2008) show that directly manipulating the danger associated with descending a hill also results in an overestimation of geographical slant from the top, even when the slant is not very steep (in their case, 7 degrees).

In general, research has shown that individuals also overestimate vertical distances at a greater rate from the top than from the bottom (Jackson & Cormack, 2007; Stefanucci & Proffitt, 2009). In addition, fear of heights is correlated with this overestimation, such that those with a greater fear of heights estimate the height as taller, especially from the top. This relationship persists when examining groups who may have extreme fears. Teachman, Stefanucci, Clerkin, Cody, and Proffitt (2008) tested for differences in height perception in individuals who had a preexisting high or low level of height fear as assessed by a standardized measure of trait-level fear. Those participants who were high in height fear overestimated height more than those who were low in height fear. Furthermore, these perceptual distortions in height fear were independent of explicit and implicit cognitive associations involved in height fear.

The presence of one component of fear, emotional arousal, also leads to an increase in height overestimation when viewing a height from the top. Stefanucci and Storbeck (2009) induced emotional arousal in a group of participants by having them view highly arousing images. A second group viewed low arousal images. The participants who viewed arousing images estimated a height to be taller from the top than those who viewed neutral images. Interestingly, this overestimation occurred even though participants viewed images that were unrelated to heights, and were told that viewing the images was a memory task and unrelated to the perception task. Furthermore, when participants were given a strategy to increase their arousal while viewing the images, their overestimations of the height were increased further.

Finally, Riskind, Moore, and Bowley (1995) demonstrated that arachnophobics (people with a clinical phobia of spiders) misperceive the movement of spiders. People with a fear of spiders, compared to a low-fear group, perceived that a spider in a room moved more rapidly and selectively to them, rather than towards other individuals in the same room. In general, these studies show that people who are afraid, because they have viewed frightened faces, arousing images, have a fear of falling, or have a phobia see the world very differently than people who are unafraid.

*Neurobiological Substrates*

Emerging evidence suggests that the amygdala, a sub-cortical brain structure involved in processing fear, and the orbitofrontal cortex (OFC), a cortical area important for sensory integration and emotion processing support substantial projections to primary and higher-order sensory areas (Amaral, Price, Pitkanen, & Charmichael, 1992). The result of these connections may be that the affective value of objects is computed simultaneously during object perception (Barrett & Bar, 2009). Neuroimaging studies show that affective objects (i.e. emotional faces) increase activity in both the amygdala and ventral visual cortex (Pessoa, Kastner, & Ungerleider, 2003). In fact, Duncan and Barrett (2007) argue that the amygdala is critical for visual awareness and, as a result, visual perception is different for people in different affective states. In support of their thesis, Anderson and Phelps (2001) found that the presentation of aversive, or frightening, stimuli decreased attentional blink, a condition in which a lapse in visual attention during a rapid presentation of images causes a blink in visual attention, preventing the observer from processing the target stimuli. Interestingly, a patient with bilateral amygdala damage did not demonstrate the same decreases in attentional blink and showed no enhanced perception for the aversive stimuli. Their results reveal that the amygdala is an important neural substrate for affective influences on perception.

Another brain area, the orbitofrontal cortex (OFC) has been implicated as an important area for the integration of affect and perception (Barrett & Bar, 2009). While the OFC does not process fear as extensively as the amygdala, the OFC does play an important role in processing reward, threat, and hedonic experience as well as visual, olfactory and auditory information (Kringelbach, 2005). The ongoing integration of sensory and affective information in the OFC and strong connections between the OFC and low level visual networks indicate that conscious percepts may be intrinsically infused with affective value. In other words, the affective value of objects is not computed after object perception is complete, rather affective responses support vision from the very moment that visual simulation begins (Barrett & Bar, 2009). In sum, behavioral, neuroanatomical, and neuroimaging data lend credibility to the thesis that affect changes, and perhaps guides visual perception and attention. Do these changes extend into olfaction and audition?

**Emotional Influences on Olfactory Processes**

*Behavioral Research*

There is a well documented link between olfaction and emotion and a substantial body of research has investigated the way that evocative odors can alter mood, affect learning, and change memory (for a review, see Herz, 2002). Recent work has indicated that evocative odors, when presented subliminally, can even change how much people like neutral faces (Li, Moallem, Paller, & Gottfried, 2007). In contrast to the extensive work in visual perception, the effect of emotional state on olfaction has received little empirical attention until recently. Two recent studies have begun to test the relationship between affective state and olfactory perception, and both indicate that the emotions of the perceiver can alter olfactory perception. Neither study, however, measured the effect of fear on basic olfactory perception.

Chen and Dalton (2005) investigated the effect of emotion and personality on olfactory perception, using emotionally toned film clips to change emotional state before exposure to an odor that was strong enough to be consciously detected, termed a suprathreshold odor. They found that neurotic and anxious individuals reacted more quickly to emotionally valenced odors than to neutral odors. Additionally, unpleasant odors were rated as more intense when they were presented to participants in an emotional as compared to a neutral state. In general, their findings indicate that current emotional state, at least in the context of personality differences, can change olfactory perception.

The second study, conducted by Pollatos and colleagues (2007) investigated the relationship between affective pictures, olfactory perception, and gender. The authors showed people pleasant, unpleasant and neutral pictures (similar to Stefanucci and Storbeck, 2009, described above) and measured their olfactory sensitivity and ability to discriminate neutral, suprathreshold odorants. Olfactory sensitivity was significantly reduced following unpleasant picture presentation for both males and females. Sensitivity was also reduced following pleasant picture presentation for only the males. For all participants, pleasantness and intensity ratings of the neutral odor were related to the valence of the pictures. After unpleasant picture presentation, the odor was rated as less pleasant and more intense, whereas viewing positive pictures induced a significant increase in reported odor pleasantness. In general, both studies indicate that emotional state can change olfactory perception.

*Neurobiological Substrates*

The primary neural substrates involved in emotion and olfactory perception and recognition are similar to those described for emotion and vision (see above): the amygdala and orbitofrontal cortex (Anderson, et al., 2003; Hamann, 2003). This relationship lends credence to the thesis that emotional state can change basic perception in a similar way across several perceptual modalities. Neuroimaging studies have shown that the representation of the intensity, and to a lesser extent the valence of odors, is related to activity in the amygdala (Anderson et al., 2003; Royet et al., 2000; Winston, Gottfried, Kilner, & Dolan, 2005) Given that the amygdala projects to primary olfactory processing areas, these connections indicate that emotion could affect olfactory processing at the beginning of stimulus presentation. Winston and colleagues (2005) compared amygdala responses to high and low concentrations of pleasant, neutral, and unpleasant odors and demonstrated intense amygdala activation related to the perception of the intensity of odors as well as for perception of the pleasant and unpleasantness. However, the amygdala did not respond to neutral odors.

Findings indicate that the orbitofrontal cortex (OFC) is more explicitly involved in perception of odor valence. Anderson and colleagues (2003) had participants smell a variety of pleasant and unpleasant odors and found that the OFC responded more when participants rated the valence of odors. It is important to note that the OFC has strong interconnections with the amygdala as well as direct projections to and from the primary olfactory cortex. In sum, the behavioral and neurological data suggest that emotion can change olfactory perception. However, this thesis will be the first to assess whether fear, in particular, has an impact on olfactory perception.

## Emotional Influences on Auditory Processes

### *Behavioral Research*

The relationship between negative affect and auditory perception has not been well explored in the literature. The evidence that is available comes from clinical research on individuals with trait-level anxiety and disorders of arousal (Dess & Edelheit, 1998; Pollack, Carter, Amir, & Marks, 2006). However, neuroimaging data suggests a similar pattern of activation in the amygdala and orbitofrontal cortex during processing of evocative auditory stimuli (Royet, et al., 2000), lending credibility to our hypothesis that fear has the potential to influence auditory perception.

Pollack and colleagues (2006) investigated the role of anxiety sensitivity, a trait-level tendency to fear anxiety-related sensations, in the perception of heartbeats. They had participants listen for heartbeat sounds disguised in white noise and assessed individuals' perceptions of the loudness of heartbeats as well as their ability to detect them. Individuals high in anxiety sensitivity showed an elevated false alarm rate on the detection task and a lower threshold for reporting normal heartbeats. Interestingly, individuals high in anxiety sensitivity also reported hearing the heartbeats as louder than participants low in anxiety sensitivity. The authors concluded that there may be fear-specific differences in auditory processing.

Dess and Edelheit (1998) found that stress and temperament also led to changes in auditory perception. Individuals rated a tone's loudness after exposure to a mild stressor. Temperament, specifically trait level arousability, was also assessed. Stress increased the loudness ratings of tones among the highly arousable individuals compared with individuals low in arousability. Though the main dependent variable in this experiment was taste perception, these peripheral results lend claim to our hypothesis that emotion, particularly highly arousing emotion, with a negative valence, can affect auditory perception.

*Neurobiological Substrates*

The primary neurological substrates involved in emotion and audition are similar to those described in both vision and olfaction: the amygdala and orbitofrontal cortex

(OFC). Royet and colleagues (2000), for example, found that emotionally valenced auditory stimuli, like the sound of a baby crying or an explosion, led to increased activation in the OFC. Similarly, Schafe and LeDoux (2004), using animal models across many experiments, have found that the processing of evocative sounds is highly dependent on activation of the amygdala and animals with amygdala lesions are incapable of properly processing auditory information.

*Summary*

In summary, behavioral research in vision, olfaction, and audition support the thesis that the emotional state of the observer, particularly a fear state, may have profound effects on the perception of stimuli across modalities. Further, neurobiological findings that emotion and perception are processed in the same areas for vision, audition, and olfaction, gives credence to our hypothesis that fear may systematically change all three types of perception.

**Overview of Studies**

The following studies investigated the role of fear in olfactory and auditory perception. Experiment 1 investigated the role of fear in the perception of positive and negative odors at both weak and strong intensities and found that, interestingly, only the odorless control stimuli was perceived differently when individuals were afraid. Experiment 2 sought to clarify the finding of Experiment 1 by manipulating fear and testing only weak and neutral odors and found that weak odors were rated as less intense by fearful individuals. Experiment 3 investigated the relationship between fear and auditory perception and found that individuals who were afraid perceived tones as louder than participants who were unafraid.

In the olfactory studies, participants rated the intensity and pleasantness of the odors; two dimensions that are commonly used to assess olfactory perception (Chen & Dalton, 2005; Pollatos et al., 2007). In the auditory study, participants rated the loudness and duration of tones; dimensions commonly used to assess auditory perception (Dess & Edelheit, 2008; Radionova, 1994). In all of the experiments, perception of the stimuli was measured by asking participants to estimate their perceptions on an unmarked slider from 0 to 100 and participants were provided with examples of 0 and 100 on each scale in order to calibrate their responses.

Fear was manipulated by asking participants to write about either a frightening event in their past or a neutral event. This paradigm is a well validated and frequently used method of emotion manipulation and results in robust differences in self-reports (Schwarz & Clore, 1983; Westermann, Spies, Stahl, & Hesse, 1996). To ensure that the mood manipulation was efficacious, at the end of the experiment participants rated a number of adjectives on how well they described their feelings during the writing task; modified from the Positive Affect and Negative Affect Scale (PANAS, Watson, Clark, & Tellegen, 1988). Figure 2 depicts the basic experimental design for all three experiments.

## Experiment 1: Fear and Evocative Odors

### Method

*Participants.* Forty (10 male, 30 female, Mean age = 19 years, range = 18-52, Caucasian = 77.5%, Asian = 10.0%, Hispanic = 10.0%, African American = 2.5%,) college students from the College of William & Mary were recruited through an introductory psychology course. Participants received course credit for their participation and all gave informed consent before participating.

*Stimuli and Apparatus.* Participants in both conditions completed a brief initial emotion survey which was a modified version of the PANAS (Watson & Clark, 1988). Participants were given a list of eight adjectives (discouraged, content, frustrated, anxious, happy, nervous, sad, angry) and asked to rate how much they were experiencing those emotions at that moment on a seven-point Likert scale with 1 being *not at all* and 7 being *extremely*. At the end of the experiment, participants in both conditions completed another modified PANAS survey (Watson, Clark, & Tellegen, 1988); however at this time point, they were given a list of six adjectives (calm, nervous, anxious, afraid, at ease, and scared) and asked to rate how much they were experiencing those emotions *during the writing task* on a seven-point Likert scale with 1 being *not at all* and 7 being *extremely*.

*Fear Manipulation.* Participants in the fear condition were given a sheet of paper and asked: *In as much detail as possible, please write about the most frightening experience you've had in the last five years. Try to write it with enough detail that a person you've never met might begin to feel afraid.* Participants in the neutral condition were also given a sheet of paper and asked: *In as much detail as possible, please write about what you do when you get ready in the morning. Try to write it with enough detail that a person you've never met would really understand your process.*

*Coding of Written Responses.* Each participant's written response to the manipulation was double coded by trained research assistants. Research assistants recorded the number of "fear" words used in the document (any verb, noun, or adjective directly describing fear or a frightening experience). They also recorded the total number of "emotion" words (any verb, noun, or adjective directly describing an emotional experience). Finally, they rated the overall emotional tone of the written response on a scale of 1 (not emotional) to 7 (intensely emotional). The raters' scores were then averaged together and the number of fear words, emotion words, and the tone of the response were combined to produce a "story rating" score for each participant.

*Odors.* The olfactory stimuli included four unique odors at two intensities, weak and strong, and one odorless stimulus as a control (adapted from Forestell & Mennella, 2005). Each odor was presented individually in foil-covered, 250-mL, polyethylene plastic squeeze bottles with flip-up caps. The scents, bubblegum, strawberry, tuna, and pyridine, (spoiled milk), were mixed at two different intensities. On the basis of pretests, different concentrations of odors were used[1]. The low intensity smells were prepared as

[1] Based upon pretest data (N=5), mean intensity ratings for the weak odors were Tuna ($M$ = 55, $SD$ = 6), Pyridine ($M$ = 45, $SD$ = 10), Strawberry ($M$ = 42, $SD$ = 5) and Bubble Gum ($M$ = 49, $SD$ = 3), mean

follows: bubblegum (0.03% solution in 100ml of mineral oil; IFF, New York, New York), strawberry (0.06% solution in 100ml of oil; Takasago, Kanagawa, Japan), pyridine (0.03% solution in 75ml of oil; ACROS, Morris Plains, NJ), and tuna (1ml of oil drained from a can of tuna in 25ml oil). The high intensity group was prepared as follows: bubblegum (0.03% solution in 10ml oil), strawberry (0.06% solution in 5ml oil), pyridine (0.03% solution in 10ml oil), and tuna (25ml of oil drained from a can of tuna). In addition, 50ml of mineral oil without any scent was included as a control stimulus. In order to prevent participants from acclimating to the odors, participants were presented with all of the weak odors first, in a randomized order, and then they were presented with the strong odors, also randomized. The neutral bottle was presented twice: once during each block of odors. The interstimulus interval was approximately 60s.

Participants rated the odors on a slider (Figure 3), a modified 12-inch ruler for which all of the marks and numbers were covered except 0 and 100, which were written in on the left and right ends, respectively. There were 9 hash marks written across the extent of the ruler but no numbers corresponded to those hash marks. The "sliding" portion of the slider was a piece of plastic on wheels connected to the ruler which participants slid back and forth to make their ratings of pleasantness and intensity. A "0" on the pleasantness scale was defined to participants as an incredibly unpleasant odor, and a "100" was defined as the most pleasant scent imaginable. A "0" on the intensity scale was defined as barely detectable, the faintest odor you can imagine, and a "100" was defined as the most intense odor imaginable.

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intensity ratings for strong odors were Tuna ($M = 92$, $SD = 8$), Pyridine ($M = 85$, $SD = 16$), Strawberry ($M = 90$, $SD = 11$) and Bubble Gum ($M = 80$, $SD = 6$)

*Procedure.* Participants arrived in the lab and were given the cover story that they were going to complete a writing task. They were informed that for this task, they would have to wait for 10 minutes after the writing to complete a recall task. The experimenter then explained that instead of waiting, they could be part of an unrelated pilot study on the perception of scents in which they would smell a series of odors and then rate them. All participants agreed to participate in the pilot study. Once participants had consented to participate in the pilot, they filled out the current emotions questionnaire and were asked to begin the writing task. The instructions given were based on the condition to which they were randomly assigned. Participants were told that they would have ten minutes to complete the writing task. In order to maximize the emotion priming effects of the writing manipulation, participants were interrupted and told to stop writing after they had completed one full page of writing or 10 minutes had elapsed (whichever came first).

Participants were then informed that they were going to begin the olfactory perception pilot study. Before the presentation of the scents, participants were told that they were going to smell several different odors and rate each odor for pleasantness and intensity on the slider with a scale of 0 – 100. Throughout the presentation of the odors, the experimenter randomized whether participants were asked for their pleasantness or intensity ratings first.

Participants were instructed to leave the bottles on the table, squeeze the bottle, and then waft the odor toward their nose. They were further instructed to smell each odor for no fewer than two seconds and no more than five seconds. The experimenter demonstrated the proper wafting technique for participants. Participants then began to smell the odors that were presented to them. After participants smelled the scent from each bottle, they were asked to rate the odor for both pleasantness and intensity. The researcher determined the participants' ratings by flipping over the slider and recording the number that matched the rating (numbers ranged from 0 -100 and were written on the back of the slider), out of sight of participants.

Once the researcher had presented all nine odors to the participant, the participant was asked to complete the manipulation check. Participants were given explicit instructions to report how they were feeling *during the writing task.* After the survey, participants were asked to report what they thought the experiment was about. At this point, participants received a complete and thorough debriefing about the true nature of the study in which they were informed that the two tasks were really part of the same study.

**Results**

*Initial Emotions*. Table 1 presents participants' emotion ratings at the beginning of the experiment as well as their responses to the manipulation check. In order to assess whether there were differences between the groups in their initial emotion ratings, we conducted a series of *t*-tests and found no significant differences between the groups (*p*s $> .14$) in their ratings of their initial emotions.

*Change in Emotions and Manipulation Check.* Two of the emotions in the initial emotion survey, *anxious* and *nervous* were also included in the manipulation check. We computed a difference score by subtracting the pre-test *anxious* and *nervous* ratings from the post-test *anxious* and *nervous* ratings and compared the scores between the groups. The fear group increased their rating of how *nervous* they were ($M = .15$, $SD = 1.39$)

whereas the neutral group decreased their rating ($M$ = -.40, $SD$ = 1.53). However, this difference was not significant, $t$ (38) = 1.19, $p$ = .24, $d$ = 0.37. The fear group decreased their rating of how *anxious* they were ($M$ = -.15, $SD$ = 1.72) less than the neutral group ($M$ = -.80, $SD$ = 1.15). Again, this difference was not significant, $t$ (38) = 1.40, $p$ = .17, $d$ = 0.44. These results are not surprising given the high level of baseline anxiety and nervousness reported by all participants in the initial emotion survey.

Conversely, in the manipulation check participants in the fear group reported feeling more scared ($M$ = 1.65, $SD$ = 0.81) than participants in the neutral group ($M$ = 1.05, $SD$ = 0.22), $t$ (39) = 3.18, $p$ =.003, $d$ = 1.02 as well as more afraid ($M$ = 1.55, $SD$ = 0.67) than neutral participants ($M$ = 1.15, $SD$ = 0.11), $t$ (39) = 2.12, $p$ =.04, $d$ = .83, and more anxious ($M$ = 2.35, $SD$ = 1.13) than neutral participants ($M$ = 1.55, $SD$ = 0.69), $t$ (39) = 2.70, $p$ =.01, $d$ = .85. Further, they reported feeling less calm ($M$ = 3.15, $SD$ = 0.81) than neutral participants ($M$ = 3.95, $SD$ = 0.76), $t$ (39) = -3.22, $p$ = .003, $d$ = -1.02 as well as less at ease ($M$ = 2.80, $SD$ = 1.06) than neutral participants ($M$ = 3.80, $SD$ = 1.01), $t$ (39) = -3.07, $p$ = .004, $d$ = -.97.

*Story Ratings.* We conducted a series of independent $t$-tests in order to assess whether participants' responses to the writing task were different between groups. In the writing task, participants in the fear group used more fear words in their written responses ($M$ = 2.08, $SD$ = 1.08) than participants in the neutral group ($M$ = 0, $SD$ = 0), $t$ (38) = 8.59, $p$ <.001, $d$ = 2.74. Participants in the fear group also used more general emotion words in their written responses ($M$ = 2.30, $SD$ = 1.20) than did participants in the neutral group ($M$ = .10, $SD$ = .30), $t$ (38) = 7.89, $p$ <.001, $d$ = 2.52. Finally, the tone of the written responses of participants in the fear group ($M$ = 3.05, $SD$ = 1.01) was rated as significantly more emotional than participants in the neutral condition ($M$ = 1.00, $SD$ = 0), $t$ (38) = 9.06, $p$ <.001, $d$ = 2.87.

In order to control for individual differences in the writing manipulation, an average "story rating" score was computed for each participant by combining the number of fear words, emotion words, and the emotional tone of their written response. This "story rating" variable was used as a covariate in subsequent analyses.

*Intensity Ratings.* We conducted a 5 (odor: pyridine, tuna, strawberry, bubblegum, neutral) x 2 (intensity: weak, strong) x 2 (condition: fear, neutral) analysis of covariance (ANCOVA), with condition as the between-participants factor, story rating as a covariate, and all other factors as within-participants factors, in order to determine if the experimental manipulation affected participants' ratings of odor intensity. Table 2 presents the mean intensity ratings for each odor by experimental group. There was a significant main effect of odor $F(4, 34) = 19.77, p <.001, \eta_p^2 = .35$ as well as a main effect of intensity $F(1, 38) = 3.45, p = .05, \eta_p^2 = .09$, suggesting that participants detected a difference in intensity between the odors as well as a difference between the weak and strong intensities. However, there was no main effect of condition $F(1, 38) = 1.41, p = .24, \eta_p^2 = .04$ (see Figure 4).

*Pleasantness Ratings.* We conducted a 5 (odor: pyridine, tuna, strawberry, bubblegum, neutral) x 2 (intensity: weak, strong) x 2 (condition: fear, neutral) ANCOVA, with condition as the between-participants factor, story rating as a covariate, and all other factors as within-participants, in order to determine if the experimental manipulation affected participants' ratings of the pleasantness of the odors. Table 2 presents the mean pleasantness ratings for each odor by experimental group. Again, there was a significant main effect of odor, $F(4, 34) = 17.69$, $p < .001$, $\eta_p^2 = .32$. This result was not surprising given the large variation in the hedonics of the odors presented. The main effect of intensity $F(1, 38) = 3.29$, $p = .08$, $\eta_p^2 = .08$ approached significance, indicating that participants' ratings of pleasantness were somewhat affected by the change in intensity. Again, there was no main effect of condition, $F(1, 38) = 0.57$, $p = .46$, $\eta_p^2 = .02$ (see Figure 5).

*Odorless Control Stimuli.* While the omnibus test for differences between the fear and neutral groups failed to reach significance, a closer examination of the data revealed a significant difference between the fear and neutral groups in their ratings of the intensity and pleasantness of the two odorless control stimuli. We conducted a 2 (intensities: weak, strong) x 2 (ratings: intensity, pleasantness) x 2 (groups: fear, neutral) ANCOVA with condition as the between-participants factor and story rating as a covariate and found a significant main effect of condition, $F(1,35) = 4.05$, $p =.04$, $\eta_p^2 = .10$. Thus, participants in the fear condition rated the odorless control as significantly more intense and more pleasant than participants in the neutral condition.

**Discussion**

There was no significant difference between the fear and neutral groups in their ratings of the intensity or pleasantness of the odors presented in this experiment. One possible explanation for this is that the effects of the manipulation wore off before completion of the task. While the fear manipulation is consistent and well validated, the changes observed are usually short lived (Westermann, Spies, Stahl, & Hesse, 1996). However, a separate analysis of the first odor presented to participants did not yield significant differences between groups (*p*s > .14) indicating that the effect of the fear manipulation was not more intense at the beginning of the olfactory task. Another possibility is that the neutral group was not truly neutral. A high basal level of anxiety and nervousness in both groups suggests the two groups may not have been sufficiently different. This possibility is difficult to rule out given the high levels of anxiety and nervousness in a typical undergraduate population. A final possibility is that the strong odors were simply too strong for fear to have any significant impact on perception. Even a weak version of tuna and pyridine are powerful odorants. Furthermore, it is easy to imagine that the highly positive emotions evoked by the smell of bubblegum or strawberry at a strong intensity might dampen the negative emotions evoked by the fear manipulation.

Interestingly, a closer examination of the differences between the odors revealed a significant difference between the groups in their ratings of both the intensity and the pleasantness of the odorless control stimuli. Given that there was no obvious sensory information presented to participants, a significant difference between the groups seems particularly perplexing. One possible reason for this difference is that the interstimulus interval was not sufficiently long. Though the 60 interval has been used in previous research (Forestell & Mennella, 2005), it is possible that 60 seconds was not a sufficient amount of time for the odor to completely dissipate and that the previous odor was still lingering when participants made their judgments. This explanation does not account for the consistent increase in ratings, however. If a participant still smelled a residual tuna odor when they were asked to smell the mineral oil, it seems unlikely that the participant would rate the mineral oil as highly pleasant. Nor does this explanation account for the differences found between groups.

Another, perhaps more probable, explanation for the difference between groups in the odorless control is that the bottle was not truly odorless. The polyethylene bottles may have had an odor of their own, an odor which was masked in the bottles containing other, more potent odors but which could be easily detected when the bottle contained odorless mineral oil. If this is indeed the case, then perhaps fear has an effect on the perception of a neutral or weak odor like the smell of plastic.

Testing weak and neutral odors directly may ameliorate some of the potential confounds in this experiment. First, it is less likely that a weak or neutral odorant will remain in the nose long after stimulus presentation. Second, if all of the odors presented are either weak or neutral, any smell emanating from the plastic will be present in all of the stimuli and will not be masked by the strength of the odor presented. Third, testing only weak and neutral odors will hopefully control some of the influence that powerfully hedonic odorants have on the emotions of the perceiver.

## Experiment 2: Effect of Fear on Neutral and Weak Odors

The aim of Experiment 2 was to directly test the impact of fear on weak and neutral olfactory stimuli. In this experiment, participants wrote about either a fearful or neutral experience and then smelled a series of neutral and weak odors as well as an odorless control and rated the intensity and pleasantness of each. If fear has a greater impact on the perception of ambiguous olfactory stimuli, then we should see larger differences between fearful and neutral participants when they are asked to rate neutral and weak odors as opposed to the strong and evocative odors of Experiment 1.

### Method

*Participants.* Seventy-three (27 male, 46 female, mean age = 19 years, range = 18-26, Caucasian = 76.7%, Asian = 12.3%, African American = 11.0%,) undergraduate students from the College of William & Mary received introductory psychology course credit for their participation and all gave informed consent before participating.

*Surveys, Fear Manipulation, and Coding.* The surveys, writing task, and coding procedure were the same as in Experiment 1.

*Odors.* The olfactory stimuli included four unique odors at a low intensity and two odorless stimuli. Each odor was presented individually in foil-covered, 250-mL, polyethylene plastic squeeze bottles with flip-up caps, as in Experiment 1. The odors presented in this experiment were cola, green tea, tuna and strawberry. The two new odors, cola and green tea have been previously identified as neutral odors (adapted from Forestell & Menella, 2005). On the basis of pretests, different concentrations of odors were used[2]. The smells were prepared as follows: cola (75ml flattened), green tea (75ml brewed and cooled to room temperature), tuna (1ml of oil drained from a can of tuna in 25ml oil), and strawberry (0.06% solution in 100ml of oil; Takasago, Kanagawa, Japan). In addition, two bottles of 50ml of mineral oil without any scent were included as control stimuli.

*Procedure.* Participants arrived in the lab and, just as in Experiment 1, they were told they would complete a writing task and were asked if they would participate in a pilot study where they would smell a series of odors and rate them for intensity and pleasantness. Once participants consented to participate in the pilot, they were asked to begin the writing task and the instructions given were based on their randomly assigned

[2] Based upon pretest data (N=5), mean intensity ratings for the odors were Cola ($M$ = 50, $SD$ = 11), Green tea, ($M$ = 47, $SD$ = 7), Strawberry ($M$ = 61, $SD$ = 9), and Tuna ($M$ = 64, $SD$ = 3)

condition. Identical to Experiment 1, participants completed a current emotions questionnaire and were then told that they would have ten minutes to complete the writing task and were interrupted and told to stop writing after they had completed one full page of writing or after 10 minutes had elapsed.

Participants were informed that they were going to begin the olfactory perception pilot study. Participants were asked to rate the intensity and pleasantness of the odors on the same slider used in Experiment 1. A "0" on the pleasantness scale was similarly defined to participants as an incredibly unpleasant odor, and a "100" was defined as the most pleasant scent imaginable. A "0" on the intensity scale was defined as barely detectable, the faintest odor you can imagine, and a "100" was defined as the most intense odor imaginable. Throughout the presentation of the odors, researchers randomized whether participants were asked for their pleasantness or intensity ratings first.

In contrast to Experiment 1, in which participants squeezed the bottles themselves, the experimenter held the bottles 2-4 inches under participant's noses and squeezed each odor three times. Participants were instructed to breathe deeply while the researcher squeezed. Participants then began to smell the odors that were presented to them. After participants smelled the scent from each bottle, they were asked to rate the odor for both pleasantness and intensity. The researcher stood behind the participant and recorded the participant's rating using the hash marks written on the slider. In order to prevent participants from being desensitized to the neutral odors, participants were presented with all of the neutral odors first (green tea, cola, and two bottles of mineral oil), in a randomized order, and then they were presented with the valenced odors (strawberry and tuna), also randomized. The interstimulus interval was approximately 60s.

Once the researcher had presented all six odors to the participant, the participant was asked to complete the manipulation check. Participants were given explicit instructions to report how they were feeling *during the writing task.* After the survey, participants were asked to report what they thought the experiment was about. At this point, participants received a complete and thorough debriefing about the true nature of the study in which they were informed that the two tasks were really part of the same study.

**Results**

*Initial Emotions.* Table 1 presents participants' emotion ratings at the beginning of the experiment as well as their responses to the manipulation check. In order to assess whether there were differences between the groups in their initial emotion ratings, we conducted a series of *t*-tests and found no significant differences between the groups in their ratings of their initial emotions (*p*s > .09).

*Change in Emotions and Manipulation Check.* Two of the emotions in the initial emotion survey, *anxious* and *nervous* were also included in the manipulation check. We computed a difference score by subtracting the pre-test *anxious* and *nervous* ratings from the post-test *anxious* and *nervous* ratings and compared the scores between the groups. The fear group increased their rating of how *nervous* they were ($M = .03$, $SD = 1.66$) whereas the neutral group decreased their rating ($M = -.57$, $SD = 1.01$). However, this difference only approached significance, $t\ (71) = 1.85$, $p = .06$, $d = 0.43$. The fear group increased their rating of how *anxious* they were ($M = .08$, $SD = 1.46$) while the neutral group significantly decreased their rating ($M$ = -.97, $SD$ = 1.38), $t$ (71) = 3.17, $p$ = .002, $d$ = 0.74. Again, as with Experiment 1, a high level of baseline anxiety and nervousness reported by all participants in the initial emotion survey makes it difficult to interpret these results.

Conversely, on the manipulation check, participants in the fear group reported feeling more scared ($M$ = 2.00, $SD$ = 1.13) than participants in the neutral group ($M$ = 1.04, $SD$ = 0.20), $t$ (50) = 4.18, $p$ <.001, $d$ = 1.17 as well as more afraid ($M$ = 1.76, $SD$ = 0.95) than neutral participants ($M$ = 1.00, $SD$ = 0), $t$ (50) = 4.04, $p$ <.001, $d$ = 1.10, and more anxious ($M$ = 2.50, $SD$ = 1.17) than neutral participants ($M$ = 1.32, $SD$ = 0.47), $t$ (50) = 4.66, $p$ <.001, $d$ = 1.31. Further, they reported feeling less calm ($M$ = 2.77, $SD$ = 1.17) than neutral participants ($M$ = 3.72, $SD$ = 1.02), $t$ (50) = -3.07, $p$ = .003, $d$ = -0.87, as well as less at ease ($M$ = 2.69, $SD$ = 1.19) than neutral participants ($M$ = 3.96, $SD$ = 1.05), $t$ (50) = -4.00, $p$ < .001, $d$ = -1.13.

*Story Ratings.* We conducted a series of independent $t$-tests in order to assess whether participants' responses to the writing task and the manipulation check were different between groups. During the writing task, participants in the fear group used more fear words in their written responses ($M$ = 3.16, $SD$ = 1.88) than participants in the neutral group ($M$ = .03, $SD$ = .16), $t$ (71) = 10.09, $p$ <.001, $d$ = 2.36. Participants in the fear group also used more general emotion words in their written responses ($M$ = 3.92, $SD$ = 2.44) than did participants in the neutral group ($M$ = .31, $SD$ = .61), $t$ (71) = 8.70, $p$ <.001, $d$ = 2.04. Finally, the tone of the written responses of participants in the fear group ($M$ = 4.61, $SD$ = 1.11) was rated as significantly more emotional than participants in the neutral condition ($M$ = 1.04, $SD$ = .18), $t$ (71) = 19.21, $p$ <.001, $d$ = 4.52.

In order to control for individual differences in the writing manipulation, an average "story rating" score was computed for each participant by combining the number of fear words, emotion words, and the emotional tone of their written response. This "story rating" variable was used as a covariate in subsequent analyses.

*Intensity Ratings.* We conducted a 5 (odor: green tea, cola, strawberry, tuna, mineral oil[3]) x 2 (condition: fear, neutral) analysis of covariance (ANCOVA), with condition as the between-participants factor, story rating as a covariate, and all other factors as within-participants factors, in order to determine if the experimental manipulation affected participants' ratings of odor intensity. Table 3 presents the mean intensity ratings for each odor by experimental group. There was a significant main effect of odor $F(4, 67) = 28.86, p <.001, \eta_p^2 = .28$, suggesting that the intensity ratings differed between odors. An analysis of the simple main effects of odor revealed that mineral oil, and green tea were judged to be significantly less intense than cola ($MSE$ = 3.26, $p < .001$), strawberry ($MSE = 2.58, p < .001$) and tuna ($MSE = 3.50, p < .001$). There was no main effect of condition $F(1, 70) = 2.12, p = .15, \eta_p^2 = .03$.

In order to determine whether the intensity ratings of the actual odorants were different between groups, we conducted a 4 (odors: green tea, cola, strawberry, and tuna) x 2 (condition: fear, neutral) ANCOVA with condition as the between-participants factor and story rating as a covariate, in order to determine if the experimental manipulation affected participants' ratings of odor intensity for the actual odorants, leaving out mineral oil, which has no odor. There was a significant main effect of condition, $F(1,70) = 3.78$,

[3] The odorless control stimulus, mineral oil, was presented to participants twice. The two sets of ratings were averaged together and one "mineral oil" score for each dimension (intensity and pleasantness) is included in these analyses.

$p = 0.05$, $\eta_p^2 = .10$, indicating that participants in the fear condition rated the odors as less intense than participants in the neutral condition (see Figure 6).

*Pleasantness Ratings.* We conducted a 5 (odor: green tea, cola, strawberry, tuna, mineral oil) x 2 (condition: fear, neutral) analysis of covariance (ANCOVA), with condition as the between-participants factor, story rating as a covariate, and all other factors as within-participants, in order to determine if the experimental manipulation affected participants' ratings of the pleasantness of the odors. Table 3 presents the mean pleasantness ratings for each odor by experimental group. There was a significant main effect of odor $F(4, 67) = 39.39$, $p <.001$, $\eta_p^2 = .36$, and each odor was significantly different from the other odors. However, there was no main effect of condition $F(1, 70) = .045$, $p = .83$, $\eta_p^2 = .001$, ratings of pleasantness did not differ across conditions (see Figure 7).

*Odorless Control Stimuli.* As in Experiment 1, fearful participants rated the odorless control stimuli as more intense ($M = 43.9$, $SD = 14.8$) than neutral participants ($M = 38.8$, $SD = 16.76$), although this difference was not significant, $t$ (71) = 1.36, $p = .17$, $d = 0.32$. Fearful participants also rated the odorless control stimuli as more pleasant ($M = 60.60$, $SD = 14.99$) than neutral participants ($M = 58.75$, $SD = 13.41$), again this difference was not significant, $t$ (71) = 0.54, $p = .59$, $d = 0.13$.

**Discussion**

We tested whether fear affects low intensity and neutral odors. Our results tenuously suggest that fearful individuals perceive weak odors differently than individuals who are not afraid. We found that individuals in the fear writing group judged weak and neutral odors to be significantly less intense than neutral participants.

This result may be due to a decrease in olfactory sensitivity during fear. This finding is consistent with previous work conducted by Pollatos and colleagues (2007) which found that participants who viewed negative images were slower to detect odors than participants in a neutral condition.

Previous research has found differences in ratings of pleasantness when participants are experiencing negative emotions (Chen & Dalton, 2005; Pollatos, et al., 2007). We, however, found no significant differences in either olfactory experiment between the two groups in their ratings of the pleasantness of the odors. One explanation is that fear simply does not affect pleasantness ratings. However, another possibility is that participants needed an olfactory anchor in order to get properly oriented to the scale. In other words, participants weren't able to appropriately measure their perception of the pleasantness of the odors using the scale we provided. Both of the previous studies that showed differences in pleasantness ratings gave participants actual olfactory examples of the extremes of the scale before asking them to make their judgments. Our experiments, by contrast, asked participants to *imagine* a highly positive and negative odor to anchor the scale. Considering the highly subjective nature of a construct like pleasantness, it is possible that without actual olfactory anchors, participants were simply using different scales when they made their estimates.

In Experiment 1, fearful participants rated a blank bottle of mineral oil as significantly more intense and more pleasant than participants who were not afraid. In Experiment 2, fearful participants again rated the odorless control as more intense and more pleasant than participants in the neutral condition (although this difference was not significant). The ostensible reason for the difference between groups in Experiment 1 was that the odorless control was not actually odorless; that the bottle itself had an odor and it was the odor of the bottle that participants were rating differently. However, in light of finding in this experiment that weak and neutral odors are perceived as *less intense* when individuals are afraid, this explanation no longer makes sense. If participants in the fear condition were actually rating the faint odor of plastic from the bottle (a weak and presumably neutral odor), they should have rated the bottle of mineral oil as *less intense* than participants in the neutral group not *more intense*. An alternate, and perhaps more plausible, explanation is that without actual perceptual stimuli being presented, participants used the emotional arousal that they were experiencing as a result of the fear manipulation as information when they made their estimates. This *arousal as information* hypothesis is well supported in the literature (Stefanucci & Storbeck, 2009; Storbeck & Clore, 2006) and may be a more appropriate explanation for our results.

In general, these findings cannot be described as overwhelming evidence that fear dramatically changes olfactory perception. However, they do suggest a few things about a possible relationship between fear and olfactory perception. First, ambiguous olfactory stimuli may be the most likely to be affected by fear. The bottles containing mineral oil, which has no odor, were rated differently by the groups in both experiments. Additionally, fear may lower olfactory sensitivity, but only for weak and neutral odors. The difference in intensity ratings between groups was evidenced in the weak and neutral odors of Experiment 2 but no differences were observed in the strong intensity odors of Experiment 1.

**Experiment 3: An Effect of Fear on Auditory Perception**

The aim of Experiment 3 was to test the impact of fear on auditory perception. In this experiment, just like Experiments 1 and 2, participants wrote about either a fearful or neutral experience. However, unlike Experiments 1 and 2, they then listened to a series of tones and judged their loudness and duration.

*Participants.* Twenty-three (13 female, 10 male, mean age = 21 years, range = 20-22, ethnicity = 96% Caucasian, 4% Hispanic) undergraduate students from the College of William & Mary received introductory course credit for their participation and all gave informed consent before participating.

*Stimuli and Apparatus.* The surveys, writing task, and coding procedure were the same as in Experiments 1 and 2. Participants listened to the tones through speakers (Creative, Inspire 290) which were placed in front of them on a desk, but were connected to a computer on a different desk located behind them. All tones were created or modified prior to the experiment using iTunes sound editing software, and were presented during the experiment using Windows Media Player. Five of the tones were each 320 milliseconds long and consisted of five frequencies (1000Hz, 2000Hz, 3000Hz, 4000Hz, and 5000Hz) the other five tones were 640 milliseconds long and consisted of the same five frequencies (1000Hz, 2000Hz, 3000Hz, 4000Hz, and 5000Hz). Tones were played in two sets: the five 320 millisecond tones were always presented first in random order while the five 640 millisecond tones were presented last, also in random order. The decibels of the tones were presented at a range of 95-104 decibels throughout the experiment. The interstimulus interval was approximately 35s.

*Procedure.* Participants arrived in the lab and, similar to Experiments 1 and 2, they were told they would be completing a writing task and were asked if they would participate in a pilot study for which they would listen to a series of tones and rate them for loudness and duration. Once participants consented to participate in the pilot, they filled out a current emotions questionnaire and began the writing task. Again, instructions given were based on their randomly assigned condition. Participants were told that they would have ten minutes to complete the writing task and were interrupted and told to stop writing after they had completed one full page of writing or after 10 minutes had elapsed.

Participants were then informed that they were going to begin the auditory perception pilot study. Before the presentation of the tones, participants were told that they were going to listen to several tones and rate each for loudness and duration on a scale of 0 – 100. Participants listened to two sets of two "anchor" tones, which served as examples of a 0 on the loudness scale, a 100 on the loudness scale, a 0 on the duration scale, and a 100 on the duration scale. The 0 loudness anchor tone was an 800 millisecond tone at 65 decibels and the 100 loudness anchor tone was the same 800 millisecond tone at 121 decibels. After the loudness anchors were presented, the volume on the speakers was set to 50 (~ 95 decibels) and remained there for the rest of the experiment. The 0 duration anchor tone was a 50 millisecond tone and the 100 duration anchor was a 4000 millisecond tone. Participants were instructed to use the anchors when making their judgments about the tones. Participants were then given the same slider described in Experiment 1 and were asked to use the slider to make their estimates of the loudness and duration of the tone. Throughout the presentation of the tones, researchers randomized whether participants were asked for their loudness or duration ratings first.

Participants were prompted to listen to the anchor tones as many times as they needed to in order to *"really get a feel for the scale."* Once participants felt comfortable, researchers began the presentation of the tones. After participants listened to each tone (which was presented only once), they were asked to rate the tone for both loudness and duration. The researcher stood behind the participant and after each rating, they recorded the participant's rating as indicated by the hash marks on the slider.

Once the researcher had presented all nine odors to the participant, the participant was asked to complete the manipulation check. Participants were given explicit instructions to report how they were feeling *during the writing task.* After the survey, participants were asked to report what they thought the experiment was about. At this point, participants received a complete and thorough debriefing about the true nature of the study in which they were informed that the two tasks were really part of the same study.

**Results**

*Initial Emotions.* Table 1 presents participants' emotion ratings at the beginning of the experiment as well as their responses to the manipulation check. In order to assess whether there were differences between the groups in their initial emotion ratings, we conducted a series of *t*-tests and found no significant differences between the groups in their ratings of their initial emotions ($ps > .27$).

*Change in Emotions and Manipulation Check.* Two of the emotions in the initial emotion survey, *anxious* and *nervous* were also included in the manipulation check. We computed a difference score by subtracting the pre-test *anxious* and *nervous* ratings from the post-test *anxious* and *nervous* ratings and compared the scores between the groups. The fear group increased their rating of how *nervous* they were ($M$ = .36, $SD$ = .80) whereas the neutral group decreased their rating ($M$ = -.30, $SD$ = 1.16). However, this difference was not significant, $t$ (22) = 1.53, $p$ = .14, $d$ = 0.67. The fear group increased their rating of how *anxious* they were ($M$ = .09, $SD$ = .83) while the neutral group significantly decreased their rating ($M$ = -1.20, $SD$ = 1.23), $t$ (22) = 2.84, $p$ = .01, $d$ = 1.24. Again, a high level of baseline anxiety and nervousness reported by all participants in the initial emotion survey makes it difficult to interpret these results.

On the manipulation check, participants in the fear group reported feeling more scared ($M$ = 2.00, $SD$ = 1.09) than participants in the neutral group ($M$ = 1.00, $SD$ = 0), $t$ (22) = 2.88, $p$ =.01, $d$ = 1.27, as well as more afraid ($M$ = 1.82, $SD$ = 0.98) than neutral participants ($M$ = 1.00, $SD$ = 0), $t$ (22) = 2.63, $p$ =.02, $d$ = 1.16 and more anxious ($M$ = 2.36, $SD$ = 1.12) than neutral participants ($M$ = 1.40, $SD$ = 0.52), $t$ (22) = 2.49, $p$ =.02, $d$ = 1.08. Further, they reported feeling less calm ($M$ = 3.00, $SD$ = 1.0) than neutral participants ($M$ = 4.10, $SD$ = 0.57), $t$ (22) = -3.06, $p$ = .007, $d$ = -1.34, as well as less at ease ($M$ = 2.73, $SD$ = 1.19) than neutral participants ($M$ = 4.00, $SD$ = 0.67), $t$ (39) = -2.98, $p$ = .008, $d$ = -1.30.

*Story Ratings.* We conducted a series of independent $t$-tests in order to assess whether participants' responses to the writing task and the manipulation check were different between groups. In the writing task, participants in the fear group used more fear words in their written responses ($M$ = 2.86, $SD$ = 1.34) than participants in the neutral group ($M$ = 0, $SD$ = 0), $t$ (22) = 6.73, $p$ <.001, $d$ = 2.94. Participants in the fear group also used more general emotion words in their written responses (*M* = 4.00, *SD* = 2.90) than did participants in the neutral group (*M* = .30, *SD* = .42), *t* (22) = 3.98, *p* = .001, *d* = 1.74. Finally, the tone of the written responses of participants in the fear group (*M* = 4.54, *SD* = 1.15) was rated as significantly more emotional than participants in the neutral condition (*M* = 1.05, *SD* = .45), *t* (22) = 9.51, *p* <.001, *d* = 3.92.

Due to the small sample size in this experiment, the "story rating" variable was not used as a covariate in these analyses.

*Loudness Ratings.* We conducted a 5 (tones: 1000hz, 2000hz, 3000hz, 4000hz, 5000hz) x 2 (tone length: short, long) x 2 (condition: fear, neutral) ANOVA, for loudness ratings in order to determine if the experimental manipulation affected participants' estimates of loudness. Table 4 presents the mean loudness ratings for each tone by experimental group. There was a main effect of tones $F(4,18) = 7.07, p < .001, \eta_p^2 = .25$. indicating that participants detected a difference between the different tones. An analysis of the simple main effects revealed that the 1000Hz tones were significantly different from the 2000Hz tones, *MSE* = 1.19, *p* = .002, 3000Hz tones, *MSE* = 1.05, *p* = .001, 4000Hz tones, *MSE* = 1.64, *p* = .015, and 5000Hz, *MSE* = 1.47, *p* < .001. There was also a main effect of tone length, $F(1, 21) = 21.84, p<.001, \eta_p^2 = .51$, indicating that participants' estimates of loudness increased when the tones got longer. Finally, there was a significant main effect of condition $F(1,21) = 6.40, p = .01, \eta_p^2 = .23$. Participants in the fear condition estimated that the tones were significantly louder than participants in the neutral condition (See Figure 8)

*Duration Ratings.* We conducted a 5 (tones: 1000hz, 2000hz, 3000hz, 4000hz, 5000hz) x 2 (tone length: short, long) x 2 (condition: fear, neutral) ANOVA, for duration ratings in order to determine if the experimental manipulation affected participants' estimates of the duration of the tones. Table 4 presents the mean duration ratings for each tone by experimental group. There was no main effect of tones, indicating that participants' ratings of the duration of the tones were not affected by changes in frequency. There was, however, a main effect of tone length, $F(1, 21) = 21.00, p<.001$, $\eta_p^2 = .84$, indicating that participants' ratings of the duration of tones changed when the tones got longer. Finally, there was no main effect of condition $F(1,21) = 1.38$, $p = .25$, $\eta_p^2 = .06$. Condition did not affect participants' estimates of the duration of the tones (see Figure 9).

**Discussion**

Fearful participants judged the tones as significantly louder than participants who were not afraid. However, there was no significant difference between the groups in ratings of duration. This indicates that the change was not the result of an increase in responses overall in the fear condition. Rather, the manipulation appears to have changed what the participants heard. Unlike Experiments 1 and 2, in which the results were somewhat difficult to interpret, the difference between the groups in this experiment was substantial and unambiguous. Fearful individuals heard the tones as louder than individuals who were not afraid.

## General Discussion

### *Summary of Studies*

These experiments, as a group, support the hypothesis that fear influences auditory perception and, to a lesser extent, olfaction. In all of the experiments, participants' mood was manipulated by writing about a frightening experience in their past after which they judged either odors or tones. In each experiment, participants in the fear group rated the olfactory or auditory stimuli differently than participants in the neutral group, and in the auditory experiment this difference was substantial. Before discussing the implications of this group of studies, I will briefly summarize the main findings of each study.

After writing about either a frightening or neutral experience in their past, participants in Experiment 1 judged the intensity and pleasantness of several pleasant, unpleasant, and neutral odors at a weak and strong intensity. Individuals in the fear writing group rated the odorless control stimuli as more intense and more pleasant than the individuals who wrote about a neutral experience.

The results of Experiment 1, led us to wonder whether participants were having emotional responses to the high intensity, valenced odors which could influence the effect of the fear manipulation. In Experiment 2, we tested the effect of fear on low intensity and neutral odors. Participants in the fear writing group judged weak and neutral odors as significantly less intense than neutral participants, suggesting that olfactory sensitivity may have been reduced in fearful participants, a finding that is consistent with previous work (Pollatos, et al., 2007).

Experiment 3 tested the effect of fear on auditory perception. Participants wrote about a frightening or neutral experience and then rated the loudness and duration of tones. In contrast to Experiments 1 and 2, for which the results were somewhat ambiguous, Experiment 3 clearly demonstrated that fear can affect auditory perception. Individuals in the fear group judged that the tones were louder individuals who were not afraid. It appears that the fearful individuals actually heard the tones differently than the individuals who were not afraid. The remainder of this section will further discuss the results, their limitations, implications and possible future directions.

**Does Fear Affect Perception or Simply Bias Responses?**

A common question in perception research is whether the effect is truly perceptual or the result of a cognitive bias which affects responses, but not the perception itself. This is confounded by the difficulty in measuring perception; perceptual judgments are necessarily conscious reports of perceptual experience and not direct measures of perception. In this work, one might be concerned that fear influenced participants' post-perceptual reports of auditory and olfactory perception rather than what they actually perceived. Participants who were afraid may have judged the tones and odors differently because fear led to an overall increase in responses. However, by measuring different aspects of the perceptual experience, it is possible to consider whether the effect of fear on auditory and olfactory perception is perceptual or the result of a response bias.

The first verification that response bias was not the driving factor in these experiments is that participants were naïve to the true nature of the experiments. In all three experiments, participants were asked to write about a frightening or neutral experience in their past. While the emotional value of the story was explicit, the intention of the experiment was presented as concerned with investigating the process of writing. The auditory and olfactory experiments were presented as separate studies, unrelated to the writing manipulation. When debriefed, no participants reported doubting the intentions of the experimenter or suspecting that the two tasks were part of the same experiment. This evidence suggests that participants were not aware of the fact that fear was the relevant factor being investigated, and were therefore unlikely to guess the hypothesis and adjust their estimates due to the perceived desire of the experimenter.

The second piece of evidence is that in Experiments 2 and 3; only one perceptual measure differed between the fear and neutral groups[4]. In Experiment 2, fearful individuals rated the odors as less intense but ratings of pleasantness did not differ significantly. In Experiment 3, individuals who were afraid judged the tones as significantly louder, but ratings of duration did not vary between groups suggesting that the effect on loudness was likely perceptual rather than a response bias. In all three experiments, if participants had intuited the intent of the experimental manipulation or were exaggerating their responses because they were afraid, then such a bias would likely have been observed in all measures. It was not. This suggests that the effects observed in these studies were due to changes in perception, rather than a cognitive bias.

**Limitations for Olfaction**

It cannot be denied that the results of Experiments 1 and 2, which tested the effect of fear on olfactory perception, were somewhat opaque and the potential limitations of our manipulation in addition to the limitations of testing emotion and olfaction merit

[4] Only the odorless control stimuli of Experiments 1 and 2 produced differences in both measures. However, given that there were no perceptual stimuli presented in an odorless control, this difference does not suggest a response bias. Or rather, a response bias may be expected in this case as there was no perceptual information available to participants when they were asked to make perceptual judgments.

discussion. For one thing, the presentation of the olfactory stimuli may not have been consistent across odors or participants. Though every attempt was made to standardize the presentation of the odors, our experiments lacked the methodological control of an olfactometer, a device which controls the amount of an odor that is released, ensuring that odor presentation is consistent across trials. Additionally, the lab space used to run Experiments 1 and 2 was not designed for olfactory experimentation and therefore did not have proper ventilation. There is always the possibility that odors will commingle in the air, changing participants' olfactory experience.

At a more general level, there is substantial overlap in the neural structures of emotion and olfactory perception and the type of manipulation used in these experiments may not be adequate to examine the relationship between fear and olfactory perception. As discussed in the introduction, the representation of the intensity of odors, and to a lesser extent valence, has been associated with activity in the amygdala, a brain area involved in the basic processing of fear (Anderson et al., 2003; Winston et al., 2005). Because fear and incoming olfactory information appear to be processed simultaneously in the same area, it is possible that the odors themselves altered the emotional state of participants, either by increasing or decreasing fear or by introducing another, unaccounted for emotion. This may have distorted or dampened the effect of our manipulation. For example, if you love the smell of strawberries, then smelling them might evoke positive emotions which could negate any feelings of fear resulting from the emotion manipulation.

This possibility is strengthened by the fact that odorants themselves are used to prime fear. In fact, fearful odors have been found to affect visual perception. Zhou and

Chen (2009) demonstrated that the smell of sweat, a chemosignal of fear, biased individuals toward interpreting ambiguous facial expressions as more fearful. If evocative odors are powerful enough to bias visual perception, it may be impossible in our experiments to parse out the effect of fear on the odorant from the effect of the odorants on fear. Future research in this area will necessarily require a stronger manipulation of fear, greater control of the olfactory stimuli, and perhaps a mechanism to determine the direction of the relationship between fear and olfactory perception.

Regardless of the limitations, Experiment 2 did reveal a fairly clear difference between the fear and neutral groups in their judgments of the intensity of the odors. This leads us to conclude that there is a relationship, if tenuous, between a fearful observer and altered perception of olfactory stimuli.

**Fear Affects Auditory Perception**

In stark contrast to the ambiguity of Experiments 1 and 2, Experiment 3 clearly showed that fear can affect the perception of tones. Individuals who were afraid heard the tones as louder than participants who were not afraid. Fear, in this experiment, appears to have changed auditory perception. It is impossible to know, however, which component of fear affected auditory perception. Emotional arousal has been reliably associated with changes in visual perception (Stefanucci & Storbeck, 2009) and it seems likely that arousal may have been a factor here. Whether arousal was the driving force behind the differences observed is unclear. Again, the writing manipulation used in this experiment is consistent and reliable, but has not been shown to be particularly arousing (Westermann, Spies, Stahl, & Hesse, 1996). One obvious future direction for this research is to examine arousal and valence separately with regard to their effect on auditory perception. This would require an alternate manipulation of emotion, which would also be useful for assessing whether other manipulations (viewing pictures or listening to music, for instance) can also produce the observed effects.

Few researchers have examined the role of emotion in auditory perception and, as a result, the processes that underlie the perceptual change evidenced in this research are not well known. One compelling explanation is that when people express fear, they actually receive more sensory information. Susskind and colleagues (2008) show that individuals who are afraid contort their face in a way that maximizes the intake of perceptual information: widening their eyes, flaring their nostrils, and lifting their ears. Perhaps the participants in our study heard the tones as louder when they were afraid as a result of these types of changes.

As discussed in the introduction, there may be a neurological basis for our finding as well. The amygdala, for example, projects to multiple auditory areas in the temporal lobe (Schafe & Ledoux, 2004). Research in visual perception suggests that amygdala activity enhances visual awareness, fundamentally changing low-level visual perception (Duncan & Barrett, 2007). Fear may enhance or change auditory perception in a similar way.

The final question is *why* fear would change auditory perception. Mineka and Ohman (2002) suggest that low-level fear is selective, automatic, impenetrable to conscious cognitive control, and evolved in order to help us form quick associations in fear states. In this context, fear may influence auditory perception so that we can respond more quickly when threatened. If a bear is chasing you in the woods, perceiving that he is closer than he is (because his roar sounds louder) may motivate you to move more quickly out of his way and to safety. Regardless of underlying processes or their origins, the present study suggests that fear may qualitatively change the way that we hear.

Taken as a whole, these experiments suggest that fear affects the perception of neutral and weak odors as well as the perception of tones. This work extends previous research showing that fear influences visual processes and demonstrates that fear affects other perceptual modalities as well. This suggests to us that emotion may crucially impact the way we experience and interact with the world around us.

Table 1.

*Mean Initial and Post-task Emotion Ratings Separated By Condition for Exp. 1, 2, & 3*

| | Experiment | | | | | |
|---|---|---|---|---|---|---|
| | Olfaction 1 | | Olfaction 2 | | Auditory | |
| | Fear | Neutral | Fear | Neutral | Fear | Neutral |
| Before | | | | | | |
| Content | 4.70(0.92) | 4.55(1.47) | 4.46(1.42) | 4.76(1.30) | 4.83(1.53) | 4.82(0.87) |
| Happy | 4.45(1.32) | 4.40(1.35) | 4.50(1.20) | 4.44(1.19) | 5.08(1.31) | 4.46(1.29) |
| Discourage | 2.30(1.63) | 2.20(1.50) | 2.07(1.41) | 1.48(1.00) | 1.75(1.36) | 1.72(0.65) |
| Frustrated | 2.45(1.43) | 2.80(1.99) | 2.84(1.64) | 1.48(0.96) | 2.17(1.27) | 1.72(0.90) |
| Anxious | 2.50(1.36) | 2.35(0.93) | 2.46(1.50) | 2.16(1.34) | 2.17(1.47) | 2.45(1.44) |
| Nervous | 1.90(1.12) | 2.10(1.29) | 2.23(1.48) | 1.92(1.22) | 1.75(0.75) | 1.91(1.45) |
| Sad | 1.60(1.09) | 1.95(1.27) | 1.61(0.69) | 1.40(0.91) | 1.83(1.70) | 1.27(0.47) |
| Angry | 1.30(0.80) | 1.30(0.73) | 1.76(1.30) | 1.16(0.73) | 1.33(0.89) | 1.09(0.30) |
| After | | | | | | |
| Calm | 3.15(0.81)** | 3.95(0.76) | 2.77(1.17)*** | 3.72(1.02) | 3.00(1.00)** | 4.10(0.57) |
| At Ease | 2.80(1.06)** | 3.80(1.00) | 2.69(1.19)*** | 3.96(1.06) | 2.73(1.19)** | 4.00(0.67) |
| Anxious | 2.35(1.13)** | 1.55(0.68) | 2.50(1.17)*** | 1.32(0.47) | 2.37(1.12)* | 1.40(0.52) |
| Nervous | 2.05(0.94) | 1.70(0.80) | 2.08(0.97)** | 1.70(0.80) | 2.18(0.98)* | 1.40(0.52) |
| Afraid | 1.55(0.68)* | 1.15(0.49) | 1.77(0.95)*** | 1.00(0.00) | 1.82(0.98)* | 1.00(0.00) |
| Scared | 1.65(0.81)** | 1.05(0.22) | 2.00(1.13)*** | 1.04(0.20) | 2.00(1.10)** | 1.00(0.00) |

*Note: Asterisks indicate a significant difference in the means between fear and neutral groups*

* $p<.05$. **$p<.01$. ***$p<.001$.

Table 2.

*Mean Intensity and Pleasantness Ratings by Condition in Experiment 1*

| | Intensity *M(SE)* | | Pleasantness *M(SE)* | |
|---|---|---|---|---|
| | Fear[a] | Neutral[b] | Fear[a] | Neutral[b] |
| Weak | | | | |
| Pyridine | 68.69(7.40) | 58.56(7.50) | 28.96(8.49) | 23.18(8.50) |
| Tuna | 72.74(6.55) | 73.41(6.54) | 24.30(7.18) | 5.14(7.19) |
| Strawberry | 61.74(7.62) | 66.36(6.77) | 75.04(5.87) | 74.16(5.87) |
| Bubblegum | 59.15(7.63) | 52.29(7.62) | 63.97(5.98) | 70.97(5.99) |
| Mineral Oil | 30.90(7.43) | 17.44(7.17) | 54.86(7.27) | 37.28(7.22) |
| Strong | | | | |
| Pyridine | 85.10(5.39) | 78.05(5.40) | 7.00(4.43) | 11.29(4.44) |
| Tuna | 90.89(6.13) | 75.16(6.14) | 11.33(6.28) | 15.81(6.30) |
| Strawberry | 69.55(6.14) | 73.80(6.13) | 70.38(5.38) | 80.17(5.37) |
| Bubblegum | 78.35(6.28) | 68.60(6.25) | 80.64(5.03) | 72.86(4.99) |
| Mineral Oil | 21.79(7.22) | 10.51(7.20) | 47.89(7.41) | 32.62(7.40) |

*Note.* The weak odors were presented first and the strong odors were presented last. Within the weak and strong groups, odor presentation was randomized.

[a]n = 20. [b]n = 20.

Table 3.

*Mean Intensity and Pleasantness Ratings by Condition in Experiment 2*

| | Intensity *M(SE)* | | Pleasantness *M(SE)* | |
|---|---|---|---|---|
| | Fear[a] | Neutral[b] | Fear[a] | Neutral[b] |
| Odor | | | | |
| Tea | 41.54(3.80) | 46.25(3.74) | 42.95(3.67) | 39.31(3.62) |
| Cola | 55.03(3.19) | 61.31(3.14) | 51.83(3.35) | 48.62(3.30) |
| Strawberry | 68.20(2.41) | 74.51(2.37) | 69.59(3.07) | 73.53(3.03) |
| Tuna | 74.01(3.05) | 78.82(3.00) | 18.53(3.13) | 17.18(3.08) |
| Mineral Oil | 43.27(3.80) | 39.45(3.74) | 58.98(2.44) | 60.37(2.41) |

*Note.* The neutral odors were presented first and the hedonic odors (tuna and strawberry) were presented last. Within the neutral and hedonic groups, odor presentation was randomized.

[a]n = 36. [b]n = 37.

Table 4.

*Mean Loudness and Duration Ratings by Condition in Experiment 3*

| | Loudness *M(SE)* | | Duration *M(SE)* | |
|---|---|---|---|---|
| | Fear[a] | Neutral[b] | Fear[a] | Neutral[b] |
| Short[c] | | | | |
| 1000Hz | 51.67(5.50) | 37.73(5.75) | 20.50(3.62) | 17.82(3.78) |
| 2000Hz | 55.00(4.88) | 41.36(5.09) | 23.75(3.64) | 15.90(3.80) |
| 3000Hz | 60.83(5.98) | 41.36(6.24) | 23.33(2.55) | 14.54(2.66) |
| 4000Hz | 60.42(4.74) | 44.09(4.95) | 26.25(3.71) | 14.18(3.88) |
| 5000Hz | 69.16(5.45) | 42.27(5.69) | 23.75(4.28) | 21.00(4.46) |
| Long[d] | | | | |
| 1000Hz | 59.16(4.23) | 44.54(4.42) | 50.41(5.17) | 46.81(5.40) |
| 2000Hz | 69.16(4.43) | 52.72(4.63) | 53.75(6.22) | 50.91(6.49) |
| 3000Hz | 64.16(4.15) | 55.00(4.33) | 52.08(5.17) | 52.08(5.40) |
| 4000Hz | 65.41(4.49) | 52.72(4.69) | 52.91(5.11) | 47.27(5.34) |
| 5000Hz | 69.16(4.17) | 60.90(4.35) | 57.08(5.68) | 46.82(5.93) |

*Note.* The short tones were presented first and the long tones were presented last. Within the short and long groups, tone presentation was randomized.

[a]n = 11. [b]n = 12.

[c]Short = 320 milliseconds. [d]Long = 640 milliseconds

*Figure 1.* Circumplex model of affect. The inner circle shows a map of core affect. The outer circle shows where several prototypical emotions typically fall. From Russell and Barrett (1999).

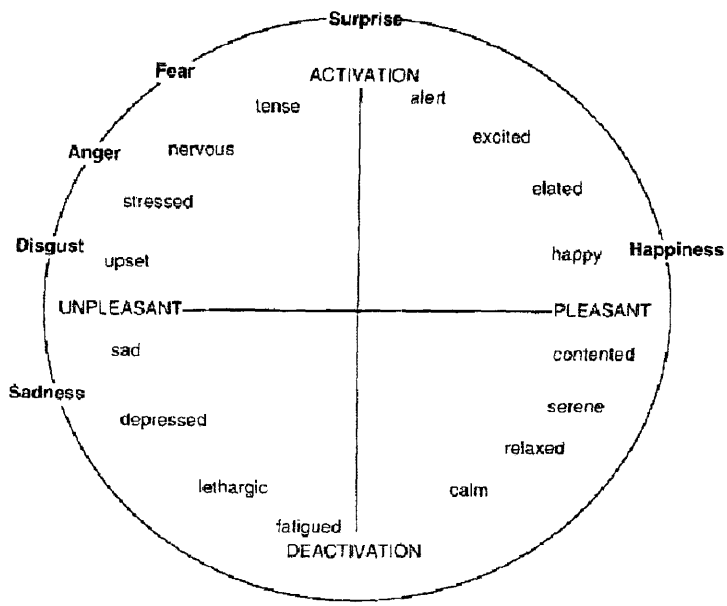


*Figure 2.* Experimental design. In all three experiments, participants wrote about a neutral or frightening experience and then rated the pleasantness and intensity of a series of odors (Experiments 1 & 2) or the loudness and duration of a series of tones (Experiment 3). At the end of the task, participants completed a manipulation check about their emotions during the writing task.

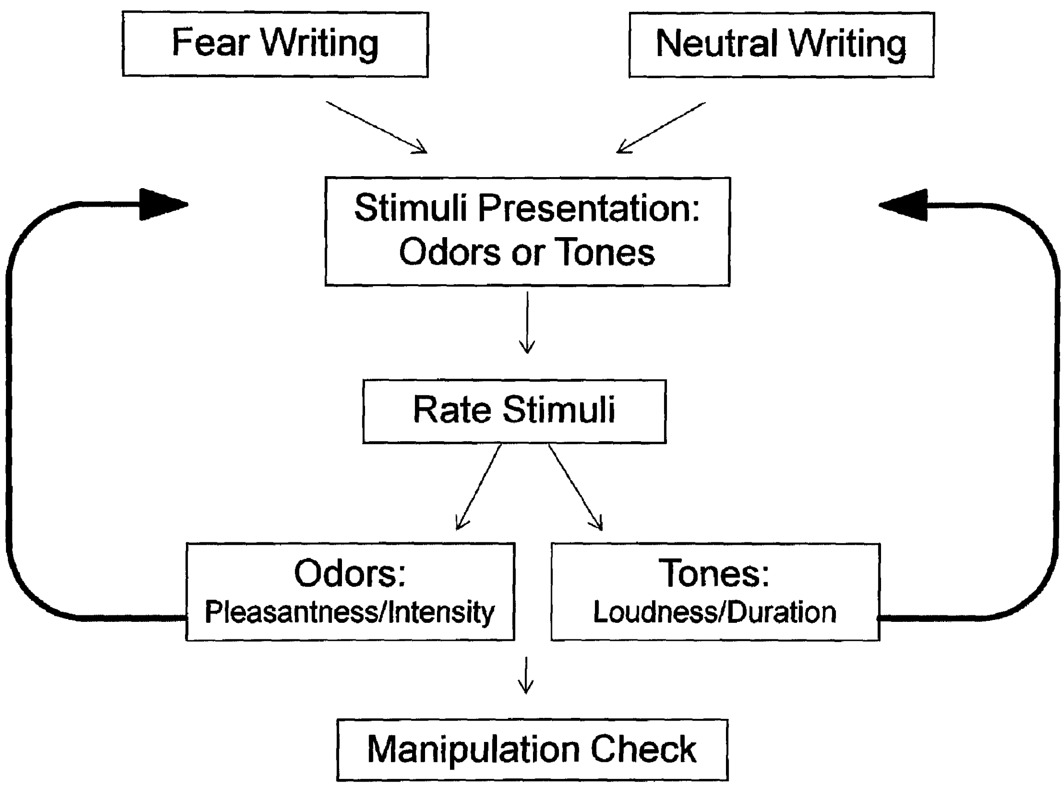


*Figure 3.* Picture of the slider participants used to rate pleasantness and intensity of odors (Experiments 1 and 2) and loudness and duration of tones (Experiment 3). Only the numbers 0 and 100 were visible to participants.

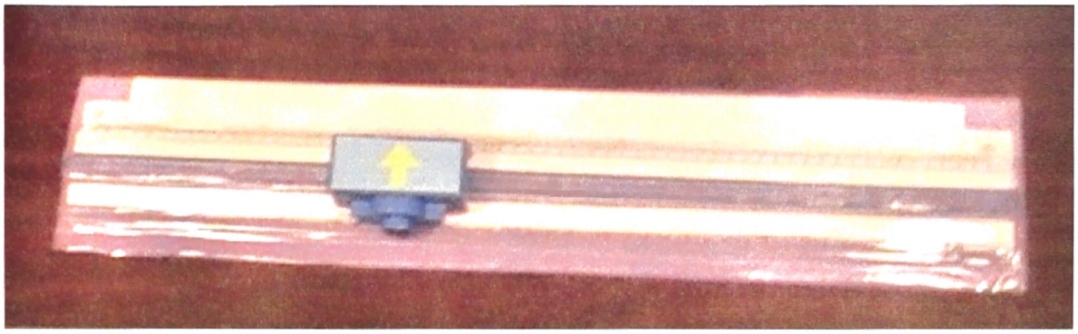
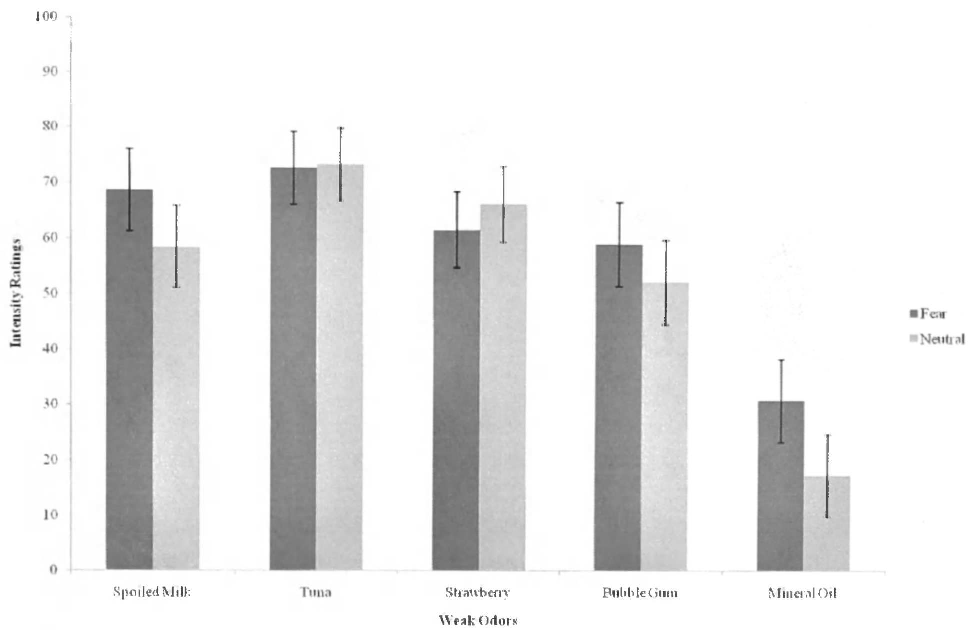


*Figure 4.* Mean intensity ratings (+*SE*) for the weak and strong odors, controlling for the emotional content of writing task, for Neutral (n = 20) and Fearful (n = 20) groups in Experiment 1.



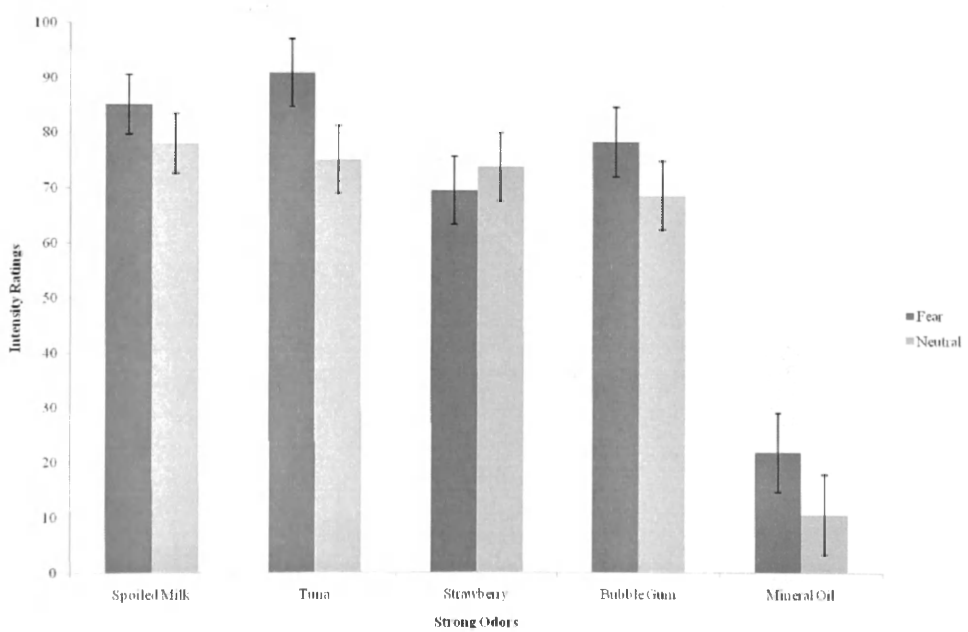



*Figure 5.* Mean pleasantness ratings (+*SE*) for the weak and strong odors, controlling for the emotional content of writing task, for Neutral (n = 20) and Fearful (n = 20) groups in Experiment 1.

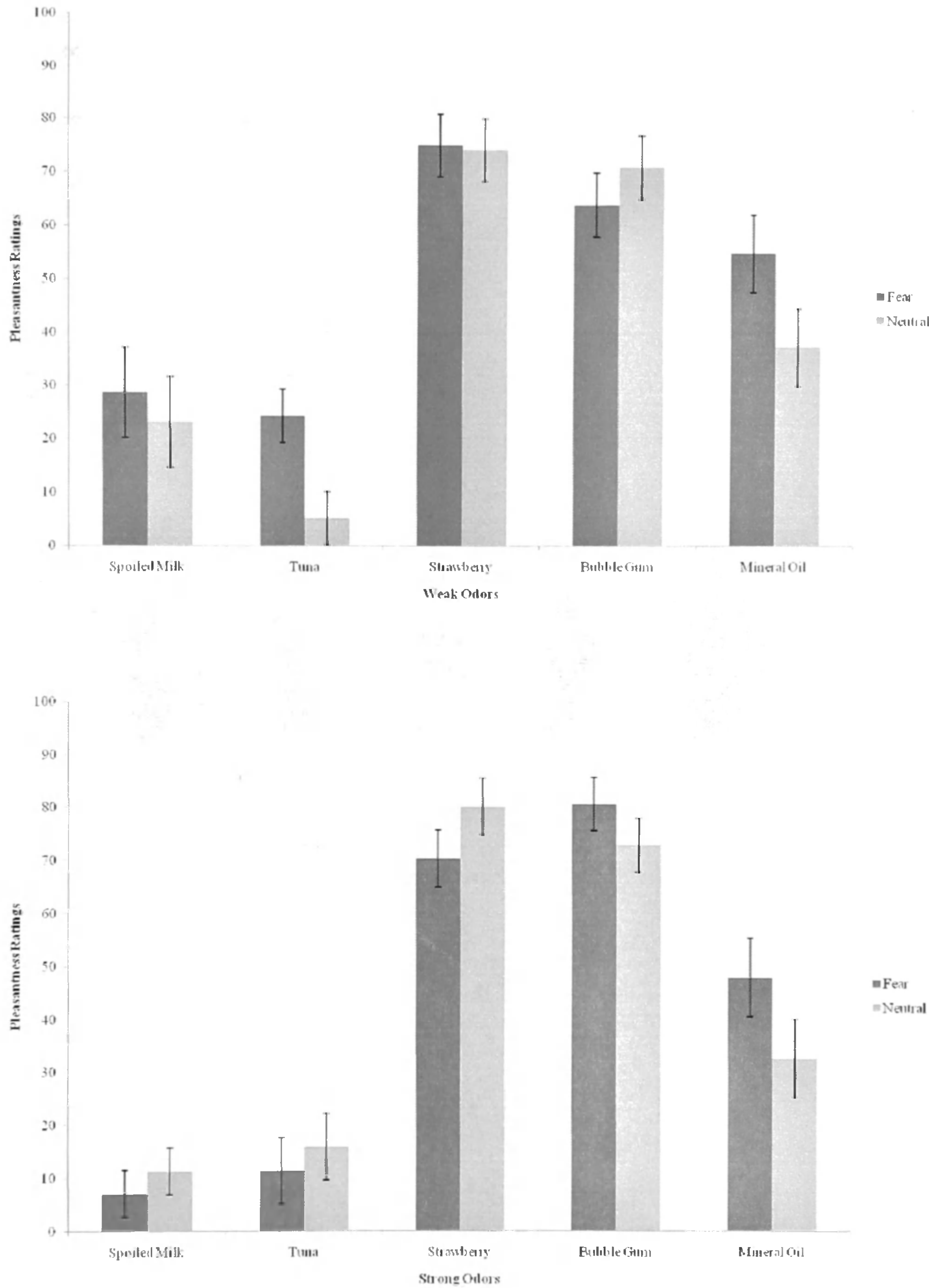


*Figure 6.* Mean intensity ratings (+*SE*) of the odors, controlling for the emotional content of writing task, for Neutral (n = 37) and Fearful (n = 36) groups in Experiment 2.

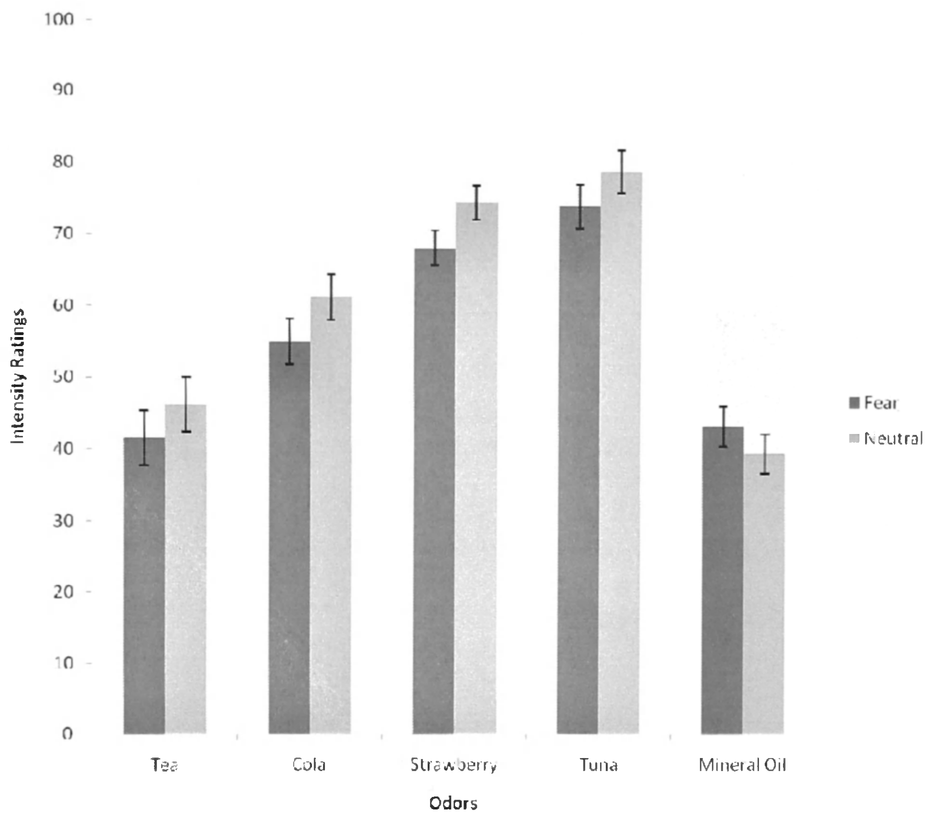


*Figure 7.* Mean pleasantness ratings (+*SE*) of the odors, controlling for the emotional content of writing task, for Neutral (n = 37) and Fearful (n = 36) groups in Experiment 2.

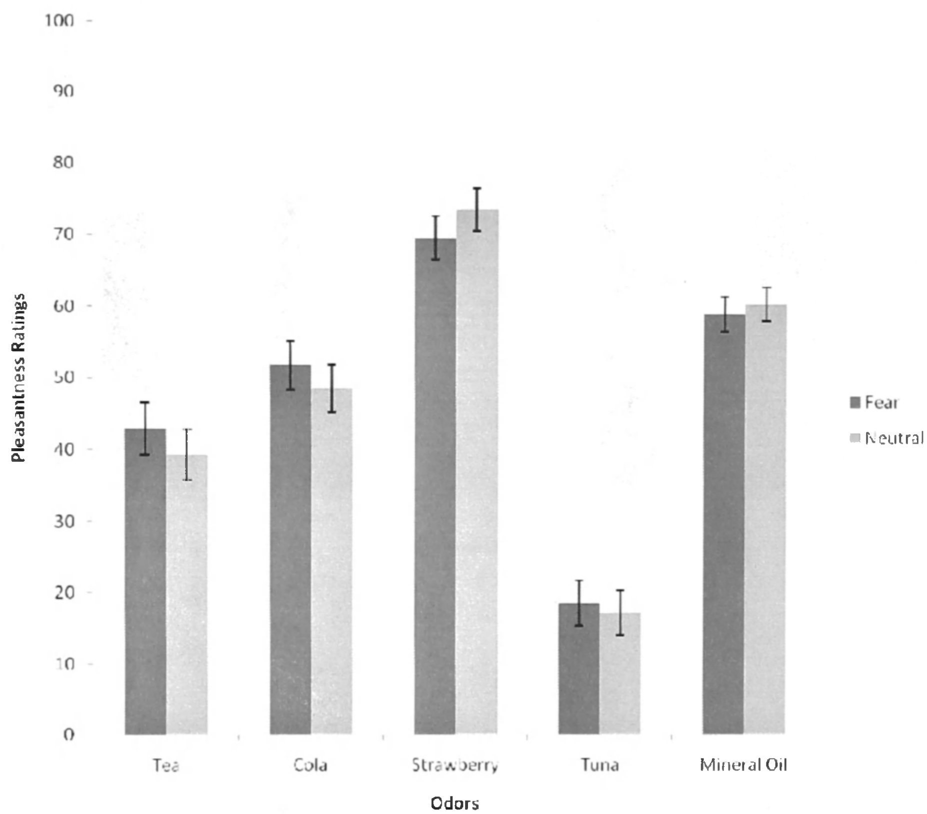
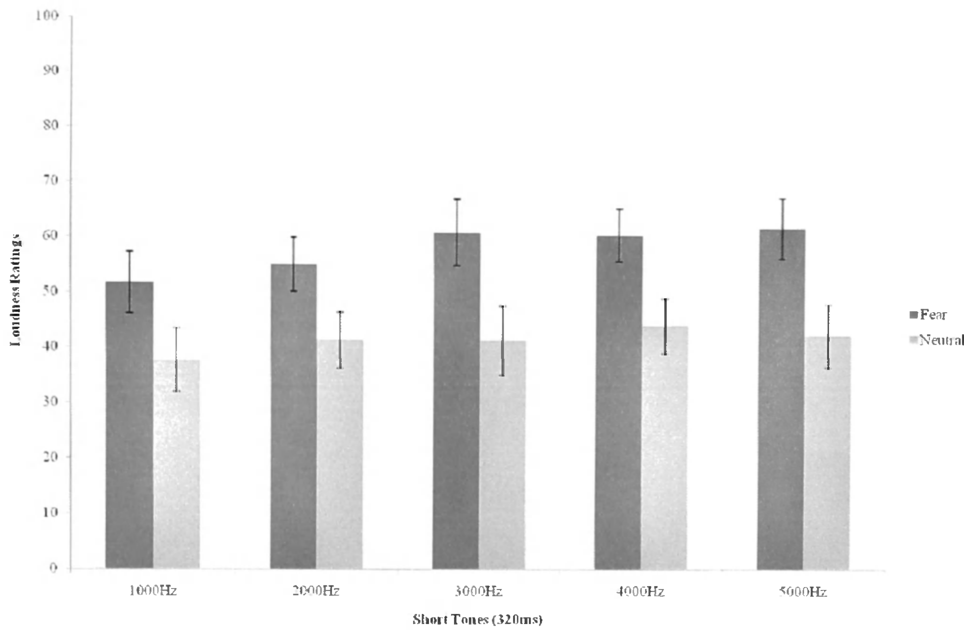


*Figure 8.* Mean loudness ratings (+*SE*) of the short (320ms) and long (640ms) tones for Neutral (n = 11) and Fearful (n = 12) groups in Experiment 2.



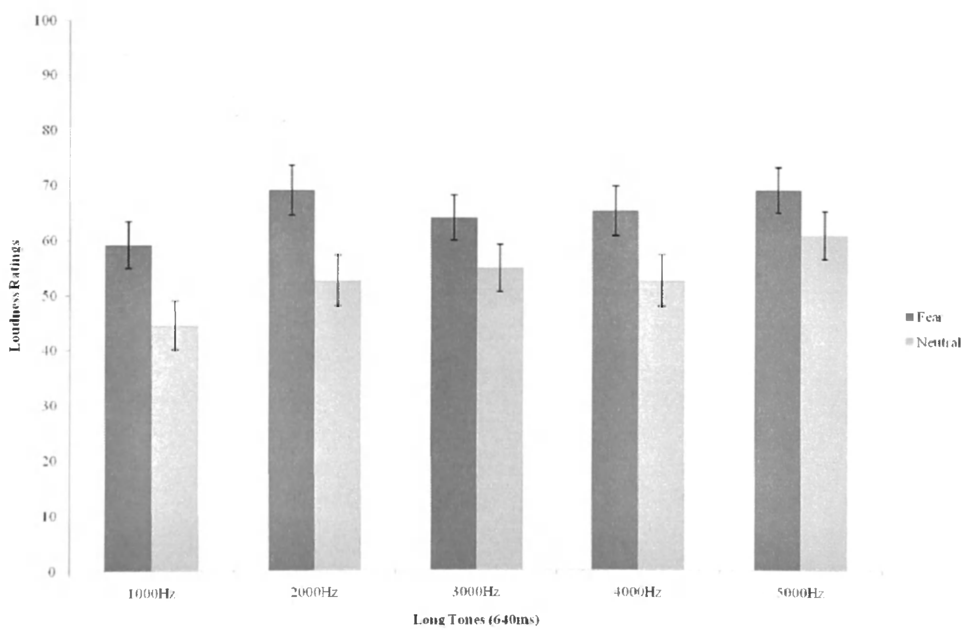
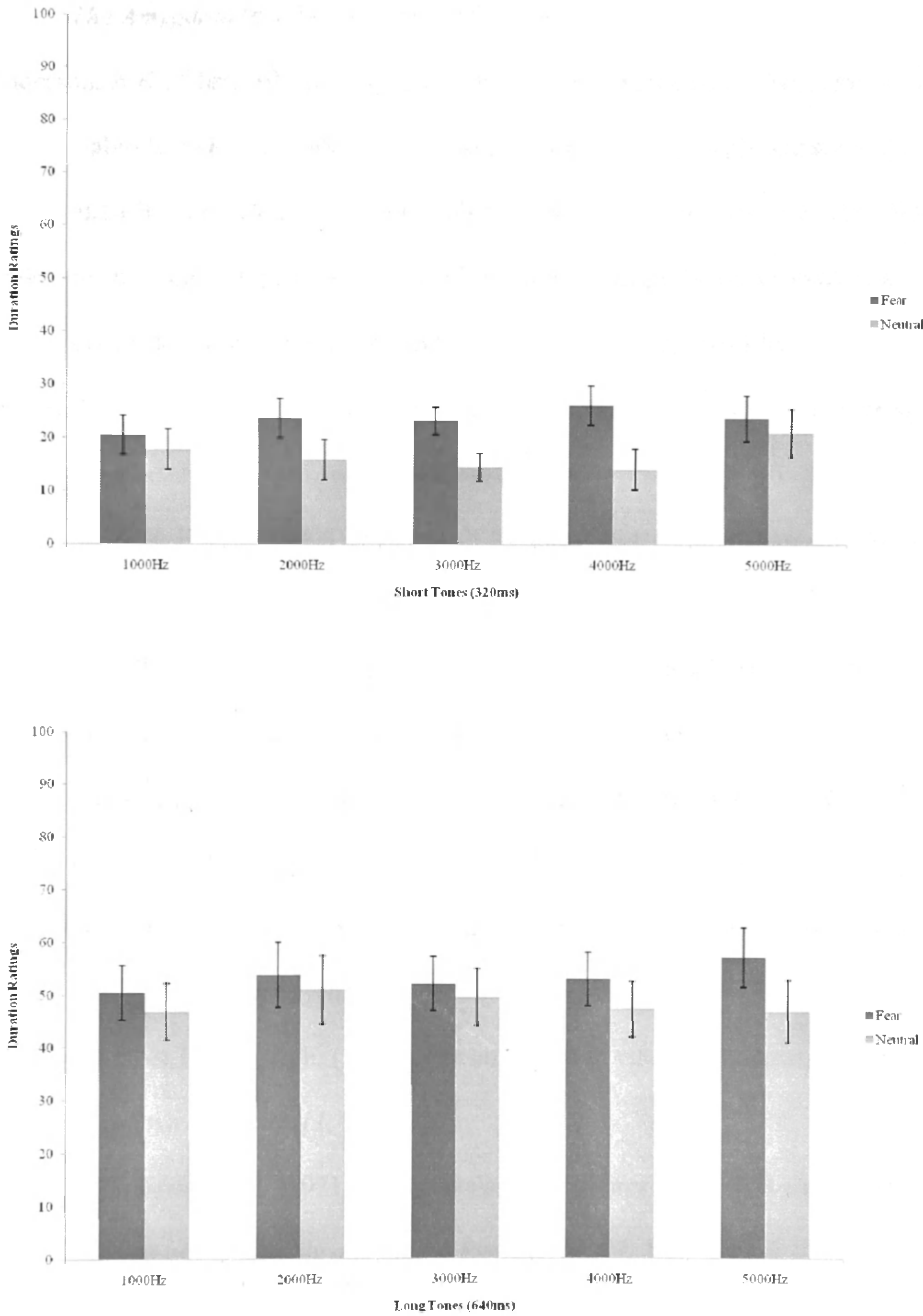



*Figure 9.* Mean duration ratings (+*SE*) of the short (320ms) and long (640ms) tones for Neutral (n = 11) and Fearful (n = 12) groups in Experiment 2.



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# Vita

Erika Siegel was born in Los Angeles, CA, November 10, 1981. She graduated with honors from the University of California, Irvine in Irvine, CA in May, 2007 with a Bachelor of Arts degree in Psychology and Social Behavior. In August, 2007, she entered the College of William & Mary to pursue a Master of Arts degree in Experimental Psychology. She defended her thesis in May, 2009 and graduated in August, 2009. Erika is currently pursuing her doctorate degree in Cognitive and Cognitive Neuroscience at Boston College in Boston, MA.