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THE RELATIONSHIP BETWEEN HAND-NEARNESS, EMOTIONAL AROUSAL, AND VISUAL PROCESSING

by

Christopher Charles Davoli

A dissertation presented to the
Graduate School of Arts and Sciences
of Washington University in
partial fulfillment of the
requirements for the degree
of Doctor of Philosophy

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ABSTRACT OF THE DISSERTATION

The Relationship Between Hand-nearness, Emotional Arousal, and Visual Processing

by

Christopher Charles Davoli

Doctor of Philosophy in Psychology

Washington University in St. Louis, 2010

Professor Richard A. Abrams, Chairperson

When an observer holds his or her hands near an object (*hand-nearness*), visual processing of that object differs in several ways from visual processing of an object far from the hands. Interestingly, the changes that visual processing undergoes during hand-nearness are the same as those that occur when an observer is emotionally aroused. In the present dissertation, three experiments examined whether hand-nearness and emotional arousal affect visual processing through a shared cognitive mechanism. More specifically, it was proposed that hand-nearness activates the same visual processing mechanism that is engaged during arousal. All experiments included replications of studies that have shown effects of emotional arousal on visual processing when the hands are held over response buttons far from the stimuli (the conventional, hands-far experimental posture). In each experiment, there was a manipulation of hand-posture so that participants performed the task with their hands held far from or near to the visual display. Experiment 1 included a direct replication of the Fox et al. (2000) visual search study, in which slowed rates of search were found through displays of emotionally negative faces. Experiment 2 included a conceptual replication of the Becker (2009) visual search study, in which it was found that exposure to emotionally negative faces produced faster search through a subsequent emotionally neutral environment. Experiment 3 included a direct replication of the Fox et al. (2002) inhibition-of-return (IOR) study, in which the IOR effect was substantially reduced following an angry compared to a happy or a neutral face-cue. In the present dissertation it was found that hand-nearness attenuated the effect of emotional arousal following the presence and removal of an arousing stimulus. The present results suggest that hand-nearness and emotional arousal affect visual processing in part through a shared mechanism. It is proposed that this mechanism is one that is tuned specifically towards processing the visual environment in a way that is advantageous to survival.

Acknowledgements

Inspiration has much to do with the mindset of the potentially inspired observer—his willingness to receive the strange and wonderful vibrations from the “outside,” to realize that they are his own. It seems wrong, then, to single out any one person or thing as a source of inspiration, as it is to be found in all. Nevertheless, I remain an observer imperfect. Here’s to the people, places, things, and entities that snap me out of it and remind me to receive, realize, appreciate, be:

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To Emily K. Bloesch: puppies!

Table of Contents

List of Figures

Epigraph

“At first there was a very strange sense that all perception and abstract cognition had become kinesthetic—that these were no more than extensions of one’s neuromuscular being. (…) The world is experienced as a physical extension of oneself, of one’s own nervous system. […] A phenomenon of importance (…) is the non-connective tactile awareness of things that consists of an extension of visual awareness to incorporate tactile awareness into its scope. The substance of a thing was both seen and felt through the visual perception.” (p. 13-16)

“In general, to touch a thing or a person is to enter into a closer, more intimate kind of relationship than is possible when one only looks at the object.” (p. 169)

excerpts from *The Varieties of Psychedelic Experience*
by
Robert Masters
Jean Houston

Chapter 1: Overview

In everyday language, we use proximity between the hands and objects as a device for expressing the emotional relationship between us and the world: “Look but don’t touch;” “I can’t wait to get my hands on that;” “He’s a touchy-feely kind of person;” “It’s out of my hands;” “Hands-on learning.” Through idioms and turns-of-phrase, it is apparent how extensively our relationships with the physical world are expressed and conceptualized through language and symbolism appealing to our hands. As the hands are perhaps the primary way in which we interact with the physical world, it stands to reason that they should be knowledgeable of our emotional relationships with stimuli in the environment. Indeed, emotional associations between us and stimuli help us become more selective in terms of what and whom we approach or avoid. From the broadest perspective, the present dissertation attempts to elucidate the many ways in which our relationships with environmental stimuli are intricately tied to our hands.

Emotional arousal and holding the hands near an object (*hand-nearness*) can affect cognition in a number of analogous, if not identical, ways. This is especially noticeable in the domain of visual processing. Is it merely a coincidence that emotional arousal and hand-nearness similarly alter visual processing, or is it possible that those factors affect visual processing through a shared cognitive mechanism? Could holding the hands near an object activate the visual processing mechanism that is engaged during arousal? With the purpose of answering those questions, I offer the first direct exploration of the relationship between emotional arousal, hand-nearness, and visual processing in the present dissertation.

By inserting emotionally arousing stimuli into standard, emotionally neutral tasks of visual processing, one can measure how emotional arousal specifically alters performance. This is a common practice used by psychologists to explore the effects of emotion on visual cognition. Using paradigms that produce known effects of emotional arousal on visual processing, I manipulated the proximity with which participants held their hands to the primary events of the tasks. Thus, participants performed several tests of visual processing during which emotionally arousing stimuli were presented far from (as has been customary in the literature) or near to the hands. I explored the separate and combined effects of emotional arousal and hand-posture on visual processing to elucidate the extent to which those factors operate through a shared mechanism.

Chapter 2: Background

Hand-nearness and subsequent changes in visual processing

The most conventional posture that participants are instructed to assume while participating in psychology experiments—particularly studies of cognitive processes such as attention, perception, and memory—is one in which they sit at a table or a desk and hold their hands over response buttons (typically on a computer keyboard). Recently, however, there has been strong evidence showing that posture should not be taken for granted in understanding visual processing. Visual processes are sensitive to the spatial relationship, in particular the proximity, between the body and objects in the physical world.

A collection of studies (to be described; their main findings hereby collectively referred to as *hand-proximity effects*) have demonstrated that a simple modification to the conventional posture in hand-object proximity can alter behavior in several well-established visual tasks. Experimentally, this modification is a minor alteration to the conventional posture: a placement of the hands near to (e.g., on the sides of) a visual display compared to the usual position of relatively close to the body and thus far from the display. The effects that follow this manipulation of hand-proximity, however, are rather profound.

Reed, Grubb, and Steele (2006) showed that visual attention can be biased to the region around the hand. In their study, they had participants perform a standard cuing task, in which a target appeared in one of two locations on a visual display. Prior to the onset of the target, one of the two locations was cued. Participants' task was to respond as quickly as possible to the target.

Furthermore, participants held their non-responding hand either on the desk in front of them (i.e., far from the stimuli) or outstretched toward the screen near one of the possible locations at which the target appeared. Reed et al. found that participants were faster to respond to targets—regardless of whether they appeared at the same location as the cue or not—when the targets appeared at the location near their hand, as opposed to the location on the other side of the screen. Reed et al. interpreted this as evidence for spatial attention being biased toward the region around the hand.

Not only is spatial attention biased toward the area around the hands, but several visual attention behaviors are altered when processing objects near the hands. Abrams, Davoli, Du, Knapp, and Paull (2008) showed three examples in their study (described in the following paragraphs). In the first experiment, participants performed a standard visual search task, in which they searched through a variable number of distractor letters for a target letter (which could be one of two letters). Participants performed this task in two postural conditions: one in which they held their hands on either side of (i.e., near to) the display, and one in which they held their hands on their laps (i.e., far from the display). Abrams et al. found that participants searched through the items at a slower rate when they held their hands near the display. Search-rate is thought to be an important measure of search performance (Treisman & Gelade, 1980; Wolfe, 1998), as it can be indicative of the extent to which visual attention is captured by (e.g., Yantis & Jonides, 1984; Davoli, Suszko, & Abrams, 2007) or lingers on (Fox et al., 2000) an item or items in the search display. Abrams et al. interpreted the slowing of search as indicative of delayed disengagement of spatial attention from objects near the hands.

In support of this interpretation of delayed disengagement from objects near the hands, Abrams et al. (2008) also found a corresponding reduction in inhibition of return (IOR) for those spatial locations, which would be expected if visual attention lingered. IOR is a phenomenon that keeps people from returning to recently attended locations, presumably for purposes of facilitating efficient search of the visual world (e.g., Klein & MacInnes, 1999; but see Dodd, Van der Stigehel, & Hollingworth, 2009). IOR was first shown in a laboratory setting by Posner and Cohen (1984) by having participants perform a standard cuing task while the amount of time between the cue and the target is manipulated. Attention is captured by the exogenous cue, but after a certain amount of time presumably moves away from that location, as it is not informative of the location of the impending target. In conditions in which the cue-target interval is long enough for spatial attention to move back toward the center of the display, it is found that participants are actually faster to respond to the non-cued location—that is, returning to the recently attended but inherently useless cued location is inhibited (e.g., Klein, 1988; Klein, 2000). The reduced IOR that Abrams et al. found when the hands were held near the stimuli, then, indicates that subjects' attention was engaged at the initially cued location for a longer time, providing more evidence of delayed disengagement of spatial attention near the hands.

Abrams et al. (2008) also found evidence for delayed disengagement of temporal attention near the hands. They showed this using rapid serial visual presentation, a technique that has been popularized by researchers of the attentional blink paradigm (e.g., Raymond, Shapiro, & Arnell, 1992). In this task, a centrally-located stream of several items is quickly presented, one item after the other (with very short presentation time for each item, typically ~100 ms or less). Within this stream are two targets, T1 and T2, which are to be especially attended to for responses at the end of the trial. For example, every item in a stream of several items may be a letter except one, which is a number. This number is T1, and participants have to respond at the end of the trial to some feature of the number (e.g., parity). Following T1, there is one of two target letters (e.g., A or B). This letter is T2, and participants also have to make a response indicating the identity of T2 at the end of the trial. The critical manipulation of a task such as this is the number of intervening items between T1 and T2. The typical finding is that participants have particular difficulty identifying T2 when it occurs within 250-500 ms of T1. In other words, temporal attention, engaged by T1, “blinks” over T2. Abrams et al. replicated the standard attentional blink effect in their study. Interestingly, however, they found a substantially more pronounced attentional blink when participants held their hands near the display, as if attention was engaged at T1 for a greater amount of time. Thus, not only does there appear to be delayed disengagement of spatial attention from objects near the hands, but also of temporal attention.

Preliminary evidence from our laboratory also suggests that sensitivity to low contrast is improved near the hands. Montana and Abrams (unpublished data) had replicated a design by He, Cavanagh, and Intriligator (1996), in which participants were presented with a row of Gabor patches either above or below fixation. The task was to report the orientation of the central patch, and the patches varied along the dimension of contrast (with the orientation of lower contrast patches being more difficult to discriminate than higher contrast patches). The original finding by He et al. showed that participants were better at discriminating the orientation of the target patch at lower contrasts in the lower visual field compared to the upper visual field, indicating greater sensitivity to contrast (and by extension, orientation) in the lower visual field.

Montana and Abrams used the same paradigm with a manipulation of hand-proximity. They found that when the hands were held far from the display (i.e., similar to the posture adopted by participants in He et al. study), their results resembled those of He et al. That is, there was greater contrast sensitivity for items in the lower visual field. However, when participants held their hands near the display, the differences in sensitivity across upper- and lower-visual fields disappeared. That is, participants were equally sensitive to low contrasts regardless of visual field.

Objects with which we interact are typically located in the lower visual field, perhaps as a byproduct of our eyes being located higher on our body than our hands. Because this is so, it is thought that our visual system has evolved in such a way as to render processing in the lower visual field more sensitive to the spatial qualities of objects (e.g., orientation) for purposes of successful interaction with those objects (Previc, 1990). In accordance with this notion, Montana and Abrams proposed that when one brings items into peripersonal space, such as by holding the hands near a visual display, all objects that fall within that peripersonal space, whether they objectively exist in the upper or lower visual field, receive the processing benefits that are awarded to items in the lower visual field.

Interestingly, the benefits that occur for spatial processing near the hands appear to come at the cost of semantic processing. Davoli, Du, Montana, Garverick, and Abrams (2010) found evidence for impoverished semantic processing near the hands in two experiments. First, they had participants read sentences and judge them based on their semantic sensibleness. For example, a sensible sentence might read “Tim carried his suitcase to the car.” A nonsensical version of this same sentence could read “Tim typed his suitcase to the car.” Although the time it took participants to respond was the same when the hands were near or far from the sentences, participants were more likely to judge nonsensical sentences as sensible ones when their hands were near. This indicated that semantic processing (i.e., the extraction of meaning from text) was impoverished when reading occurred near the hands.

Results of a second experiment of Davoli et al. (2010) supported this interpretation. Participants performed a version of the classic Stroop (1935) task with their hands held near or far from the stimuli. In the Stroop task, subjects are to respond to the color in which a string of letters appears while attempting to ignore the semantic content of the letter string. Several studies have confirmed that such a task is made more difficult when the string of letters spells out a color in which the word could appear but does not (e.g., the word GREEN appearing in red; MacLeod, 1991). This is thought to reflect the relative automaticity with which words are read, which interferes with the appropriate response when the response does not match the word. Thus, the Stroop task is a strong test of semantic processing.

Interestingly, when participants held their hands near the stimuli, they showed far less interference from the semantic content of color-words that were incongruent with the appropriate response. In other words, they were quicker to respond when their hands were held near the stimuli. Furthermore, a comparison of performance in a neutral condition (i.e., when the string of letters was simply a series of X's) revealed no difference across postures, indicating that it was not enhanced color processing that produced the better performance near the hands. Rather, it seems that semantic processing was impoverished near the hands.

Ruling out alternative explanations

Before proceeding with what hand-proximity effects could mean and why they might exist, it is important to explain that several critical control experiments have ruled out alternative explanations. For example, when participants hold their hands near the visual display as opposed to far from it, the hands were in full view in the former condition but not in the latter. Perhaps having the hands in view caused the delayed disengagement of attention or the reduced semantic processing, because attention was divided between the primary experimental task and the monitoring of the hands. This explanation was ruled out by Reed et al. (2006) and Abrams et al. (2008). Both of those studies included an experiment in which the hand(s) near the display was (were) obscured from view.

Nevertheless, Reed et al. and Abrams et al. found the same pattern of results as when the hand(s) was (were) in view.

In some of the studies discussed above, participants always responded with their hands, whether they held them near to or far from the stimuli. But this confound introduced the possibility that mere proximity may not be accounting for the observed effects. Instead, hand-actions near the proximal events could have produced the effects. Abrams et al. (2008) tested this alternative explanation by having subjects make foot responses to target identity in a visual search task, while still holding their hands near to or far from the visual display. They again found the same pattern of results as when participants made responses with their hands. That is, slower rates of search occurred in the hands-near posture, effectively ruling out any contribution that hand-actions near the display could have had on the effects.

It is also possible that the hands-near posture was overall less comfortable or unusual, thereby producing the effects that were attributed to proximity. This alternative explanation has been ruled out in several ways. First, if the hands-near posture was simply uncomfortable, one would expect this posture to produce a constant decrement in performance across all tasks, which would be revealed by a main effect of hand-posture. However, no such main effect of hand-posture has been observed (Abrams et al., 2008; Davoli et al., 2010). In fact, the participants of Davoli et al. (2010) were better (though not significantly so) at performing the Stroop task when they held their hands near the display. Furthermore, and importantly, reading time of the sentences was not different between postures in Experiment 1 of Davoli et al. (2010), which would not be expected if it was more difficult to perform the task in the hands-near posture.

Finally, Davoli and Abrams (2009) conducted a conceptual replication of the visual search task used in Abrams et al. (2008), except participants never actually assumed the hands-near or hands-far postures, but simply imagined assuming them. Davoli and Abrams found that participants searched through the display at a slower rate when they imagined holding their hands near the display, even though they actually held their hands in precisely the same location throughout the experiment. This finding rules out all three alternative explanations addressed above (hand-visibility, hand-actions, and unusualness scenario). Thus, hand-nearness, even when it is imagined, seems to underlie the observed effects on visual processing described thus far.

Hand-proximity effects: Interim summary

The hand-proximity effects described above indicate that spatial processing is enhanced near the hands (Abrams et al., 2008; Montana & Abrams, unpublished data; Reed et al., 2006), even though this enhancement comes at the cost of semantic processing (Davoli et al., 2010). These results reflect the importance of representing where objects are in relation to the hands. Such a bias seems advantageous, as objects near the hands could be threats or obstacles that should be avoided or objects of desire that should be grasped. Knowing the spatial attributes of such objects would certainly aid in the completion of those goals (see Previc, 1998; Previc, Declerck, & de Brabander, 2005 for theoretical discussions of this issue). In the following section, several key pieces of evidence are discussed that reveal that hand-proximity effects are not isolated findings, but rather appear to be behavioral extensions of a neurological system that is specifically responsible for representing near-body space.

Brain mechanisms devoted to representing peripersonal space.

It is possible that hand-proximity effects are a part of a greater system that exists to represent near-body space. The existence of a system devoted to the space around the body has been shown using different methodologies, including single-cell recordings in monkeys and functional magnetic resonance imaging (fMRI).

Single-cell recordings. Many studies have found neurons in the monkey brain that respond to both tactile stimulation as well as visual stimulation near the tactile receptive field (see Graziano, Gross, Taylor, & Moore, 2004 for a review). These bimodal neurons have been found in multiple inter-connected cortical areas, including area F4 of the ventral premotor cortex (PMv; Fogassi et al., 1996; Gentilucci et al., 1988; Graziano, Hu, & Gross, 1997) and area 7b of the posterior parietal cortex (PPC; Graziano & Gross, 1995), and sub-cortically in the putamen (Graziano & Gross, 1993). Most visual receptive fields of bimodal neurons do not extend beyond 20-50 cm from the body, although some extend beyond one meter, and field size varies by brain region (Graziano & Gross, 1993; Graziano & Gross, 1995; Graziano et al., 1997). This range of several centimeters was corroborated behaviorally by Reed et al. (2006), who showed in their cuing task that the bias of spatial attention toward the hand decreased as the hand was positioned further from the target location. Most bimodal neurons have visual receptive fields that are body-part centered. That is, they follow a body-part across changes in posture to consistently represent the visual space around that part (Fogassi et al., 1996; Graziano & Gross, 1993; Graziano et al., 1997). Furthermore, direct stimulation of some of these neurons has been shown to produce a reflexive flinch response in monkeys, defensive in nature, which could be critical in protecting the body from dangers that quickly invade peripersonal space (Graziano et al., 2004).

fMRI studies. The existence of bimodal neurons has not been directly examined in humans, for reasons of the ethicality of performing invasive single-cell recordings in humans. However, fMRI has shown that regions within human PMv and PPC respond to stimulation in multiple modalities, and that they also respond preferentially to visual events near the body compared to far from it. Importantly, PMv and PPC are thought to be homologous to those regions in monkeys that house bimodal neurons (Bremmer et al., 2001; Grefkes & Fink, 2005; Grefkes, Weiss, Zilles, & Fink, 2002; Rizzolatti, Fogassi, & Gallese, 2002).

A recent study by Makin, Holmes, and Zohary (2007) showed that there are brain regions that specifically represent peripersonal space in humans. In their study, each participant lay in the MRI scanner for four experimental conditions, within which both visual and proprioceptive information about the hand relative to a stimulus was varied. In all conditions, participants watched through a mirror as a ball moved toward and away from a stationary target that was either near to or far from the body. In one condition, the left hand was placed at rest next to the near target and was visible via the mirror. Thus, there was visual information about the hand and proprioceptive information about the spatial location of the hand relative to that of the passing ball in this condition (as in, whether or not the ball was on a collision course with the hand). In a second condition, the hand was placed next to the target but was occluded. Thus, relevant proprioceptive information about the location of hand relative to that of the ball was available, but there was no visual information about the hand. In a third condition, the hand was retracted and a visible dummy hand was placed next to the near target. Thus, visual information about a hand (albeit not their own) was available, but proprioceptive information about participants' actual hand relative to the ball was irrelevant as the ball would never approach their actual hand in this condition. Finally, in a fourth condition, the hand was retracted and no dummy hand was present. Thus, neither visual information about the hand nor relevant proprioceptive information was available. Throughout the experiment, participants remained fixated on a point halfway between the near and far targets, and they made judgments about whether the ball would hit the center of either target. Importantly, the ball never actually made contact with the hand (real or dummy).

Makin et al. (2007) found activation patterns suggesting that some brain regions showed a preference for objects near the body. The anterior intraparietal sulcus (aIPS) showed significantly greater activation for near compared to far stimuli when the hand was real and visible. When compared to the condition in which there was no visual or proprioceptive information available (during which the aIPS showed no preference for near or far stimuli), significant aIPS preferences for near stimuli were found in both the proprioceptive-only and visual-only conditions (although neither of those activation patterns were as strong as when both visual and proprioceptive information was present). Finally, PMv showed weak preferences for near stimuli in the proprioceptive-only and visual-only conditions. Importantly, in another experiment, both PMv and aIPS responded to purely tactile stimulation on the hand while participants kept their eyes closed.

These findings indicate that a visual object that enters the space near the body causes activation of brain regions that respond to tactile stimulation, as if the tactile modality is being readied for interaction with the approaching object. Furthermore, because aIPS and PMv responded preferentially to near stimuli even when vision of the hand was obscured, this is evidence that humans have a representation of peripersonal space that is body-part centered.

Behavioral evidence for neural representation of body-part centered peripersonal space. The findings of Makin et al. (2007) strongly support Driver and Spence’s (1998a; 1998b) cross-modal attentional model for the representation of peripersonal space. In their design, at-rest participants sit facing forward with each hand extended outward into space. An uninformative visual cue is then presented next to either hand, followed briefly afterwards by tactile stimulation to either the cued hand or the uncued hand. Participants make speeded discrimination responses to the nature of the tactile stimulation (e.g., continued versus pulsed stimulation) via foot response.

Using this method, Spence, Nicholls, Gillespie, and Driver (1998) found that participants were faster to respond to tactile stimulation when it occurred in the same location as the visual cue compared to the uncued location. Importantly, the hands and the tactile stimulators were obscured from view, ensuring that the only source of visual stimulation came from a visual cue. This effect has been referred to as the cross-modal congruency effect, as stimulation in one modality can attract the attention of other modalities that represent the stimulated spatial location (e.g., Maravita, Spence, & Driver, 2003). Driver and Spence (1998a; 1998b) suggested that cross-modal cuing may be a feature of spatial attention that allows us to represent and, if necessary, react to objects that are in our peripersonal space. For instance, if an insect is quickly approaching the skin, one’s tactile and proprioceptive attention would reflexively move to the region in which the insect was landing. This cross-modal attentional shift also operates in the opposite manner (and also with the auditory modality). For example, when an insect is crawling on the skin, our vision is immediately directed to that location on the skin (Driver & Spence, 1998a; 1998b).

Kennett, Spence, and Driver (2002) found that cross-modal attention re-maps with changes in posture. When participants crossed their hands, such that the left hand was located in right visual space and the right hand was located in left visual space, participants remained faster to make tactile discriminations when the uninformative visual cue occurred on the same side of space as the stimulated hand. This finding provides evidence that representations of peripersonal space are informed by proprioceptive feedback about the physical positioning of the limbs in space. This finding corroborates Makin et al.'s (2007) finding that peripersonal space representation can be based on proprioceptive information alone, and is reminiscent of the bimodal neurons found in monkeys that represent near-body space in a body-part centered fashion (e.g., Graziano et al., 1997).

Brain regions important to the representation of peripersonal space. The brain regions that Makin et al. (2007) found to be involved in peripersonal space representation are consistent with those that have previously been implicated. The preferential response of PMv to peripersonal stimuli is consistent with evidence from monkeys showing that area F4 of PMv plays a prominent role in representing near-body space (Fogassi et al., 1996; Gentilucci et al., 1988; Graziano et al., 1997). Makin et al. also found involvement from aIPS, an area that has a known role in integrating spatial properties of objects with appropriate grasps both in monkeys (Andersen & Buneo, 2002; Gallese, Murata, Kaseda, Niki, & Sakata, 1994; Murata, Gallese, Luppino, Kaseda, & Sakata, 2000; Sakata, Taira, Murata, & Mine, 1995) and in humans (Castiello, 2005; Culham & Valyear, 2006; Tunik, Frey, & Grafton, 2005). Interestingly, Murata et al. (2000) found no evidence for visuotactile neurons in the anterior intraparietal area (AIP) of monkeys, suggesting that the role of this region in monkeys may not be one of representing the space near the hand. However, human aIPS seems to integrate sensory information both for purposes of interaction and representing nearby space (as in defense from obstacles). For example, Grefkes et al. (2002) found aIPS activation during visual recognition of an object encoded in the tactile modality, and vice versa. Additionally, Jäncke, Kleinschmidt, Mirzazade, Shah, & Freund (2001) showed aIPS activation during pure active tactile exploration of three-dimensional objects (i.e., with no visual information about the object present), and during pure visual perception of graspable objects. Finally, as discussed above, Makin et al. (2007), found aIPS activation during pure passive tactile stimulation of the hand and aIPS activation specific to visual stimuli near the hand. Thus, there is mounting evidence for (human) aIPS being an area involved in the integration of visual, tactile, and proprioceptive information, likely for purposes of representing peripersonal space in addition to performing specific hand-actions.

Evidence for peripersonal space representation in the brain from neuropsychological patients.

Findings from patient studies have provided strong support for the existence of networks in the brain that represent peripersonal space. Di Pellegrino, Làdavas, and Farnè (1997) reported on a patient with cross-modal extinction following damage to the right frontotemporal cortex. In patients with extinction, identification of a stimulus presented to the contralesional side is impaired when another stimulus is simultaneously presented to the ipsilesional side. The root of this impairment is thought to be competition between the stimuli for attention, as opposed to reduced sensitivity to incoming stimuli (Vuilleumier & Rafal, 2000). Importantly, such patients are often quite accurate at identifying contralesional stimuli when presented in isolation. Extinction is typically conceived of as occurring within the same modality, such that a left visual field stimulus loses in a competition for attention to a right visual field stimulus. However, the patient of di Pellegrino et al. (1997) showed severe left tactile extinction not only when a simultaneous tactile stimulus was presented to the right hand but also when a simultaneous visual stimulus was presented near the right hand. Mattingley, Driver, Beschin, and Robertson (1997) found a similar pattern of cross-modal extinction in three patients with right hemisphere damage and also found cross-modal extinction of a left visual stimulus by a simultaneous right tactile stimulus. Làdavas, di Pellegrino, Farnè, and Zeloni (1998) showed the same pattern of cross-modal extinction as di Pellegrino et al. (1997) in 10 patients with right hemisphere damage and furthermore showed that cross-modal extinction was far more severe when a visual stimulus was presented near to (~25% detection of a left tactile target) compared to far from (~69% detection of a left tactile target) the right hand.

Schendel and Robertson (2004) also reported evidence for a system of body-part centered representations of peripersonal space and suggested that objects in peripersonal space can receive enhanced visual processing. Their patient WM experienced a stroke that caused damage to the right primary visual cortex, manifesting as severe left visual field loss. Remarkably, WM’s left field loss was substantially attenuated when his left hand was placed next to a visual stimulus. Specifically, WM sat 60 cm away (within reaching distance) from a visual display and was instructed to respond with his right hand every time he detected a briefly presented probe on the display. On each trial, the probe appeared randomly in any 1 of 44 locations across the display, spanning left, right, upper, and lower visual fields. An ongoing task during each trial ensured that WM remained fixated at the center of the display to provide a true test of detection of items in the impaired left visual field compared to the intact right visual field. In a baseline condition, WM sat with his left hand resting on his lap. In the arm-out-near condition, WM sat with his left hand positioned near to the left side of the monitor. In the arm-out-far condition, WM sat in a manner similar to that of the arm-out-near condition, but here all visual stimuli were projected beyond reach onto a whiteboard (the stimulus display was adjusted to span the same eccentricity as in the other conditions). Across all conditions, WM's detection of right visual field probes was nearly perfect (>95%). WM's detection of left visual field probes in the baseline condition was poor (~15%). However, when he placed his left hand near the display, his performance improved considerably (~25% detection). Furthermore, this benefit was not simply due to the outstretched posture, as performance in the arm-out-far condition was impaired (<10%).

Given that the critical difference between the arm-out-near and the arm-out-far conditions was the proximity of the hand to the visual display, Schendel and Robertson proposed that visual events near the hand received enhanced processing from visually-responsive neurons with receptive fields that are anchored to the hand. Of note, in the arm-out-near condition, all left visual field probes fell within 20 cm of the hand, a range that is consistent with the visual receptive field range of arm-centered bimodal neurons in monkeys (Graziano & Gross, 1993; Graziano & Gross, 1995; Graziano et al., 1997).

Di Pellegrino et al. (1997) and Làdavas et al. (1998) favored an interpretation of their results from extinction patients based on bimodal neurons. Specifically, they speculated that competition arose between the somatosensory representation of the left hand (activated by tactile stimulation of neurons for that hand) and the somatosensory representation of the right hand (activated by visual stimulation of visuotactile neurons devoted to the space around that hand), with the weaker left hand representation ultimately losing in the competition for attention. Of course, it should again be mentioned that there is no direct evidence for the existence of visuotactile neurons in humans (particularly ones that would be responsible for representing peripersonal space). However, the similarities between the evidence from monkeys and humans on the matter of brain mechanisms devoted to near-body space strongly support the existence of visuotactile neurons in humans.

Further evidence for visuotactile neurons in humans can be seen in a study by Brown, Kroliczak, Demonet, and Goodale (2008) on two patients (MB and SB) with blindsight. Blindsight refers to a complete or nearly complete lack of awareness of stimulation in a portion of the visual field due to destruction of geniculate projections to the region of the primary visual cortex (V1) that represents the blind area, or from damage to that region of V1 itself. Interestingly, patients with blindsight nevertheless may show unconscious neural responses to such stimulation. It is thought that enduring abilities could be due to visually sensitive areas that may be activated independently of a pathway through V1.

In support of this notion, Brown et al. found that patients were able to more accurately judge the size of a target appearing in the blind visual field when they placed their ipsilateral hand near to, as opposed to far from, the target. This is strong evidence that other brain regions, specifically parietal and premotor regions thought to contain bimodal visuotactile neurons representing the region around the ipsilateral hand, were involved in visual processing of stimulation in the blind field. At the very least, the human brain clearly appears to have a system that is devoted to representing the space around the body, and visual events that fall within this space are processed in a markedly different way from visual events that are far from the body.

Representation of peripersonal space as a mechanism of interaction and defense

Why might we have a system that is responsible for representing the space around the body? The space around the body, and objects that might be in that space, are important. This notion is what fuels the primary argument of the present paper: proximity between the body and objects is so important that it, in and of itself (i.e., regardless of the emotional salience of a nearby object), can produce a state of emotional arousal. Necessarily, threats (emotionally negative) that are closer to the body are of greater importance. Similarly, desired objects (emotionally positive) are of greater use when they are closer, as manual interaction is not possible unless objects are within reach.

Coventry, Valdés, Castillo, and Guijarro-Fuentes (2008) have shown that the demonstrative language we use (this versus that) to represent our spatial relationship to objects changes at the boundary of peripersonal space, regardless of how that boundary is presently defined (e.g., by the body or by an extension of the body such as a tool; cf. Berti & Frassinetti, 2000; Iriki, Tanaka, & Iwamura, 1996; Schendel & Robertson, 2004). Inherently emotionally neutral objects may nevertheless undertake an emotional valence when they are brought within reach. A hot cup of coffee is just a hot cup of coffee until it is nearby, when it may become an obstacle, a source of harm, or a source of enjoyment.

Because objects in peripersonal space are so often relevant to our current goals or demand immediate attention, a representation of peripersonal space that both is informed by multiple modalities and affords rapid communication between these modalities seems evolutionarily advantageous. Therefore, the changes in visual attention found to occur when the hands are near an object seem sensible. Peripersonal items or events, given their relative importance, should be subject to enhanced visual analysis to discern how to best respond. The spatial processing enhancements (Montana & Abrams, unpublished data; Reed et al., 2006) and delayed attentional disengagement (Abrams et al., 2008) found near the hands, even for emotionally neutral stimuli such as dot-probes, block letters, and Gabor patches, presumably all aid in attaining the goals of interaction with nearby desired objects and avoidance of nearby threats.

The ideas just discussed are the backbone of the present paper, and will be returned to many times throughout. In particular, it will be shown that many of the very same alterations in processing that occur near the hands for emotionally neutral stimuli also occur when people view emotional stimuli in the conventional, hands-far posture. It will further be argued that both hand-nearness and emotional arousal affect visual processing through a common, survival-oriented mechanism. This idea will be supported by: 1) evidence showing that other survival-relevant postures and actions affect visual processing in the same manner as hand-nearness and; 2) evidence demonstrating the existence of other cognitive mechanisms that are tuned towards survival.

Importantly, hand-proximity effects reflect a fundamental plasticity of visual processing that has been repeatedly shown in other paradigms. Thus, before specifically discussing the effects of emotion on cognition and their similarities to hand-proximity effects, several of those other paradigms are reviewed.

The mutability of vision

The capacity for vision to adapt to serve our goals has been revealed in many bodies of literature. In thinking about this adaptability, it helps to distinguish between two types of goals, especially as they are referred to in the visual processing literature: 1) the evolutionary goal of survival and 2) the more commonplace goal of completing day-to-day tasks. In some instances, visual attention functions in a way that is stimulus-driven. Regardless of our present attentional focus, we appear to be hard-wired to constantly monitor the environment for important visual events that may be critical to our goal of survival. That is, something of extreme importance can override our present focus of attention. For example, abrupt onsets (Yantis & Jonides, 1984), perceptually new objects (Davoli, Suszko, & Abrams, 2007), and the onset of motion (Abrams & Christ, 2003) all have been shown to capture attention in a bottom-up fashion. Presumably, objects that unexpectedly appear or suddenly move are things that we would want to know about, and thus would want to attend to. In other cases, we can modify our visual processing to best serve our current goals. Depending on the particular task-at-hand, we can adjust what in the visual world we should and should not consider important for purposes of efficient completion of the task. This reflects the well-established notion of top-down control over attention (e.g., Folk, Remington, & Johnston, 1992; James, 1890/1950; Johnston & Dark, 1986).

The common example of driving to the store illustrates how bottom-up and top-down attention work simultaneously and advantageously (cf. Du & Abrams, 2008, for empirical evidence of synergy between those two types of attention). When driving, it is important that our visual attention be captured by a child suddenly running into the road, although we may not be vigilantly monitoring for such an event (an example of bottom-up capture). Similarly, when driving, we pass by objects that are irrelevant to our current goal of getting to the store. Attending to each of these objects would be physically and cognitively impossible and would prevent us from getting to the store in a timely fashion. We filter out objects that are not important (e.g., buildings and signs that do not match those of our destination), while monitoring for features that are indicative of our destination (an example of a top-down attentional set).

A brief review of embodied cognition.

We use our bodies to interact with the physical world. Interestingly, visual attention can be restructured to best accommodate those interactions. Before discussing the specific ways in which body and vision are intricately connected, it is important to mention a zeitgeist that has swept psychology in recent years. The movement has been referred to as embodied cognition, and although several slightly different definitions exist as the theory is maturing (e.g., Wilson, 2002), the basic idea is that to understand cognitive processes such as perception, attention, and memory, it must be acknowledged that these processes cannot be separated from the active bodies in which they occur (e.g., Fischer & Zwaan; Thomas & Lleras, 2007). By a stricter definition, such processes as we experience them arise from having bodies (Glenberg, 1997).

Regardless of the debate over semantics, many studies have shown that our understanding of the world through physical experience can affect cognitive processes. For example, Beilock and Holt (2007) showed that expert typists rated letter dyads that would be typed with different fingers (creating low motor interference) as more likeable than dyads that would be typed with the same finger (creating high motor interference), whereas novices showed no preference for either dyad. Importantly, neither novices nor expert typists could explain why they preferred a particular dyad. Other examples of cognitive processes that are affected by what is done with the body include attitude-formation towards novel stimuli (Cacioppo, Priester, & Bernston, 1993), problem-solving (Grant & Spivey, 2003; Thomas & Lleras, 2007), mental rotation (Wexler, Kosslyn, & Berthoz, 1998; Wohlschläger & Wohlschläger, 1998), language processing (Goldin-Meadow, 2006; Iverson & Goldin-Meadow, 2005), language comprehension (Fischer & Zwann, 2008; Holt & Beilock, 2006) and memory (Dijkstra, Kaschak, & Zwaan, 2008; Glenberg, 1997).

Perception-for-action and action affordances. Interestingly, sight of objects can ready the action system for interaction with those objects. This phenomenon is referred to in the perception-for-action literature as an action affordance and is further evidence of the way in which semantic knowledge about objects is not easily dissociated from memories of how to interact with them. Indeed, knowing how to interact with objects is a critical part of our comprehensive knowledge of objects.

Action affordances have been demonstrated behaviorally through the following basic paradigm. Participants are required to make an action response to some dimension of a stimulus. When that stimulus (or some other object that is viewed simultaneously) elicits (i.e., affords) an action that is compatible (incompatible) with the required response, facilitation (interference) occurs for the response (Bub & Masson, 2006; Bub, Masson, & Bukach, 2003; Craighero, Fadiga, Umiltà, & Rizzolatti, 1996; Craighero, Fadiga, Rizzolatti, & Umiltà, 1998; Ellis & Tucker, 2000; Morgan & Tipper, 2006; Tipper, Paul, & Hayes, 2006). For example, a task might require a left-handed grasp-response if a spatula appears in red and a right-handed grasp-response if it appears in green. If, on a particular trial, a green spatula is oriented such that its handle is in right hemi-space, and thus more appropriately grasped with the right hand, participants show strong facilitation in making the (correct) right-handed response.

Neuroimaging studies have provided corroborating evidence for neural mechanisms of action affordances. Mere visual inspection of graspable objects, in the absence of any intention to act, has been shown to automatically activate brain regions recruited during hand-actions. In an fMRI study by Grèzes, Tucker, Armony, Ellis, and Passingham (2003), subjects classified visual stimuli as ‘natural’ or ‘man-made’ by making either a precision grip with one hand or a power grip with the other. Within both the natural and man-made categories of visual stimuli, however, half of the objects would afford a precision grip and the other half would afford a power grip. Behavioral results confirmed the typical action affordance finding: Congruent grips facilitated reaction time, and incongruent grips slowed reaction time. Additionally, greater activation in the parietal cortex and the premotor cortex correlated with greater reaction time differences between congruent and incongruent trials. Grèzes et al. proposed that this greater activation was a reflection of the increase in competition on incongruent trials between the afforded motor routine and the task-appropriate grip.

In the study by Grèzes et al. (2003), although the grips that subjects made were not directly related to the grip-evoking properties of the objects they viewed, subjects still were performing grips on each trial. However, other studies have demonstrated that subjects do not need to grip graspable objects to activate the action system. Using positron emission tomography (PET), Grèzes and Decety (2002) showed an increase in activation in the inferior parietal lobule (located within PPC) and in PMv when subjects viewed graspable objects, regardless of whether their task was to judge the orientation of, imagine grasping and using, generate the name of, or generate the appropriate action-verb for the objects. Chao and Martin (2000), using fMRI, showed an increase in activation in the left

PMv and the left PPC when subjects viewed and named pictures of tools compared to pictures of non-manipulable objects (houses) and living things (animals, human faces). Furthermore, Creem-Regehr and Lee (2005), also using fMRI, found activation in PMv and PPC when subjects merely viewed images of tools, suggesting that passive viewing is enough to activate the action system (for a conflicting view see Bub et al., 2003).

Providing support to the claim that the neural activation found in the above studies is representative of actions afforded by the viewed objects, Hauk, Johnsrude, and Pulvermüller (2004) showed that neural activation to action-words (e.g., kick, lick, pick) was appropriately somatotopically organized. It should be noted that Chao and Martin (2000), Creem-Regehr and Lee (2005), Grèzes et al. (2003), and Grèzes and Decety (2002) did not directly address whether the activation seen in their studies was somatotopically accurate. However, those studies reported activation in the left middle frontal gyrus, which is the region that Hauk et al. (2004) found to be specifically activated by hand-action words.

Taken together, the above results demonstrate that people are in a state of readiness to interact with objects in the environment, even if interaction is not intended. In the following sections, evidence will be reviewed that shows how action can influence visual perception and attention. Specifically, a plan to act can alter perceptual and attentional processes in ways that benefit successful completion of that action.

Effects of action on visual attention.

Tipper, Lortie, and Bayliss (1992) showed that spatial attention can be allocated based on potential interactions with action-space. In their study, subjects sat in front of a board of nine buttons arranged in a 3 x 3 design, with a pair of yellow and red light-emitting diodes (LEDs) directly adjacent to each button, and a tenth starting button outside the 3 x 3 square which subjects pushed to initiate each trial. Once a trial had begun, a red target LED for one of the buttons lit up. Subjects were instructed to depress the red-lit button as quickly as possible. Additionally, on some trials, a yellow LED that corresponded to another button lit up simultaneously with the red LED, which subjects were instructed to ignore. The main result was that when the yellow (distractor) LED appeared between the starting position of the hand and the target, i.e., along the action-path of the hand, interference in response time (compared to a baseline, no-distractor condition) was greater than when the distractor did not appear along the action-path. Importantly, the physical distance between the distractor and the target was constant, regardless of whether or not the distractor was along the action-path. This pattern of results was observed not only when subjects reached a hand out from the body towards the board, but also when subjects began with a hand beyond the board and reached back towards the body, suggesting that the frame of reference of attention was truly action- rather than viewer-centered.

Presumably, the interference found by Tipper et al. (1992) was indicative of additional cognitive processes that occur when a distractor appears along the intended line of an action. Because the dependent measure was the amount of time to depress the target button, it was uncertain at what part of the response this interference actually occurred—perhaps in the time to initiate the action, perhaps during the action itself, or perhaps at both of these intervals. To resolve this issue, Pratt and Abrams (1994) replicated the original result but included more precise measurements of the phases of the action. They found that both the time to initiate the movement and time of the actual movement, particularly the latter phase in which subjects made any necessary corrections (see also Jeannerod, 1984), increased when a distractor appeared along the path of the action as opposed to beyond it. Thus, the conditions of both Tipper et al. (1992) and Pratt and Abrams (1994) that produced the most interference were those in which a distractor intruded upon the space where an action would take the body (but see Meegan & Tipper, 1998). Furthermore, the results of Pratt and Abrams (1994) suggested that interference occurred both when an object was actually brought into peripersonal space by an action (as evidenced by the increased duration of the corrective phase of the movement) and when an object was going to be brought into peripersonal space by an action (as evidenced by the increased latency to initiate the movement).

Effects of action on visual perception.

Bekkering and Neggers (2002) showed that a plan to grasp an object made subjects more sensitive to the orientation of that object. Subjects performed a basic conjunction search, with the task consisting of either a saccade-and-point or a saccade-and-grasp to a target object, defined by a combination of orientation (45° or 135°) and color (green or orange). On most trials the target was presented amongst a variable number of distractors, and there were three types of distractors equally represented on each of these trials (same color but other orientation; same orientation but other color; other color and other orientation). Subjects began each trial looking at a fixation point, and were not to move their eyes until they had decided on the target location. The primary dependent measure used by Bekkering and Neggers (2002) was saccadic error, defined as a saccade that landed within a certain distance from a distractor. Saccadic error was partitioned into orientation error (a saccade that landed near an object of the correct color but the wrong orientation) and color error (a saccade that landed near an object of the correct orientation but the wrong color).

Subjects made a smaller percentage of orientation errors when performing the saccade-and-grasp task compared to the saccade-and-point task. Bekkering and Neggers argued that the plan to grasp caused enhanced perceptual processing of the dimension of the target object that was highly relevant to the proper completion of the grasp, namely its orientation. To successfully grasp an object, one needs to consider its orientation to align the hand properly. However, information about the orientation of an object would not be needed to properly point to it; therefore, an intention to point would not be expected to enhance subjects' processing of the target's orientation.

In further support of their interpretation, Bekkering and Neggers (2002) also found that subjects made a similar percentage of color errors on both the saccade-and-grasp task and the saccade-and-point task. This suggested that the saccade-and-grasp task was not simply easier than the saccade-and-point task, but rather that accuracy of saccades depended on the capacity of a particular action plan (i.e., a plan to grasp) to enhance processing of the relevant dimension of the target (i.e., orientation). Because the dimension of color is not an instrumental parameter for performing a grasp or a point, there would seemingly be no cause for enhanced color processing under either of these action plans.

In addition to orientation, one must also consider the size of a target object for the proper completion of a grasp. Thus, it would follow that if a plan to grasp causes enhanced perceptual processing of orientation, a plan to grasp should also cause enhanced processing of size. Evidence in favor of this prediction was shown by Fagioli, Hommel, and Schubotz (2007). Their method was as follows. Subjects were seated facing a computer monitor, with a response box directly in front of them and two objects (a white cube and a white dot) positioned between the response box and the monitor. Subjects initiated each trial by depressing a button on the response box with their right index finger. While subjects continued to hold down the button, the onscreen events of the trial began. First, a cue was presented that informed subjects of an action they were to prepare and later perform at the end of the trial: either a reach-and-grasp of the cube with the right index finger and thumb, or a reach-and-touch of the dot with the tip of the right index finger. Following the cue, subjects watched a circle move from one side of the screen to the other over the course of seven frames. From one frame to the next, the circle alternated in size (small, large, small, etc.) and was redrawn so as to appear to traverse the display. On critical trials (75% of the total number), there was a size or location deviation, in which the circle repeated from the previous frame either its size or location, respectively. If participants detected a deviation of either sort, they were to release the button and perform the action planned at the beginning of the trial. If there was no deviation, no action was required.

On trials that began with the preparation of a grasp, participants made faster responses to size deviations compared to location deviations, whereas the reverse pattern was found for trials that began with the preparation of a reach-to-touch. Fagioli et al. (2007) explained their results in terms of a priming effect across the action and perception systems, where a critical dimension of the prepared action primed the perceptual system for discrimination along that same dimension. Specifically, to properly grasp an object, one needs to calculate the size of the object's graspable part, so as to form an appropriate aperture with the hand. Thus, the dimension of 'size' would be activated by the action system, which in turn would prime the perceptual system on this same dimension, producing quicker reaction times to trials that were size-salient. Similarly, to properly reach to touch an object, one would need to calculate the location of the object. Now, the dimension of 'location' would be activated, which in turn would prime the perceptual system on this same dimension, producing quicker reaction times to trials that were location-salient.

However, the results of the first experiment by Fagioli et al. (2007) could also have been explained by perceptual priming of the action system, and not the other way around. That is, the perceptual system, having encoded a deviant of size or location, could have primed the performance of an action that operates under the encoded dimension (see also Craighero, Fadiga, Rizzolatti, & Umiltà, 1999, regarding the difficulty in interpreting the direction of causality between perception and action). Thus, in a second experiment, subjects still prepared a specified action, but this time responded to a deviant via foot pedal, and delayed completion of the planned action until given an auditory signal. This methodological alteration sought to decouple the perception of a deviant from the actual performance of the action, meaning that any differences in response time to a deviant should only be attributable to the action planned at the beginning of the trial. Fagioli et al. replicated the pattern of results found in Experiment 1, supporting their initial claim that an action plan that is formulated around a particular dimension can prime the perceptual system on that same dimension.

Vishton et al. (2007) showed that the perception of objects not only could be affected by intentions to act on a trial-by-trial basis, but that such an effect can last several minutes beyond the completion of the task-related motor program. Specifically, their subjects were presented with a display depicting the Ebbinghaus illusion, and were instructed to select which of the two middle circles appeared larger. In the first experiment, half of the subjects responded verbally throughout (verbal-verbal condition), while the other half responded verbally for the first half of the experiment and responded manually with a reach-and-grasp for the second half (verbal-grasp condition). Subjects in the verbal-grasp condition showed a significant reduction in the magnitude of the Ebbinghaus illusion when responding with a grasp compared to responding verbally. Furthermore, subjects in the verbal-verbal condition actually showed an increase in the magnitude of the illusion from the first half of the experiment to the second, indicating that performance did not simply get better with mere exposure to the illusion. Rather, it seems that forming the intention to reach for an object changed how that object was perceived. Specifically, subjects appeared to be more sensitive to the true physical size of the target object upon forming an intention to grasp it—certainly reminiscent of the enhanced perceptual processing of orientation demonstrated by Bekkering and Neggers (2002).

Interestingly, Vishton et al. (2007) showed that a delayed plan to act could change perceptual processes starting at the initial formulation of that plan. In Experiment 2, both groups of subjects performed the verbal task followed by the reach task, but one group was informed prior to the verbal task that they would later be performing the reach task, while the other group was not instructed of this second task until after the completion of the verbal task. Vishton et al. found that the magnitude of the illusion in the verbal task was substantially reduced (to a magnitude that was not different than that of the reach task) for those subjects who had prior knowledge of the upcoming reach task. Just by knowing that in the future subjects would eventually have to act on the illusion, their perceptual processing was altered during the preceding interval in which they only responded verbally. This finding indicates that a plan to act (even if that plan will not be enacted immediately) can change perceptual processing and hold it in an altered state for several minutes, while waiting for the future action plan to be carried out.

Perhaps most intriguingly, Vishton et al. showed in Experiment 3 that perceptual changes upon the formation of an action plan can persist well beyond the final completion of the action. In the first two experiments, participants always began with the verbal task. In Experiment 3, however, subjects began with the grasp task, and then moved on to the verbal task. The magnitude of the illusion during the grasp and verbal tasks of Experiment 3 were not significantly different from one another, suggesting that perception of the illusion during the verbal task was still under the influence of the same perceptual changes that occurred upon the formation of a plan to grasp. Of importance is that both the grasp task and the verbal task lasted approximately 4.5 minutes each, which would seem to imply that the perceptual system was still in an altered state minutes after an actual grasp had last been performed.

The results of Vishton et al. (2007) suggest that action not only influences what an observer perceives, but also how an observer perceives. For example, Bekkering and Neggers (2002) showed that a plan to grasp led to a higher perceptual selectivity for the target orientation, or, better ability to discriminate between a match and a mismatch of the target feature. It was unclear, however, whether the action plan fundamentally altered seeing. Subjects of Vishton et al. were not simply more biased, perceptually, toward the dimension of size, but in fact actually saw the illusion differently when they intended to reach for it. This result, in addition to others that have shown resolution of ambiguous or competing visual displays through action (e.g., Maruya, Yang, & Blake, 2007; Wohlschläger, 2000), suggests that action can in fact alter seeing.

Real-world implications of the mutability of vision

The studies reviewed thus far showing the mutability of visual processing, be it through hand-nearness, a plan to act, relevant features of exogenous stimuli, top-down attentional set, etc., have taken place in a laboratory setting. However, so many of the papers reporting those results without question place the findings in an evolutionary context. (N.B., in my opinion, this custom is not a bad thing!) Though our modern challenges of not knocking over a coffee cup or orienting our hand to appropriately grasp a phone could rarely qualify as life-threatening scenarios, I believe: 1) If one adopts a looser definition of survival as "not getting hurt" and "efficient interaction with the world around us," the experimentally-observed capacity for vision to change with our best interests in mind certainly qualifies as "survival-relevant." For example, Tipper et al. (1992) and Pratt and Abrams (1994) showed that visual attention was sensitive to obstacles that could be brought into the peripersonal space of a person as a result of one's action. It seems highly unlikely that this feature of visual attention is not at least partially for purposes of protecting us from collisions. In further support of this notion, Lin, Franconeri, and Enns (2008) showed in a visual search task that non-informative, looming objects on a collision course with the viewer were prioritized over looming objects on a near-miss trajectory. Importantly, both types of objects loomed abruptly towards the viewer and halted in the same physical location. So, viewers were able to quickly extrapolate the future position of a looming object and preferentially allocate attention towards those that could result in a collision; 2) It stands to reason that the visual mutability that evolved in our ancestors, which presumably helped keep them alive long enough to reproduce, would be passed on to future generations, even as the prominence of our species' hunter/gatherer role wanes. Surely we can use that same mutability to best achieve our modern goals, even if failure to do so may not regularly have the dire consequences attributed to those of our ancestors; 3) Dangerous scenarios certainly still exist in modern society, though the content of such scenarios may frequently be different than that of what our ancestors faced. Having a reflexive "survival system" that is activated in those situations surely would be advantageous. In agreement with that argument, Blanchette (2006) showed that we devote a similar level of attentional priority to "evolutionarily new" threats (like guns and syringes) as we do to "evolutionarily old" threats (like snakes and spiders).

Visual processing and emotional arousal.

The ideas expressed in the preceding section lead into the following questions. If visual processing can change in ways that are thought to be for purposes of survival and effective interaction with the world, even when the stimuli involved are of inherently neutral emotional valence, (1) What happens to visual processing of emotionally neutral stimuli when the observer is emotionally aroused? (2) Is the processing of emotional stimuli at all different from that of non-emotional stimuli?

Before addressing those questions, it is important to establish that emotional arousal has known consequences on cognitive processes, in general. Placing participants in high-pressure situations, such as having them perform a task under time constraints, in front of an audience, or against others, is one such way of inducing emotional arousal that has drastic effects on performance. Perhaps not surprisingly, the effects of high-pressure situations on performance have been shown to interact with individual-difference factors. This phenomenon has been glorified in professional sports, but readily applies to everyday life: Even when performing well-learned (and thus relatively automatic) tasks, some individuals seem to thrive in high-pressure situations, while others, as they say, “choke” (Beilock & Carr, 2001; 2005). One situation that has been the subject of recent study in the laboratory is solving math problems under pressure. Individuals with a high working memory capacity, who are able to perform complicated math calculations with a high degree of success while in a low-pressure environment, tend to suffer a substantial decrement in performance while under pressure. Yet, individuals with low working memory, who tend to perform the same kinds of calculations with comparatively less success, often show no difference in performance across high- and low-pressure environments (see Beilock, 2008, for a review).

Individual differences aside, decades of research support the idea that performance of relatively simple tasks improves in front of an audience, while performance of complex tasks suffers (Bond & Titus, 1983; Geen, 1991; Guerin, 1986). The basic mechanism behind such a pattern is thought to be one of internal drive, or general arousal, that can be enhanced in an individual by the presence of others (Zajonc, 1965). Supposedly, the presence of others enhances intra-individual arousal on two channels: one which is devoted to the need to consistently monitor the space near the self for purposes of safety and one which reflects a desire to make a positive impression on others (e.g., Guerin, 1986). The enhanced arousal—which is resource-consuming but can have the effect of increasing alertness to stimuli—can be used to the advantage of performing simple tasks, as these are tasks that do not require many cognitive resources, but will pose a hindrance to the performance of complex tasks, which likely require the resources that are already in use as a result of social arousal.

Question #1: How does experimental induction of emotional arousal affect visual processing of neutral stimuli?

Several pieces of evidence support an intricate connection between emotional arousal and vision (see Vuilleumier, 2005; Vuilleumier & Huang, 2009, for excellent reviews of emotional attention). For example, Rowe, Hirsh, and Anderson (2007) manipulated their subjects' affect by having them listen to a happy or a sad song and found that positive arousal caused greater interference from incompatible flankers in a traditional flanker task (cf. Eriksen & Eriksen, 1974). Rowe et al. interpreted this as a broadening of the visuospatial attentional scope during positive affect. Similarly, Fredrickson and Branigan (2005) showed that negative arousal narrowed the scope of spatial attention. They manipulated affect by showing each subject a short video clip that induced one of the following emotional states: amusement; contentment/serenity; anger/disgust;

anxiety/fear; and, an emotionally neutral state. Subjects then performed a task in which they compared a global-local target to two alternatives and were asked which alternative they perceived to be more similar to the target. For example, subjects could have been shown a target that consisted of (local) squares in the (global) shape of a triangle. The alternatives, then, would have been (local) triangles in the shape of a (global) triangle, or (local) squares in the shape of a (global) square. To choose the former alternative would indicate a bias toward global processing, while choosing the latter alternative would indicate a bias toward local processing. Subjects were more likely to show local processing following exposure to the clip that induced anger—indicative of a narrowed focus of attention when in a state of negative affective arousal. In support of the widened attentional scope during positive affect proposed by Rowe et al. (2007), Fredrickson and Branigan's subjects were more likely to show global processing following the clips that induced amusement and contentment.

Converging evidence of a bias toward local processing during negative emotional arousal comes from studies of individuals with high levels of trait anxiety. Derryberry and Reed (1998) showed a similar bias towards local processing in individuals with high trait anxiety when placed in situations that also raised state anxiety (i.e., by increasing the demands on subjects for a correct response). Their results suggested that a shift toward local processing can be an immediate consequence of high levels of anxiety. Importantly, Derryberry and Reed did not find evidence for a local bias in high-trait-anxiety subjects in low state-anxiety situations. However, those researchers also did not find a local bias in low trait-anxiety subjects in high-state-anxiety situations. Thus, it appears that local processing, though it can be a direct consequence of high levels of anxiety, is not necessarily a “way of life” for high-anxiety individuals and in fact requires a substantial amount of negative arousal to occur (see also Richards, French, Johnson, Naparstek, & Williams, 1992).

Question #2: How is visual processing affected by the viewing of emotionally arousing stimuli?

Taboo words. Taboo words, such as sexual references and profanity, seem to engage our attention to a greater degree than emotionally neutral words (see Jay, 2009, for a review of our use of taboo words and his perspective on their utility). This phenomenon has specifically been revealed through the emotional Stroop task. Like in the traditional Stroop task, subjects must respond to the color in which a letter-string appears while ignoring its semantic content. Instead of using color-words, however, the emotional Stroop uses emotionally charged words (e.g., orgasm, fuck) and emotionally neutral words (e.g., concept, structure). Response times to the color of the emotionally charged words are substantially longer than those to the neutral words, suggesting that it is much more difficult to ignore the semantic content of taboo words. Of course, performance on the emotional Stroop task has been shown to interact with individual differences, depending on the kinds of emotional words that are chosen. For example, the attention of victims of sexual assault can be particularly captured by words referencing rape compared to other emotional words, and the attention of individuals anxious about health problems can be particularly captured by words relating to their specific ailment (for a thorough review, see Williams, Mathews, & MacLeod, 1996).

Threatening stimuli. The effects of threatening stimuli on cognitive processes have been of particular interest to researchers. Such stimuli that are commonly used in experimentation include fearful or angry faces, images of dangerous animals and weapons, and words that represent perilous objects, concepts, or situations. Several studies have shown that vision is highly sensitive to threatening stimuli, especially in comparison to neutral stimuli (e.g., Blanchette, 2006; Dijksterhuis & Aarts, 2003; Öhman, Flykt, & Esteves, 2001). Detection of threatening stimuli may occur relatively automatically, as has been evidenced by visual search tasks in which emotional stimuli pop out (Blanchette 2006; Öhman et al., 2001), and dot-probe paradigms have revealed that visual attention may be allocated to the location of a threatening stimulus pre-attentively (Mogg & Bradley, 1999). The extent to which emotional stimuli are truly detected without conscious involvement is still an issue of debate, however (e.g., Fox, 1996; Öhman, 2002). For example, some studies have shown that focused attention to an emotional face is necessary to produce neural responses related to emotional processing (Holmes, Vuilleumier, & Eimer, 2003; Pessoa, Kastner, & Ungerleider, 2002). Furthermore, behavior can be modulated by individual differences. For example, subjects who have a phobia for spiders but not snakes have shown facilitated search for the feared object compared to the non-feared (though nevertheless threatening) object (Öhman et al., 2001). Regardless, there is universal agreement that threatening stimuli typically are detected and attended to rapidly.

The attentional shift to a threatening stimulus is followed by delayed disengagement of spatial attention from that location (Fox et al., 2000; Gerdes, Alpers, & Pauli, 2008; Larson, Aronoff, & Stearns, 2007), which can result in reduced IOR (Fox, Russo, & Dutton, 2002), and delayed disengagement of temporal attention, which can result in a larger attentional blink for subsequent stimuli (Mathewson, Arnell, & Mansfield, 2008). Impoverished semantic processing has been found immediately following attention to a threatening stimulus (Ihssen, Heim, & Keil, 2007). There is also evidence for enhanced contrast sensitivity at the location of a threatening stimulus (Phelps, Ling, & Carrasco, 2006), though Bocanegra and Zeelenberg (2009) showed that this enhancement was specific to low spatial frequencies, while sensitivity to high spatial frequencies was actually reduced. That trade-off in contrast sensitivity is thought to reflect the importance of processing coarse features over fine detail, as coarse features are more indicative of the spatial location of stimuli, and knowing such information would be highly advantageous for survival. In support of Bocanegra and Zeelenberg’s findings, there are mostly magnocellular (responsible for low-spatial-frequency information) compared to parvocellular (responsible for high-spatial-frequency information) projections to the visual cortex from the amygdala—a (bilateral) subcortical structure that has a primary role in emotional processing (e.g., Phelps & LeDoux, 2005).

Interaction of experimentally induced emotional arousal and the viewing of threatening stimuli or situations.

Prior induction of emotional states can also interact with how people perceive threatening stimuli and situations. Harber, Iacovelli, and Yeung (2009) had their subjects recall an emotionally positive (a personal success), neutral (doing laundry), or negative (a personal failure) life-experience. They referred to this as a ‘self-worth’ manipulation. Following the self-worth manipulation, subjects then performed distance judgments. In one task, subjects judged the distance from themselves to either a live tarantula (a threatening stimulus) or a fuzzy cat toy (a neutral stimulus). They found that subjects were much more likely to perceive the tarantula as being closer (by approximately 7’’) than it actually was following the negative self-worth manipulation, compared to the neutral and positive manipulations. Furthermore, Harber et al. found that subjects were nearly perfect in assessing the distance between the tarantula and themselves following the positive manipulation. In another task, subjects were brought to the 5th floor landing of a stairwell, and, while looking down to the bottom floor from the railing, were asked to judge the distance of the drop (actual distance = 60 feet). Subjects who experienced the negative self-worth manipulation perceived the drop to be more than double its actual distance, while those following the neutral and positive manipulations were quite accurate.

Stefanucci and Storbeck (2009) corroborated the overestimation of the distance of a drop in emotionally aroused subjects using another means of inducing arousal. Specifically, separate groups of subjects viewed either arousing or non-arousing images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999) under the guise of a later memory test for a series of pictures. During the break between the learning and the test phase, subjects were given the “filler” task (which was actually the task of primary interest) of estimating the distance of a drop from a 2-story balcony (actual distance = 8 meters). Both groups of subjects overestimated the drop, but the overestimation was more extreme in those that had viewed arousing images. These results plus those from Harber et al. (2009) seem to indicate that emotional arousal can fundamentally change visual processing in ways that cause threats (like a tarantula or a fall) to be perceived as more threatening. Necessarily, a dangerous object is more dangerous the closer it is to the body, and a fall is more perilous the further it is.

Possible mechanisms of emotional attention

Several studies, discussed above, have elucidated 1) how experimental induction of emotional arousal affects visual processing of neutral stimuli, and 2) how visual processing is affected by the viewing of emotionally arousing stimuli. The behavioral effects of those studies lead into a third question: What are the possible neural mechanisms through which emotional arousal has such effects on visual processing?

Emotional arousal seems to alter visual processing at early, pre-conscious sensory stages (Vuilleumier, 2005). In particular, the amygdala appears to have a modulatory role on visual processing of emotional stimuli. Generally speaking, early-stage (pre-conscious) visual information is projected to the amygdala, where it may be recognized as emotionally salient. This salience message is then (still pre-consciously) projected back to early visual cortex, where the sensory response may be enhanced—perhaps through an alteration of neuronal firing rate or receptive field properties (Anderson & Phelps, 2001). This enhanced sensory signal can then have the effect of directing conscious attention to the emotional stimulus through a channel that is independent of other frontoparietal attentional channels (Vuilleumier, 2005; Vuilleumier & Huang, 2009). It is in this way that emotional stimuli are thought to capture attention independently of our current goals and attentional set (a clearly adaptive function of emotional attention).

In support of the existence of the salience loop discussed above, Amaral, Behniea, and Kelly (2003) found evidence for direct feedback projections from the amygdala to all visual cortical areas along the ventral pathway in monkeys (the pathway primarily responsible for processing what as opposed to where objects are; cf. Goodale & Milner, 1992). Additionally, direct evidence of both the role of the amygdala with emotional processing and its modulatory effect on visual processing has been found in patients with lesions in the amygdala. Anderson and Phelps (2001) observed that their patient, SP, showed no attenuation of the attentional blink when T2 was an emotional word. By comparison, controls showed a drastic attenuation of the attentional blink when T2 was an emotional compared to neutral word (~20% versus ~40% failure to identify T2, respectively). Using fMRI, Vuilleumier, Richardson, Armony, Driver, and Dolan (2004) found that patients with lesions in the hippocampus (but sparing the amygdala) and controls showed increased activation in the visual cortex following exposure to emotional compared to neutral faces. Interestingly, however, no such preferential response was found in patients with lesions to the hippocampus and the amygdala. Thus, even though the amygdala and visual cortex are relatively distant from one another from a structural perspective, a lesion in the former can nevertheless have a significant impact on the response of the latter.

Visual processing and emotional arousal: Interim summary.

Experimentally-induced emotional arousal has been shown to change visual processing in distinct ways, such as narrowing or broadening the scope of attention upon manipulations of negative or positive affect, respectively. There is some debate as to whether high-pressure situations, like performance of a task in front of others, have the capacity to directly alter visual processing. It is possible that such scenarios narrow the scope of attention, or alternately act through some other mechanism, like enhancing cognitive control (which could then conceivably have effects on visual attention).

The viewing of emotionally arousing stimuli can also markedly change visual processing. Such items attract attention rapidly and hold attention longer than neutral stimuli, and can enhance processing of important spatial features—though at the cost of semantic processing. Experimentally-induced negative arousal and exposure to threatening stimuli or situations may also interact to change visual processing in a way that seems to render those stimuli or situations more threatening (e.g., a tarantula is perceived to be closer, and a drop is perceived to be higher).

Some outstanding issues regarding emotional attention, and attempts at their resolution

Visual processing presumably can change in response to emotional arousal for purposes of best responding to an arousing event, as these are ones that typically have high salience and relevance to survival. This idea itself is not in dispute. However, there is an inconsistency in the literature that is of importance to resolve before drawing firm conclusions on the specific ways in which emotional arousal changes visual processing. This problem can be phrased as follows: do positive arousal and negative arousal affect visual processing in different (perhaps even dichotomous) ways, or is visual processing affected similarly by a more general state of arousal, be it positive, negative, or otherwise?

An example of this problem can be found with height estimation, which seems to change inconsistently across valences of emotional arousal. Stefanucci and Storbeck (2009) found increased overestimation of the height of a drop in subjects who viewed a selection of images from the IAPS. But importantly, that selection included both positively and negatively arousing images. This distortion is in contrast to the results of Harber et al. (2009), who showed that only negative arousal (via their self-worth manipulation) was sufficient to produce a height overestimation. Of course, it is possible that Stefanucci and Storbeck's negative images were more effective at swaying affect than the positive images, and that subjects overall had a net negative affect going in to the height-estimation task. However, it is also possible that general arousal, induced by both types of images, caused the increased overestimation. Stefanucci and Storbeck did not conduct an experiment that directly compared height estimation following positive versus negative image viewing, so this question remains open.

Some studies appear to have already resolved the problem of valence and visual processing. As reviewed above, Fredrickson and Branigan (2005) and Rowe et al. (2007) both found a widened scope of spatial attention following induction of positive affect, while Fredrickson and Branigan found the reverse pattern following negative affect. Similarly, Derryberry and Reed (1998) found a bias toward local processing in high-trait-anxious individuals during states of high state-anxiety. Several others have shown attentional orienting advantages for negative compared to positive faces, as evidenced through visual search (e.g., Fox et al., 2000) and dot-probe paradigms (e.g., Mogg & Bradley, 1999). Furthermore, exposure to neutral and positive faces did not differ in their influence on search-rate in a subsequent search task (Becker, 2009). Those results imply that visual processing and attentional mechanisms change in distinct ways depending on the valence of the emotional stimulus and are especially responsive to negative stimuli.

However, the issue becomes more puzzling when considering results from the Stroop task. To be sure, some results from the Stroop task do indeed support a narrowing of attention in negative situations. Anecdotally, the performance of tasks in front of others is typically thought to be an anxiety-provoking, and thus emotionally negative, experience. This valence seems especially validated when one considers the dual-channel hypotheses of social presence on performance (e.g., Guerin, 1986): The performer is both concerned with representing the proximity of the observer to the self for purposes of safety and with making a good impression on the observer—a goal which usually necessitates holding the self to a higher standard of performance. In accordance with what would be expected if social presence was emotionally negative, subjects have shown a marked reduction of Stroop interference in the presence of others compared to alone (Huguet, Galvaing, Monteil, & Dumas, 1999; Klauer, Herfordt, & Voss, 2008). At first, that finding seems at odds with the leading theories of social facilitation discussed earlier in this paper, namely that easier tasks are easier and harder tasks are harder in the presence of others. It is well-established that reading is a more automatic (and hence easier) process than generating and responding to a color-name (cf. MacLeod, 1991). So, should not the semantic content of the letter-string have had a greater potential for interference in the presence of others? Huguet et al. (1999) attempted to resolve this discrepancy by proposing that social presence, instead of enhancing resources to the dominant task, can be thought to narrow the focus of attention, such that irrelevant cues are filtered out. In the case of the Stroop task, a narrowed attentional focus would cause subjects to be less susceptible to the irrelevant semantic content of the letter-strings and better able to attend to the relevant color in which the letter-strings appeared.

But other results from the Stroop task suggest something different. The reduction of Stroop interference that is found in negative situations has also been found immediately following exposure to positive emotional words (Kuhl & Kazén, 1999). More specifically, Kazén and Kuhl (2005) showed that positive-achievement words (such as words related to success, solving a problem, mastery, etc.) produced a reduction in Stroop interference, but not positive-affiliation (e.g., “love,” “party”) or positive-power (e.g., “authority,” “persuasion”) words. Nevertheless, the main idea here is that words that induced positive affect caused a reduction of Stroop interference, just as social presence did. If a reduced Stroop interference effect can be explained by a narrowing of the focus of attention, and that narrowing supposedly occurs upon negative—but not positive—arousal, then how could the same reduction have been observed following exposure to positive-achievement words?

Furthermore, consider the emotional Stroop task: Here, subjects are exposed to words that are both highly negative and highly positive in the same task. Yet, emotional words, regardless of positive or negative valence, have a robust effect on performance, dramatically increasing the amount of time necessary to respond to the color relative to emotionally-neutral words. It appears, then, that attention can just as readily be captured by positive or negative emotional words as long as those words have a particular element of added salience (e.g., via their taboo nature). Perhaps half of the results (that which comes from the positive taboo words) fits with the proposed widened scope of attention during positive affect (Fredrickson & Branigan, 2005; Rowe et al., 2007), as that would presumably lead to greater interference from the semantic content of the word and thus a higher response time to the color-name. But how would those results not contradict the reduced Stroop interference effect following positive-achievement words? And how could the increased Stroop effect be explained for the negative words, when a reduced effect was found in negative situations?

The above conundrums highlight a very important point regarding emotional arousal and visual processing—one that will be returned to repeatedly throughout the present study. There seems to be a critical difference between being exposed to something that induces negative (e.g., disturbing images) or positive (e.g., positive-achievement words) affect and then performing the primary task, versus performing the primary task in concert with the emotionally arousing scenario (e.g., social presence) or when the primary stimuli themselves are emotionally arousing (as in the emotional Stroop). This difference between the consequences of affective arousal on visual processing and visual processing in the moment of affective arousal is also reflected in visual search paradigms. For example, Fox et al. (2000) found that subjects searched through displays of angry faces at a slower rate than they did for displays of happy faces, implying that subjects took longer to disengage their attention from the angry faces. On the other hand, when Becker (2009) briefly presented a fearful face, followed by a blank interval, followed by a search display of neutral objects (e.g., houses, boats, etc.), subjects searched through the display at a faster rate than when the face was happy or neutral, as if the fearful face made subjects more vigilant. Indeed, the apparent inconsistencies in the literature should not be shied away from, but rather can shed light on important (but as of yet unresolved) issues such as the time-course of visual processing alterations during and following emotional arousal. Furthermore, the collective body of literature presents the unique challenge of formulating a theory that can explain all of the observed effects of emotional arousal on visual processing.

The relationship between emotional arousal, hand-nearness, and visual processing

There are striking similarities between the ways in which emotional arousal and hand-nearness affect visual processing. Yet, until now, these bodies of literature have remained almost entirely separate. The space around a threatening stimulus is prioritized (e.g., Blanchette, 2006), as is the space around the hand (Reed et al., 2006). Phelps et al. (2006) and Bocanegra and Zeelenberg (2009) showed increased contrast sensitivity following exposure to a fearful face; Montana and Abrams (unpublished data) showed increased contrast sensitivity near the hands. Ihssen et al. (2007) showed impoverished semantic processing following exposure to emotionally arousing pictures; Davoli et al. (2010) found impoverished semantic processing near the hands. Mathewson et al. (2008) found a larger attentional blink following attention to an emotionally arousing word; Abrams et al. (2008) found a larger attentional blink near the hands. Fox et al. (2000), Gerdes, Alpers, and Pauli (2008), and Larson, Aronoff, and Stearns (2007) all found evidence for delayed disengagement from threatening stimuli in a search task; Abrams et al. (2008) found evidence for delayed disengagement from stimuli in a search task near the hands. Fox et al. (2002) showed a reduction in the inhibition of return (IOR) effect following a threatening stimulus; Abrams et al. (2008) showed a reduction in the IOR effect near the hands.

The present study

The primary purpose of the present dissertation was to investigate whether hand-nearness and emotional arousal affect visual processing through a shared cognitive mechanism. That research question was formulated through observed parallels between the ways in which hand-nearness and emotional arousal affect visual processing. Specifically, it was proposed that hand-nearness activates the emotional processing mechanism for visual processing. The present study has provided the first direct tests of that question by manipulating both hand-posture and emotional arousal in the same experiments. Emotionally negative faces are well-known inducers of emotional arousal (e.g., LeDoux, 2000; Öhman, 2002; Phelps & LeDoux, 2005) and thus were used to induce arousal in the present study.

If hand-nearness activates the emotional processing mechanism, the following prediction can be made: Viewing arousing stimuli should affect visual processing in the same ways as have been observed previously (e.g., Becker, 2009; Fox et al., 2000; Fox et al., 2002) when those stimuli are far from the hands; however, the effect of viewing arousing stimuli should be attenuated near the hands, as presumably all stimuli (arousing and non-arousing) would be processed through the emotional processing mechanism during hand-nearness.

In other words, an interaction between emotional arousal and hand-posture should be observed. However, if emotional arousal and hand-nearness do not affect visual processing through a shared mechanism, then no interaction between arousal and hand-posture should be observed. More specifically, hand-nearness should continue to have the same effects on visual processing that have been observed previously, as should emotional arousal, but should exert their influence independently of one another.

Three experiments were conducted to evaluate the relationship between emotional arousal, hand-nearness, and visual processing. All experiments were based on studies that have shown effects of emotional arousal on visual processing in the conventional (hands-far) experimental posture, but with the additional manipulation of hand-posture. Experiment 1 included a direct replication of the Fox et al. (2000) visual search study, in which slower rates of search were found through displays of emotionally negative faces. In Experiment 2, I conducted a conceptual replication of the Becker (2009) visual search study, in which it was found that brief exposure to emotionally negative faces produced faster rates of search through subsequent emotionally neutral displays. Experiment 3 included a direct replication of the Fox et al. (2002) IOR study, in which the IOR effect was substantially reduced following an angry compared to a happy or a neutral face-cue.

Chapter 3: General Method

Experimentation occurred in a dimly lit room. All stimuli were presented on a flat panel (LCD) display and were drawn in white against a black background. Viewing distance was set at 45.7 cm and maintained by a chinrest. All responses were made with two 6 cm diameter response buttons. In the hands-near posture, one response button was affixed to the left-backside of the display, and the other to the right-backside. Participants rested their arms on pillows in front of them and wrapped their hands around each side of the display, such that their fingers were in contact with the buttons. In the hands-far posture, the response buttons were affixed to either end of a 50 cm long, lightweight board. Participants held the board on their laps with their fingers in contact with the buttons. The pillows were present during the hands-far posture. The buttons were not in view during experimentation in either posture. For all of the experiments, participants completed one half of the experiment in one posture and the other half in the other posture. Posture order was counterbalanced across participants in each experiment. All participants gave informed consent prior to their participation, were debriefed after experimentation, and received course credit.

Chapter 4: Experiment 1

Experiment 1 included a replication of the Fox et al. (2000) visual-search study, in which participants searched through displays of faces and responded as to whether all of the faces were the same or one was different from the rest. As in Fox et al. (2000), the faces could have a positive or negative valence (i.e., expression). Fox et al. (2000) showed that participants searched through displays of negative faces for a lone positive face at a slower rate than they did through displays of positive faces for a lone negative face. That finding was interpreted by Fox et al. (2000) to show that people search through negative items at a slower rate compared to positive items.

Additionally, the present experiment included a manipulation of hand-proximity. All participants performed the Fox et al. (2000) task in both the hands-near and the hands-far postures. It has previously been shown that search-rate is slowed when visual search occurs near the hands (e.g., Abrams et al., 2008). The goal of Experiment 1 was to examine whether hand-posture interacted with the effects of emotional arousal—induced in participants by having them view emotionally charged faces—on visual processing. Furthermore, Experiment 1 provided the opportunity to explore the effects of emotional arousal on visual search when the search stimuli themselves induced arousal. This is in contrast to Experiment 2, which explored searches through emotionally neutral stimuli, with emotional arousal induced prior to the search.

Method

Participants. Fifty experimentally naïve Washington University undergraduates participated in the experiment. Participation lasted approximately 45 minutes.

Stimuli, procedure, and design. An example of the trial events is depicted in Figure 1. On each trial, participants were presented with a central cross (1.19° high x 1.19° wide). After 500 ms, a display of faces was presented. Each face could appear at one of eight possible equally-spaced locations that formed an imaginary circle around the central cross. The distance from the central cross to the center of each face was 10.54°. The faces (6.96° high x 5.96° wide) could either be of positive or negative emotional valence. The only difference between the positive and negative faces was the direction of the mouth, depicting a smile or a frown, respectively (see Figure 2). On half of the trials, all of the faces were of the same emotional valence (i.e., all positive or all negative; equal number of trials of each); those were considered target-absent trials. On the other half, one face was different from the others (i.e., one positive amongst a group of negative, or one negative amongst a group of positive; equal number of trials of each); those were considered target-present trials. On half of the trials, there were four total faces in the display; on the other half, there were eight. It was randomly determined at which of the fixed locations each face appeared (though on trials with eight faces, all locations were of course occupied). Participants' task on each trial was to indicate as quickly and as accurately as possible whether all of the faces in the display were the same (i.e., target absent), or whether one face was different from the rest (i.e., target present). The assignment of the response

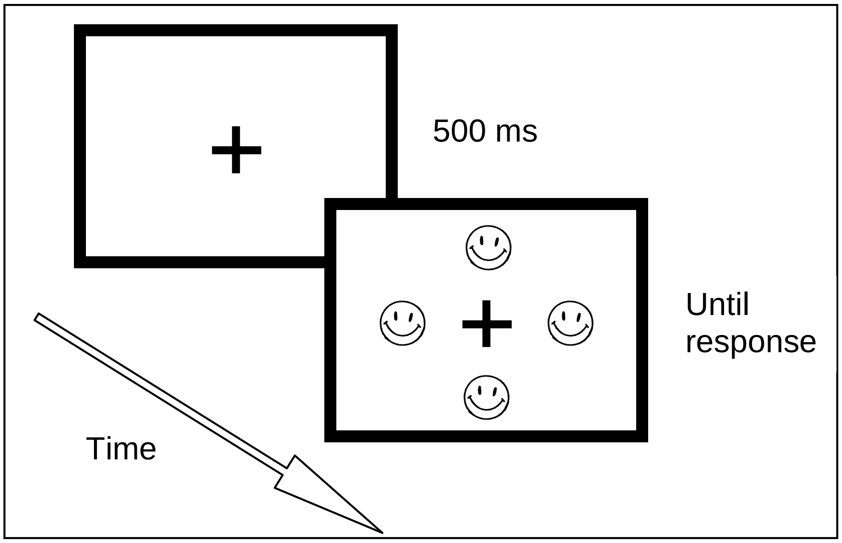


Figure 1. An example of the trial events of Experiment 1. Participants made responses as to whether all the faces in the display were the same or whether one was different from the rest. Not to scale.

buttons to “same” or “different” was counterbalanced across participants. The display remained onscreen until response or until 3 s had passed. Error messages were presented if participants pressed the wrong button, responded too quickly (< 100 ms), or did not respond within 3 s. There was a 1.5 s inter-trial interval.

A 2 (display size: 4, 8) x 2 (target presence: absent, present) x 2 (distractor type: negative, positive) x 2 (hand-posture: near, far) within-subjects design was used. Participants completed three blocks of 80 trials each per hand-posture for a total of 480 experimental trials (30 observations per unique condition). There was a break at the end of each block. Participants received 20 practice trials at the beginning of the experiment.

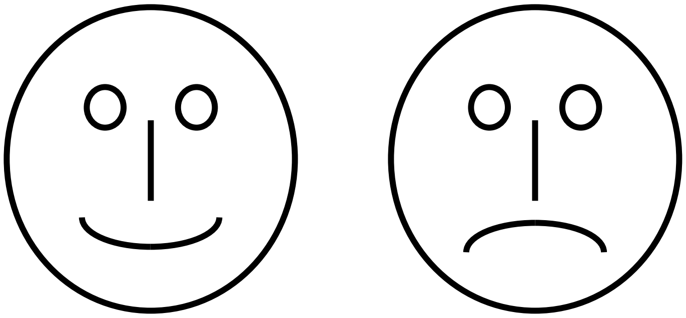
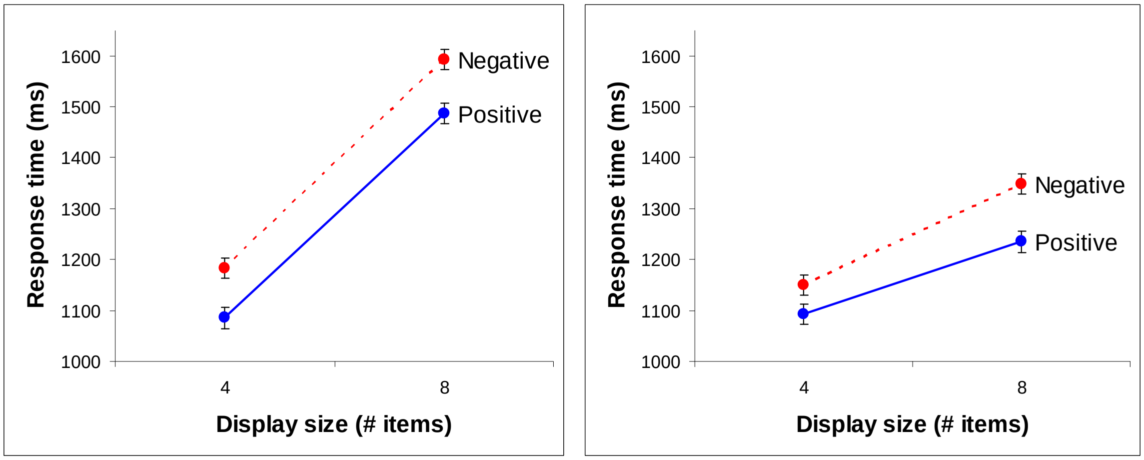


Figure 2. Face stimuli depicting positive and negative expressions, respectively, used in Experiment 1. Not to scale.

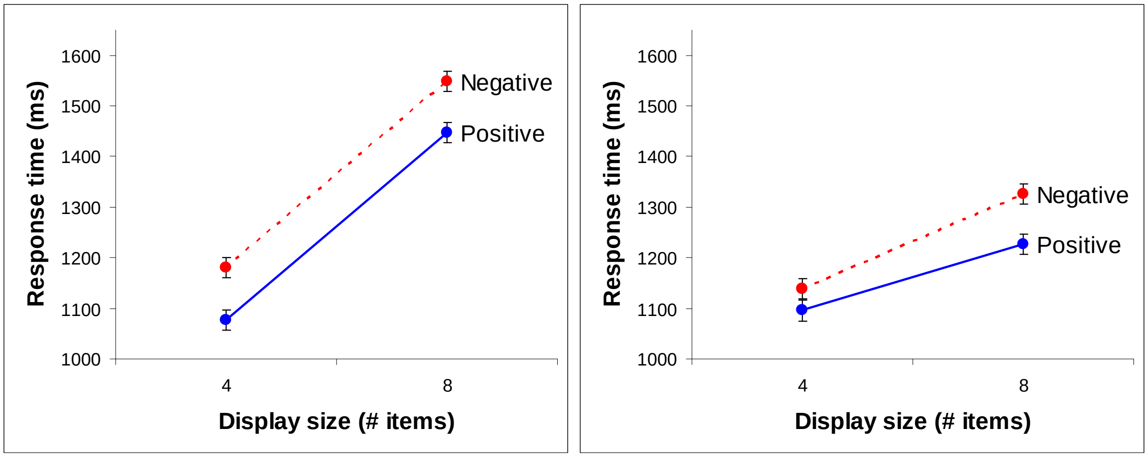
Results & Discussion

Two participants were excluded from the analysis because of excessive error-rates (>20%) and one participant was excluded from the analysis because of an equipment malfunction. Mean response times can be seen in Figure 3. The response time data were submitted to a 2 (display size: 4-face, 8-face) x 2 (target presence: absent, present) x 2 (distractor type: negative, positive) x 2 (hand-posture: near, far) repeated-measures analysis of variance (ANOVA). Significant main effects of display size, distractor type, and target presence were found. Participants responded more quickly to displays containing four compared to eight faces, $F(1, 46) = 269.94$, $p < .001$, $\eta_p^2 = .85$; this finding is indicative of a serial search process (Treisman & Gelade, 1980). Participants were faster to respond to displays containing positive compared to negative distractors, $F(1, 46) = 103.76$, $p < .001$, $\eta_p^2 = .69$. Participants responded more quickly to target-present compared to target-absent displays, $F(1, 46) = 73.57$, $p < .001$, $\eta_p^2 = .62$.



Hands-near, target-absent

Hands-near, target-present



Hands-far, target-absent

Hands-far, target-present

Figure 3. Mean response times in Experiment 1. Data points for all combinations of display size, target presence, distractor type, and hand-posture are shown. Error bars represent the within-subjects 95% confidence intervals.

In terms of interactions, display size interacted with target presence, $F(1, 46) = 255.36$, $p < .001$, $\eta_p^2 = .85$. Participants searched through target-present displays at a rate of 41.2 ms/item, but searched through target-absent displays at a rate of 96.8 ms/item. That finding is indicative of a self-terminating search process, explained as follows: Participants had to search through all faces when no discrepant face (target) was present to confidently make a “same” response. However, when a target was present, participants only had to search through as few as two items in the display (and thus on average fewer items than in “same” displays) before they could confidently make a “different” response. This is because the target could appear at any location with equal likelihood. Thus, participants presumably terminated their searches at the moment they could make an accurate response. The self-terminating search phenomenon has been observed repeatedly throughout the visual-search literature (Wolfe, 1998). Display size also interacted with distractor type, $F(1, 46) = 15.53$, $p < .001$, $\eta_p^2 = .25$. Participants searched through displays containing positive distractors at a faster rate (65.2 ms/item) compared to displays containing negative distractors (72.8 ms/item).

More importantly, there was a significant display size x target presence x distractor type interaction, $F(1, 46) = 8.34$, $p < .01$, $\eta_p^2 = .15$. That interaction can be most easily conceptualized by using the rate of search as the dependent variable (which is calculated by dividing the change in response time by the change in display size for the condition(s) of interest). As can be seen in Figure 4, for target-absent displays, the rate of search did not differ between displays containing positive (96.3 ms/item) or negative (97.3 ms/item) distractors, $t(46) = .32$, $p = .75$. For target-present displays, however, the rate of search was faster when there was one negative target among positive distractors (34.0 ms/item) compared to one positive target among negative distractors (48.3 ms/item), $t(46)$

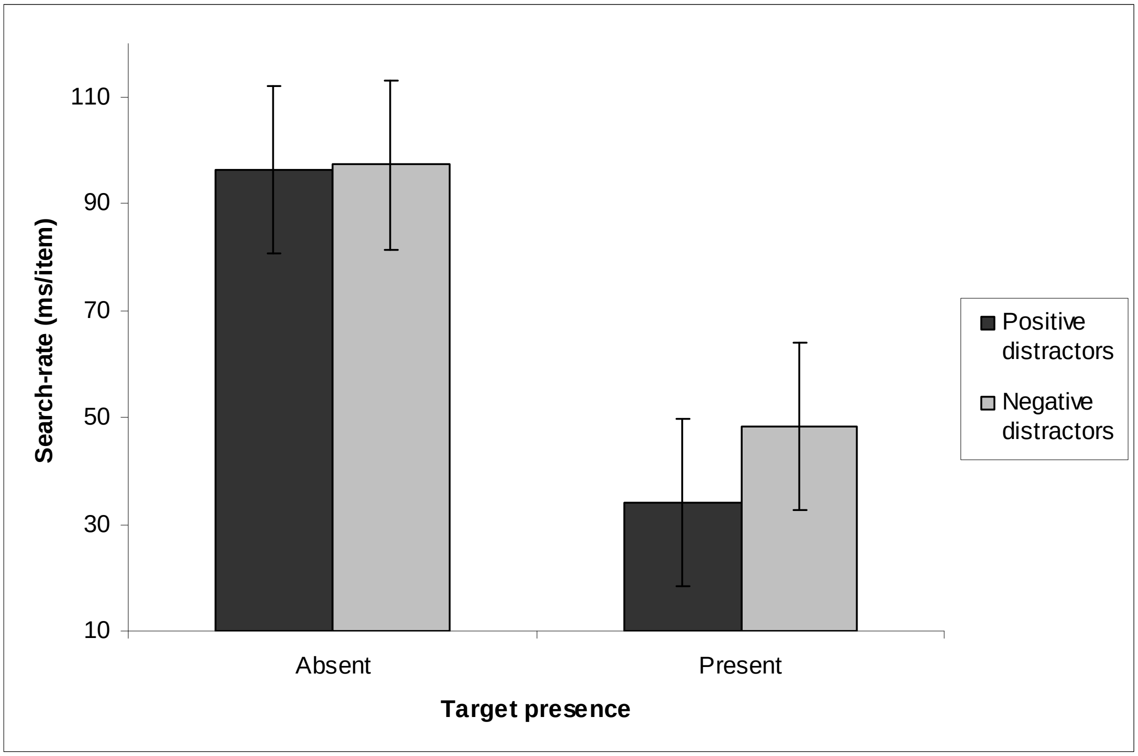


Figure 4. Search-rate as a function of target presence for positive- and negative-distractor displays in Experiment 1. Error bars represent the within-subjects 95% confidence intervals.

= 4.76, $p < .001$. The 3-way interaction found here replicates the most important finding of Fox et al. (2000; Exp. 5): participants were slower to search through displays of negative faces for one positive face compared to displays of positive faces for one negative face.

Turning to the remaining key variable, response times did not differ across hand-posture, $F < 1$, consistent with previous studies that have used a similar hand-posture manipulation in a visual-search task (e.g., Abrams et al., 2008). Nevertheless, hand-posture interacted with display size as can be seen in Figure 5, $F(1, 46) = 4.06$, $p < .05$, $\eta_p^2 = .08$. Participants searched more slowly through displays that were near to (72.0 ms/item) compared to far from (66.0 ms/item)

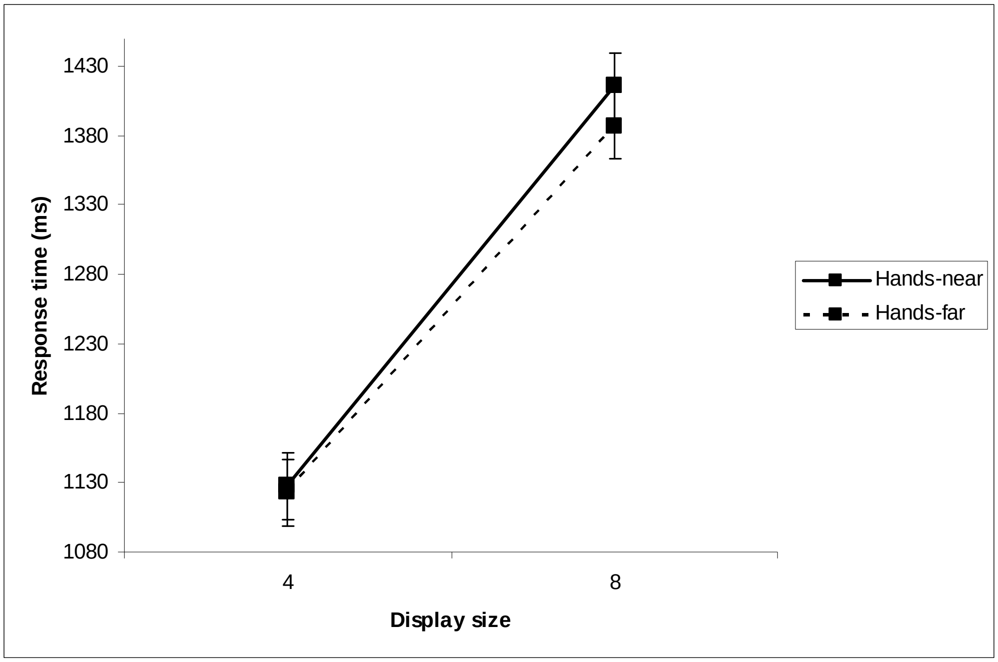
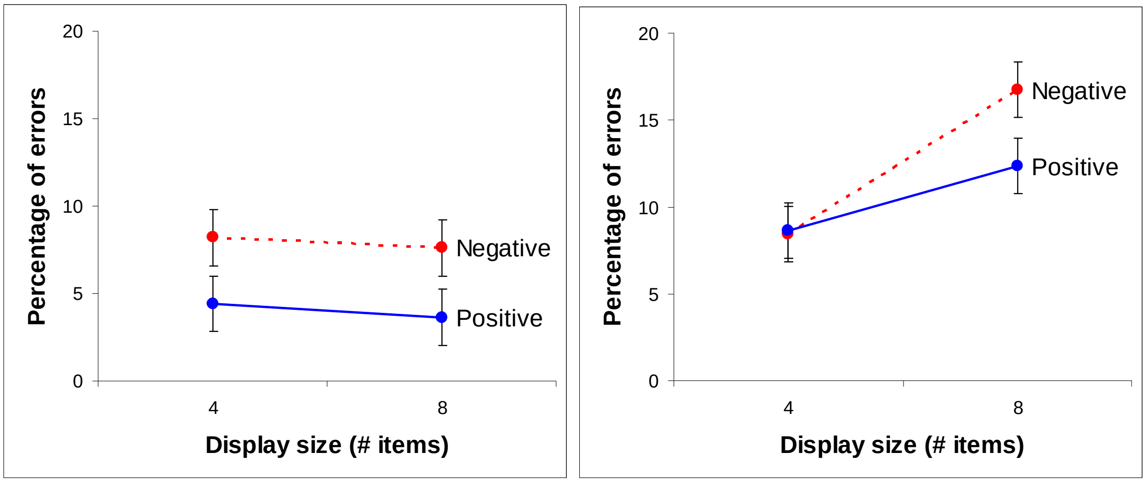


Figure 5. Response time as a function of display size across hand-postures for Experiment 1. Error bars represent the within-subjects 95% confidence intervals.

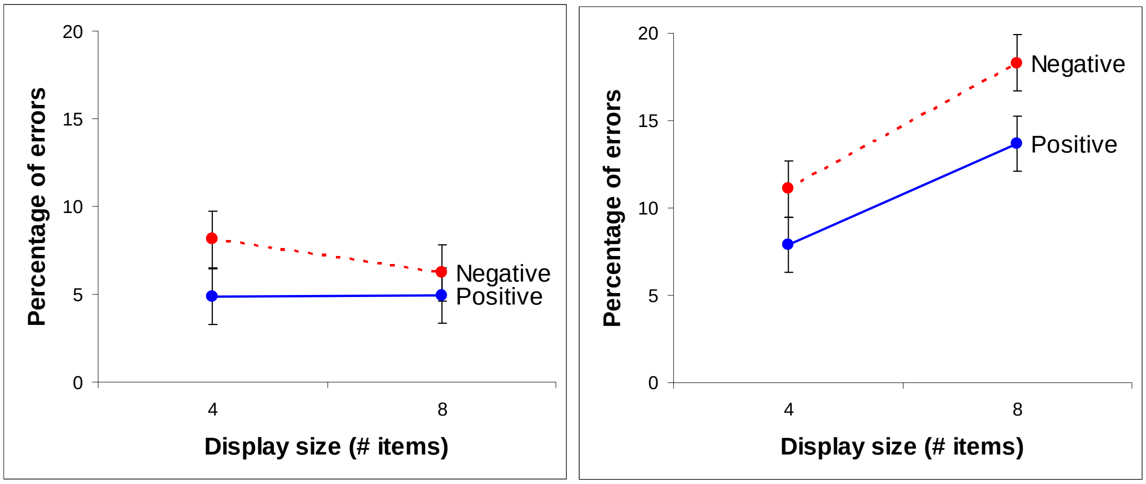
their hands, consistent with previous findings of slowed search near the hands (Abrams et al., 2008; Davoli & Abrams, 2009). Hand-posture did not interact with any other factor, all *F*s < 1.61, all *p*s > .21 (Figure 3).

Mean error percentages can be seen in Figure 6. Error percentage data were submitted to a 2 (display size: 4-face, 8-face) x 2 (target presence: absent, present) x 2 (distractor type: negative, positive) x 2 (hand-posture: near, far) repeated-measures analysis of variance (ANOVA). The overall error rate was 9.1%. Participants had a lower error percentage on 4-face compared to 8-face trials, $F(1, 46) = 25.41$, $p < .001$, $\eta_p^2 = .36$. Participants had a lower error percentage on target-absent compared to target-present trials, $F(1, 46) = 68.76$,



Hands-near, target-absent

Hands-near, target-present



Hands-far, target-absent

Hands-far, target-present

Figure 6. Mean error percentages for Experiment 1. Data points for all combinations of display size, target presence, distractor type, and hand-posture are shown. Error bars represent the within-subjects 95% confidence intervals.

$p < .001$, $\eta_p^2 = .60$. Participants had a lower error percentage on trials with positive compared to negative distractors, $F(1, 46) = 34.44$, $p < .001$, $\eta_p^2 = .43$.

Display size and target presence interacted, $F(1, 46) = 45.75$, $p < .001$, $\eta_p^2 = .50$. For target-absent displays, error percentage showed a minor decrease from 4-face to 8-face displays; however, for target-present displays, error percentage increased substantially from 4-face to 8-face displays. There was a significant display size x target presence x distractor type interaction, *F*(1, 46) = 10.52, $p < .005$, $\eta_p^2 = .19$. The difference between error percentages for negative- versus positive-distractor displays decreased from 4-face to 8-face displays when a target was absent, but increased when a target was present.

The target presence x distractor type x hand-posture interaction showed a non-significant trend, *F*(1, 46) = 3.55, $p = .066$, $\eta_p^2 = .07$. The difference between error percentages for target-present versus target-absent displays increased slightly from negative- to positive-distractor displays in the hands-near posture, but decreased slightly in the hands-far posture. The display size x distractor type x hand-posture interaction showed a non-significant trend, *F*(1, 46) = 3.16, $p = .082$, $\eta_p^2 = .06$. The difference between error percentages for positive- versus negative-distractor displays increased slightly from 4-face to 8-face displays in the hands-near posture, but decreased slightly in the hands-far posture. On the whole, however, the error percentage data do not challenge any of the conclusions derived from the response time data—namely, that hand-proximity, though altering overall search-rate, did not modulate the extent to which the emotional content of the stimuli affected performance.

The present experiment revealed that participants were slower to search for a positive face amongst negative faces than for a negative face amongst positive faces. As search-rate can be indicative of the speed with which attention disengages from a stimulus (e.g., Wolfe, 1998), slowed rates of search through displays of predominantly negative faces suggest that participants were delayed in disengaging from negative stimuli. That finding directly replicates the most critical finding of Fox et al. (2000, Exp. 5).

Most importantly for present purposes, however, was that hand-posture did not modulate the extent to which the emotional content of the stimuli affected search-rate. Although search-rate was slowed near the hands, replicating previous findings (e.g., Abrams et al., 2008), hand-posture affected search-rate entirely independently of the emotional content of the displays.

Slowed rates of visual search have been found both when participants hold their hands near a search display (Abrams et al., 2008) and when participants search through emotionally arousing stimuli (Fox et al., 2000). Indeed, both of those effects were observed in the present experiment. Hand-nearness and emotional arousal have several other similar effects on visual processing, including reduced IOR (Abrams et al., 2008; Fox et al., 2002), impoverished semantic processing (Davoli et al., 2010; Ihssen et al., 2007), and more pronounced attentional blink (Abrams et al., 2008; Mathewson et al., 2008). The purpose of the present dissertation was to explore whether those similarities are indicative of hand-nearness activating the emotional processing mechanism, and thus of a shared mechanism through which hand-nearness and emotional arousal affect visual processing. The absence of an interaction between hand-posture and emotional arousal on performance in Experiment 1 suggests that hand-nearness and arousal influence visual processing through separate mechanisms.

In the present experiment, emotional arousal was induced during the primary task, as the search stimuli were themselves emotionally expressive (cf. LeDoux, 2000; Öhman, 2002; Phelps & LeDoux, 2005). While the emotional valence of the distractor faces did influence search performance, the observed effects did not depend upon whether the hands were held near to or far from the search display. Thus, the proximity of the hands to emotional stimuli did not make a difference in how emotional arousal affected visual processing.

Chapter 5: Experiment 2

Experiment 2 included a conceptual replication of the Becker (2009) visual-search study. In Becker's study, participants were briefly shown a neutral, happy, or angry face. Shortly afterward, they searched through displays of emotionally neutral images for the presence of a target-image (a house). In the present experiment, participants were presented with a neutral, happy, or angry face. Shortly afterwards, they searched through displays of emotionally neutral items (letters) for the presence of a target letter. Additionally, the present experiment included a manipulation of hand-posture. All participants performed the search task in both the hands-near and the hands-far postures.

Becker found that participants exhibited faster rates of search following exposure to a fearful face compared to neutral or happy faces. It has previously been shown that search-rate is slowed when visual search occurs near the hands (e.g., Abrams et al., 2008). The goal of Experiment 2 was to examine whether hand-posture interacts with the effects of emotional arousal—induced in participants by having them view emotionally charged faces—on visual processing. Furthermore, in Experiment 2 emotional arousal was induced prior to the onset of the search display, which was composed of emotionally neutral items. This is in contrast to Experiment 1, in which arousal was induced during the search task by the stimuli themselves. Thus, Experiment 2 provided the opportunity to explore the effects of arousal on the subsequent processing of neutral stimuli.

Method

Participants. Thirty-three new experimentally naïve Washington University undergraduates participated in the experiment. Participation lasted approximately 50 minutes.

Stimuli, procedure, and design. An example of the trial events can be seen in Figure 7. On each trial, participants were presented with a “Ready” prompt at the center of the screen. After 750 ms, the prompt was replaced with a face. After 300 ms, the face was replaced with a central cross (1.19° high x 1.19° wide). After 600 ms, a display of letters was presented. Each letter could appear at one of eight possible equally-spaced locations that formed an imaginary circle around the central cross. The distance from the central cross to the center of each letter was 9.94°. On half of the trials, a target letter ‘H’ was presented amongst distractor letters ‘E’ and ‘U’. On the other half, only distractor letters were presented. The identities of the distractor letters were randomly selected. All letters were formed by removing two line segments from a block figure-eight and were 5.96° high x 2.98° wide. On half of the trials, there were four total letters in the display; on the other half, there were eight. It was randomly determined at which of the fixed locations each letter appeared (though on trials with eight letters, all locations were of course occupied). Participants’ task on each trial was to respond as quickly and as accurately as possible whether the target letter ‘H’ was present in or absent from the display. The assignment of the response buttons to “present” or “absent” was counterbalanced across participants. The display remained onscreen until response or until 2 s had passed. Error messages were presented if participants pressed the wrong button, responded

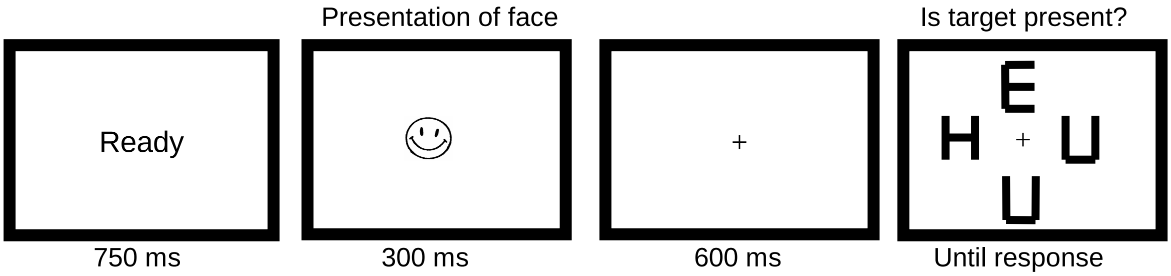


Figure 7. An example of the trial events of Experiment 2. Participants were briefly presented with a face of varying emotional valence, followed by a blank interval, followed by a search display in which they had to indicate the presence of a target-letter H. Not to scale.

too quickly (< 100 ms), or did not respond within 2 s. There was a 500 ms inter-trial interval.

The face (6.96° high x 5.96° wide) that appeared in the second frame of each trial could have a neutral, happy, or angry expression (Figure 8). Facial expression was blocked (in accordance with the design of Becker, 2009), and the same order of expression was used for both hand-postures per participant (e.g., a participant who started in the hands-far condition and received neutral faces in the first block, happy in the second, and angry in the third would receive that same order of neutral/happy/angry in the hands-near condition). Order of expression was counterbalanced across the first 24 participants and then randomly selected (without replacement) for the final nine.

A 2 (display size: 4, 8) x 2 (target presence: present, absent) x 3 (facial expression: neutral, happy, angry) x 2 (hand-posture: near, far) within-subjects design was used. There were three blocks (one for each facial expression) of 120 trials each per hand-posture, for a total of 720 experimental trials (30

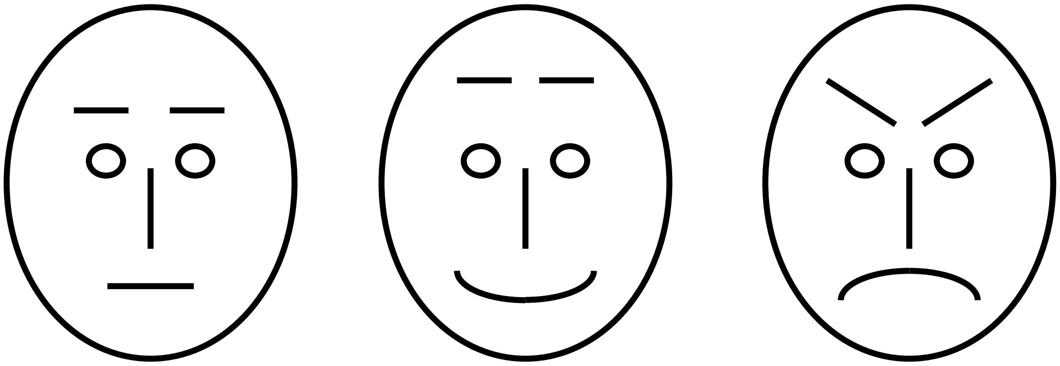


Figure 8. Face stimuli depicting neutral, happy, and angry expressions, respectively. The same faces were used in Experiment 2 and 3. Not to scale.

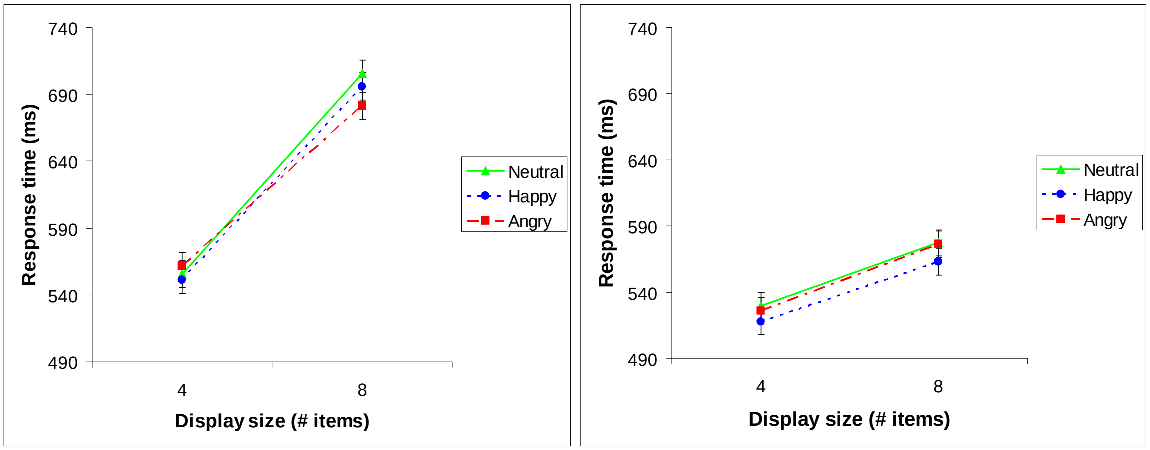
observations per unique condition). There was a break at the end of each block. Participants received 10 practice trials at the beginning of the experiment.

The method used here differed from that of Becker (2009) in the following ways: (1) The search display consisted of letters instead of emotionally neutral pictures because of the experimental control that relatively simple stimuli offer over complex images, and because we (Abrams et al., 2008; Davoli & Abrams, 2009) have previously used letters as stimuli in studies of hand-proximity and visual search; (2) There were two levels of display size (4 and 8) instead of three (3, 6, and 9) so that an experimental session could be completed within one hour; (3) The faces were line-drawings instead of pictures because line-drawings were more compatible with the programming language used for the present dissertation; (4) Angry faces were used instead of fearful faces because a line-drawing of an angry expression was thought to be less emotionally ambiguous than a fearful expression, which could be interpreted as surprise, shock, worry, or other emotions that have expressions resembling fear.

Results & Discussion

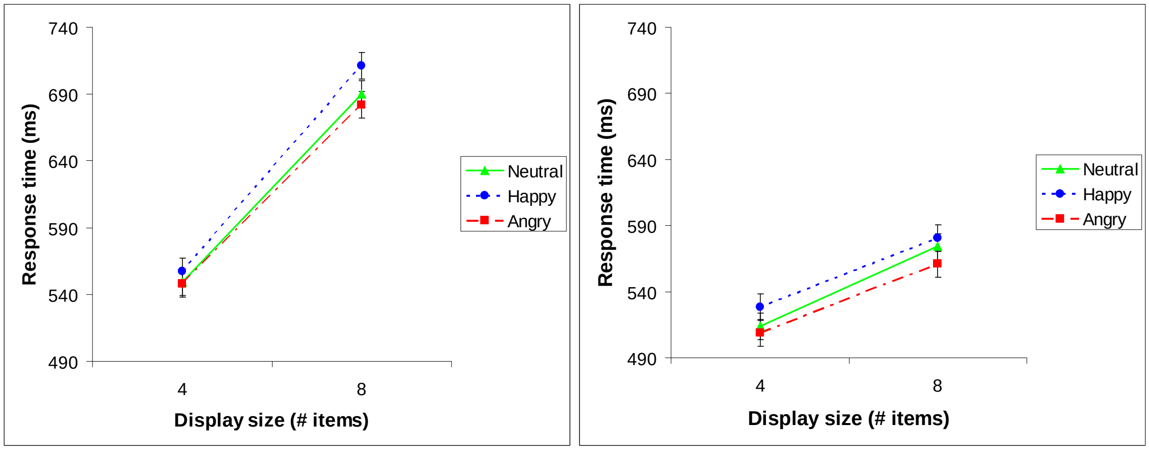
Mean response times are shown in Figure 9. The response time data were submitted to a 2 (display size: 4-letter, 8-letter) x 2 (target presence: present, absent) x 3 (facial expression: neutral, happy, angry) x 2 (hand-posture: near, far) repeated-measures ANOVA. Significant main effects of display size and target presence were found. Participants overall responded more quickly to displays containing four compared to eight letters, $F(1, 32) = 59.01$, $p < .001$, $\eta_p^2 = .65$, indicative of a serial search process (Treisman & Gelade, 1980). Participants responded more quickly to target-present compared to target-absent trials, $F(1, 32) = 86.59$, $p < .001$, $\eta_p^2 = .73$.

In terms of interactions, there was a display size x target presence interaction, $F(1, 32) = 47.57$, $p < .001$, $\eta_p^2 = .60$: participants searched through target-present displays at a rate of 12.78 ms/item, but searched through target-absent displays at a rate of 35.14 ms/item. This is indicative of a self-terminating search process (Wolfe, 1998). The display size x target presence interaction occurred within the context of a facial expression x display size x target presence interaction, $F(2, 64) = 3.25$, $p < .05$, $\eta_p^2 = .09$. That interaction can be most easily conceptualized by using search-rate as the dependent variable. As shown in Figure 10, on target-present trials, the rate of search barely changed across facial expression (neutral: 13.4 ms/item; happy: 12.1 ms/item; angry: 12.8 ms/item). On target-absent trials, however, search-rate decreased substantially when the face was angry (neutral: 36.4 ms/item; happy: 37.4 ms/item; angry: 31.7 ms/item).



Hands-near, target-absent

Hands-near, target-present



Hands-far, target-absent

Hands-far, target-present

Figure 9. Mean response times for Experiment 2. Data points for all combinations of display size, target presence, facial expression, and hand-posture are shown. Error bars represent the within-subjects 95% confidence intervals.

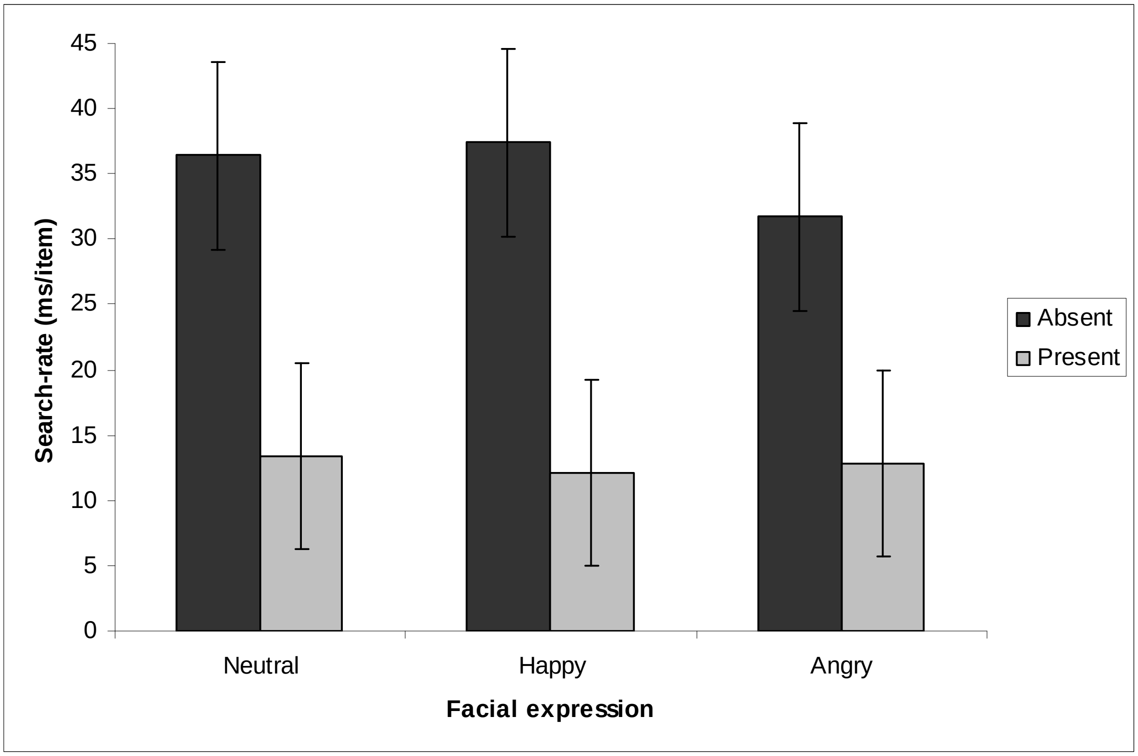


Figure 10. Search-rate as a function of facial expression across the two levels of target presence; Experiment 2. Error bars represent the within-subjects 95% confidence intervals.

Turning to the remaining key variable, response times did not differ across hand-posture, *F* < 1, which is consistent with the findings of Exp. 1 and previous studies (e.g., Abrams et al., 2008). However, hand-posture and display size did not interact, *F* < 1. This result seems to be inconsistent with the slowing of search found near the hands in Experiment 1 and in previous studies (Abrams et al., 2008; Davoli & Abrams, 2009). Interestingly, however, hand-posture did interact with facial expression, $F(2, 64) = 3.75$, $p = .029$, $\eta_p^2 = .11$. As can be seen in Figure 11, facial expression had little effect on response time near the hands, but a larger effect when the hands were far from the stimuli. Specifically, response times decreased from happy- to angry-face trials when the hands were far [*t*(32)

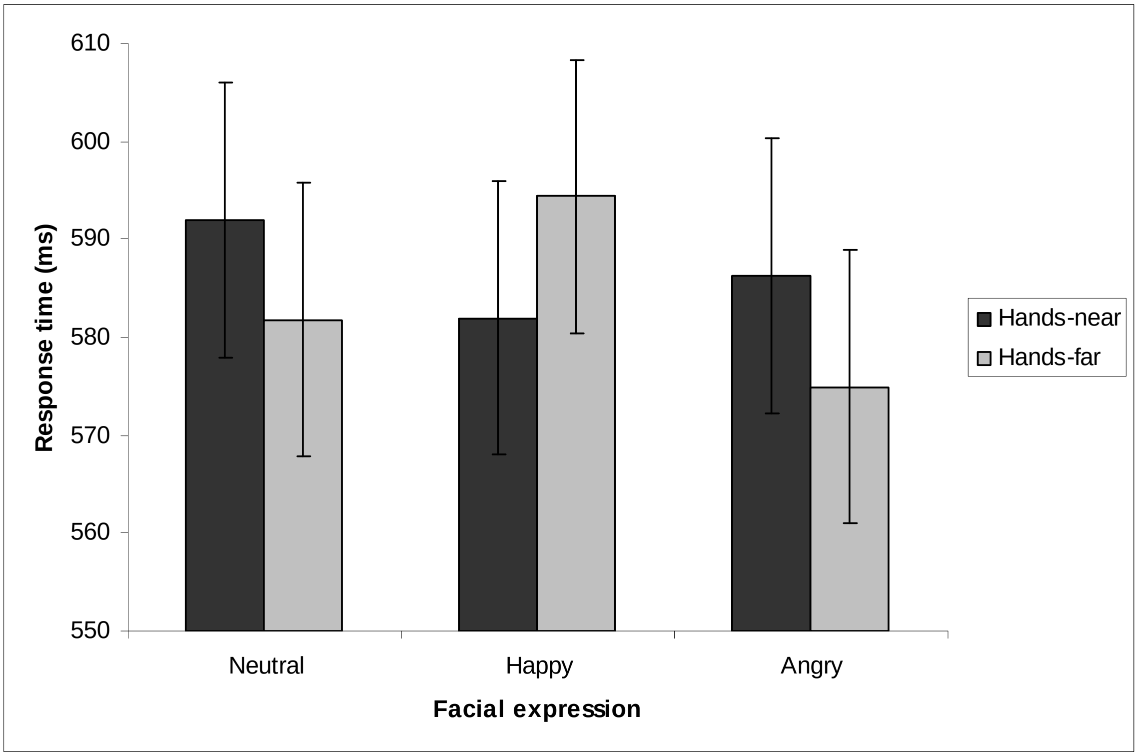
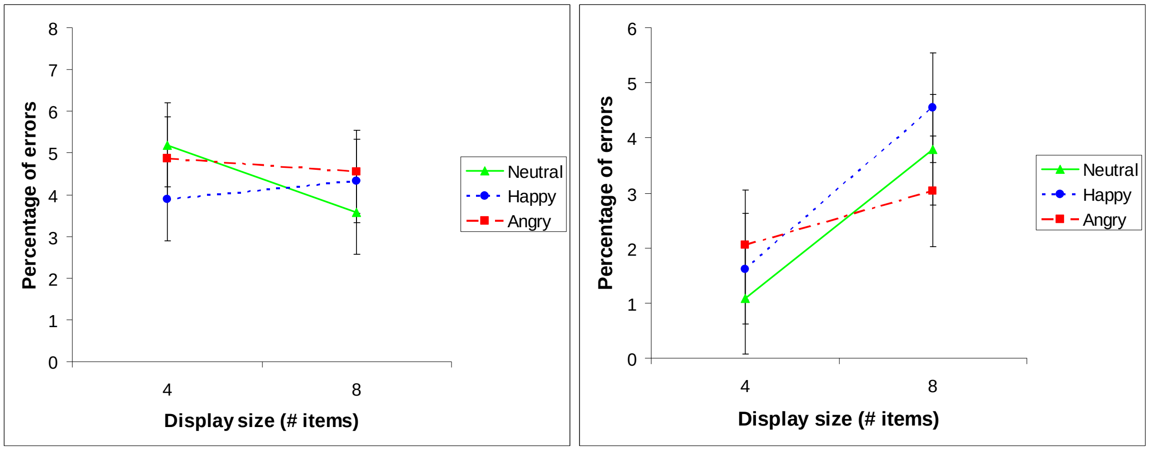


Figure 11. Response time as a function of facial expression for the hands-near and hands-far postures; Experiment 2. Error bars represent the within-subjects 95% confidence intervals.

= 1.95, *p* = .060; 19.42 ms difference]. Although that trend was non-significant, there was a small-to-moderate effect size, η_p^2 = .34. On the other hand, response times did not change when the hands were near [*t*(32) = .69, *p* = .50; 4.29 ms difference]. There was no reliable difference in response times to neutral-face trials between hand-postures, *t*(32) = .82, *p* = .42. If data from the neutral-face trials are removed from the analysis, there is still a significant hand-posture x facial expression interaction, *F*(1, 32) = 5.39, *p* = .027, η_p^2 = .14. Finally, the display size x target presence x facial expression x hand-posture interaction was not significant, *F*(2, 64) = 1.50, *p* = .23, η_p^2 = .045.

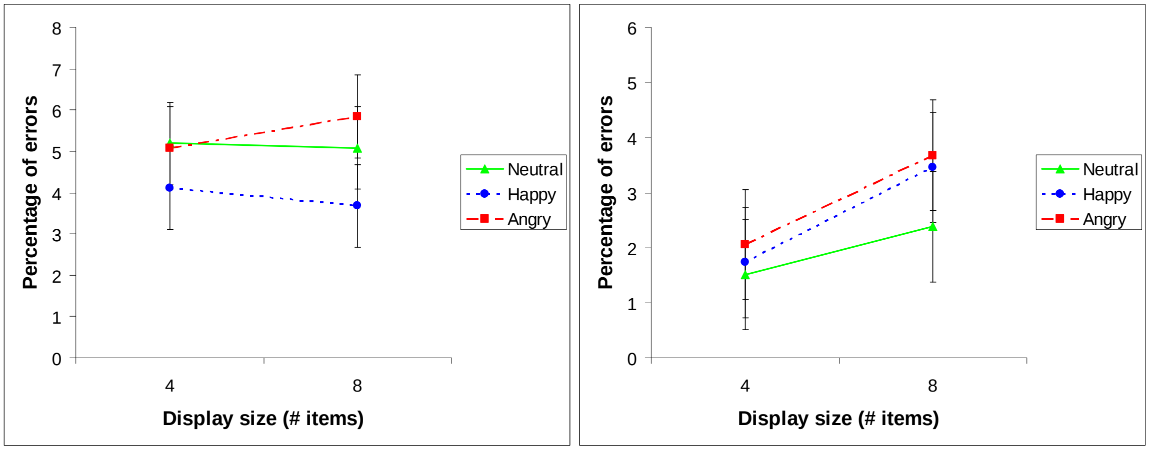
Mean error percentages are shown in Figure 12. The error percentage data were submitted to a 2 (display size: 4-letter, 8-letter) x 2 (target presence: present, absent) x 3 (facial expression: neutral, happy, angry) x 2 (hand-posture: near, far) repeated-measures ANOVA. The overall error rate was 3.6%. Participants made more errors on 8-letter compared to 4-letter displays, $F(1, 32) = 5.57$, $p = .025$, $\eta_p^2 = .15$. Participants made more errors on target-absent compared to target-present trials, $F(1, 32) = 30.57$, $p < .001$, $\eta_p^2 = .49$. Display size and target presence interacted, $F(1, 32) = 8.05$, $p < .01$, $\eta_p^2 = .20$: On target-present trials, the percentage of errors increased from 4-letter to 8-letter displays; however, on target-absent trials, the percentage of errors did not change across display sizes. The interaction between facial expression and target presence showed a non-significant trend, $F(2, 64) = 2.55$, $p = .086$, $\eta_p^2 = .08$: Error percentage was lowest for neutral faces and roughly equivalent for happy and angry faces on target-present trials; on the other hand, error percentage was lowest for happy faces and roughly equivalent for neutral and angry faces on target-absent trials. On the whole, the results of the error percentage ANOVA do not affect the interpretations of the response time data.

Becker (2009) found that search-rates for target-present trials following fearful faces were faster (31.5 ms/item) than those following happy (46.6 ms/item) or neutral (40.4 ms/item) faces. In the present experiment, however, search-rates for target-present trials in the hands-far condition (i.e., the closest to a direct replication of Becker’s experiment) only showed a very slight increase from angry (13.0 ms/item) to happy (13.1 ms/item) to neutral (15.0 ms/item)



Hands-near, target-absent

Hands-near, target-present



Hands-far, target-absent

Hands-far, target-present

Figure 12. Mean error percentages for Experiment 2. Data points for all combinations of display size, target presence, facial expression, and hand-posture are shown. Error bars represent the within-subjects 95% confidence intervals.

faces. Similarly, search-rates for target-present trials in the hands-near condition remained stable across facial expression (angry: 12.8 ms/item; happy: 12.1 ms/item; neutral: 13.4 ms/item). Those results do not replicate Becker's findings. However, it should be noted that all search-rates for target-present trials found here were quite fast compared to those of Becker and to typical serial search rates (Wolfe, 1998). Thus, it is possible that when a target was present in the display, the task was simply too easy to reveal any differences based on facial expression.

The pattern of search-rates across facial expressions for target-absent trials resembled that found by Becker (2009) for target-present trials (Figure 10). Collapsed across hand-posture, search was faster following angry (31.7 ms/item) compared to happy (37.4 ms/item) or neutral (36.4 ms/item) faces. Unfortunately, Becker did not report search-rates for target-absent trials, so direct comparisons to the present target-absent search-rates cannot be made. However, there is no reason to presume that search in the present experiment was being conducted differently depending on target presence, as participants were not aware of that attribute of the search display until their search was concluded.

More information can be gleaned by inspecting the response time data (collapsed across display size and target presence) from the present experiment (Figure 11). Here, the pattern of results from the hands-far condition does seem to resemble the pattern observed by Becker (2009) in his search-rates: Faster responses following exposure to angry faces compared to happy faces. Most interestingly, however, that pattern was not observed in the hands-near condition, where overall response times were much less influenced by facial expression. Thus, the emotional content of a stimulus made a difference in how participants subsequently processed a neutral display, but only when their hands were far from the emotional stimulus and not when their hands were near it.

The findings of Experiment 2 support the contention that hand-nearness and emotional arousal affect some aspects of visual processing through a shared mechanism. Specifically, angry faces produced speeded responses in the hands-far condition (as expected) but not in the hands-near condition. Rather, when the hands were held near to the stimuli, the emotional valence of the face had little effect on response time. That pattern of results is consistent with the contention that hand-nearness activates the emotional processing mechanism for visual processing. Why might that happen? Objects near the hands are important, as they often consist of items we wish to use or obstacles we must avoid. Furthermore, nearby objects are necessarily more able to be interacted with (or are more imperative to avoid) than those located far away. One possibility, then, is that nearby objects have such importance regarding goal-achievement (e.g., eating) and protection (e.g., preventing collision) that they may be treated as emotionally salient and thus may receive the same visual processing benefits as emotional stimuli. This theory will be elaborated on in the General Discussion.

Importantly, the conclusion drawn here of a shared mechanism between hand-nearness and emotional arousal differs from the conclusion drawn after Experiment 1. The results of Experiment 1 showed that hand-posture and emotional arousal independently affected behavior when arousal was induced during the search task. Hand-nearness slowed search-rate as has previously been observed (Abrams et al., 2008), and searching through displays of emotionally negative faces slowed search rate as also has previously been observed (Fox et al., 2000). However, hand-posture and emotional arousal did not interact—inconsistent with the contention that hand-nearness and emotional arousal affect visual processing through a shared mechanism. What might be responsible for producing the apparent contradiction between experiments?

A critical distinction between Experiments 1 and 2 involves a pair of questions raised in Chapter 2: (1) What happens to visual processing of emotionally neutral stimuli when the observer is emotionally aroused? and, (2) Is the processing of emotional stimuli at all different from that of non-emotional stimuli?. The important difference between those two questions is whether one is interested in visual processing of arousing stimuli or visual processing of neutral stimuli while aroused. An inspection of prior research shows that such a distinction can be important to consider when taking into account seemingly disparate effects. For example, there is a highly reliable increase in Stroop interference when the critical stimulus is an emotional word (e.g., Williams et al., 1996), but a sizeable reduction in Stroop interference for emotionally neutral color-words when participants perform the task in anxiety-producing situations (e.g., Huguet et al., 1999). On the surface, those studies appear to offer contradictory conclusions: Stroop interference can be increased or reduced by emotional arousal. However, it seems to be the case that visual processing of emotional stimuli is different from visual processing of neutral stimuli while in a state of arousal.

That methodological difference is presumably the explanation for why Fox et al. (2000) found slowed rates of search through emotionally negative displays, but Becker (2009) found speeded rates of search following the presence and removal of an emotionally negative face. As Experiments 1 and 2 of the present dissertation included replications of the Fox et al. (2000) and Becker methods, respectively, it is perhaps not surprising that such different effects of hand-posture were observed. Specifically, it was found that hand-nearness did not attenuate the effects of emotional arousal in the presence of emotional stimuli, but did modulate how a neutral environment was processed following the presence and removal of an emotional stimulus. Why this might be is addressed in the General Discussion.

Experiments 1 and 2 examined how hand-posture and emotional arousal affected visual search. In Experiment 3, the effects of those factors on another visual attentional behavior was studied, specifically disengagement of attention, as revealed by the IOR paradigm.

Chapter 6: Experiment 3

Experiment 3 included a replication of the Fox et al. (2002) inhibition of return (IOR) study. The basic IOR paradigm is an extension of a standard cuing task, in which two visual events (a cue and a target) are presented in succession (Posner & Cohen, 1984). However, unlike the standard cuing task in which the cue and the target are separated by a short delay (<300 ms), the cue and target in the IOR paradigm are separated by a longer delay (>600 ms). During that longer delay, spatial attention disengages from the cued location (as the cue is uninformative of the target location) and moves back towards the center of the display, characteristically resulting in faster response times to targets appearing in the uncued location (e.g., Klein, 2000). That pattern of results is the typical IOR effect, in which participants are inhibited from returning to a previously attended (i.e., cued) location. Thus, measurements of IOR are indicative of the extent to which attention has disengaged from the cue (Abrams et al., 2008; Klein, 2000).

The IOR paradigm was extended by Fox et al. (2002) to examine the influence of emotionally arousing cues on responses to neutral targets. They used faces with angry, happy, or neutral facial expressions as cues, and found that the IOR effect was dramatically reduced following an angry compared to a happy or neutral cue. Fox et al. (2002) proposed that the reduced IOR was attributable to attention being “stuck” at the location of the negative stimulus. That is, participants were unable to disengage their attention from that location, presumably because an angry face is a highly salient object that demands prolonged processing.

In the present experiment, all participants performed the Fox et al. (2002) task in both the hands-near and the hands-far postures, in which it was shown that IOR is reduced to angry cues. It has also previously been shown that IOR is reduced near the hands (Abrams et al., 2008). The goal of Experiment 3 was to examine whether hand-posture modulates the reduction in IOR caused by angry cues.

The results of Experiment 2 indicated that hand-nearness and emotional arousal affect some aspects of visual processing through a common mechanism. If indeed hand-nearness activates the emotional processing mechanism that alters visual processing, then a specific prediction can be made for the results of Experiment 3. When the hands are held far from the stimuli, reduced IOR to angry cues should be observed, in accordance with the findings of Fox et al. (2002). When the hands are held near to the stimuli, IOR to happy and neutral cues should be reduced compared to IOR found for those cues in the hands-far condition, in accordance with the findings of Abrams et al. (2008). However, IOR to angry face cues near the hands should not be further reduced compared to happy and neutral cues. This is because the emotional processing mechanism that causes reduced IOR when aroused is presumably already activated (for all facial expressions) by hand-nearness.

Importantly, hand-nearness appears to activate the emotional processing mechanism following the presence and removal of an emotional signal, and that activation bears on how a subsequent neutral environment is processed (Exp. 2). However, when processing an environment comprised of arousing stimuli, hand-nearness does not modulate the extent to which arousal alters visual processing (Exp. 1). Because Experiment 3 is identical to Experiment 2 in that an arousing stimulus is presented and then removed, it is predicted that the subsequent neutral environment will be processed in a way that depends on hand-posture.

Method

Participants. Thirty new experimentally naïve Washington University undergraduates participated in the experiment. Participation lasted approximately 40 minutes.

Stimuli, procedure, and design. An example of the trial events can be seen in Figure 13. The constant onscreen environment consisted of a central cross (.60° high x .60 wide°) and two peripheral boxes (5.76° high x 3.38° wide). The inside edge of each box was 2.19° away from the central cross. After 800 ms, a face (i.e., the ‘cue’; 2.78° high x 1.99° wide) was presented in the upper half of one of the boxes. The face could have a neutral, happy, or angry expression (see Figure 8), and all expressions were presented an equal number of times. On half of the trials the face appeared in the left box, on the other half it appeared in the right box. After 300 ms, the face was removed. After 200 ms, the central cross was brightened for 300 ms, followed by a de-brightening (i.e., a return to the constant environment). After 160 ms, a filled circle (i.e., the ‘target’; .40° high x .40° wide) was presented in the lower half of one of the boxes. On half of the trials, the circle appeared in the same box as the face (validly cued trials). On the

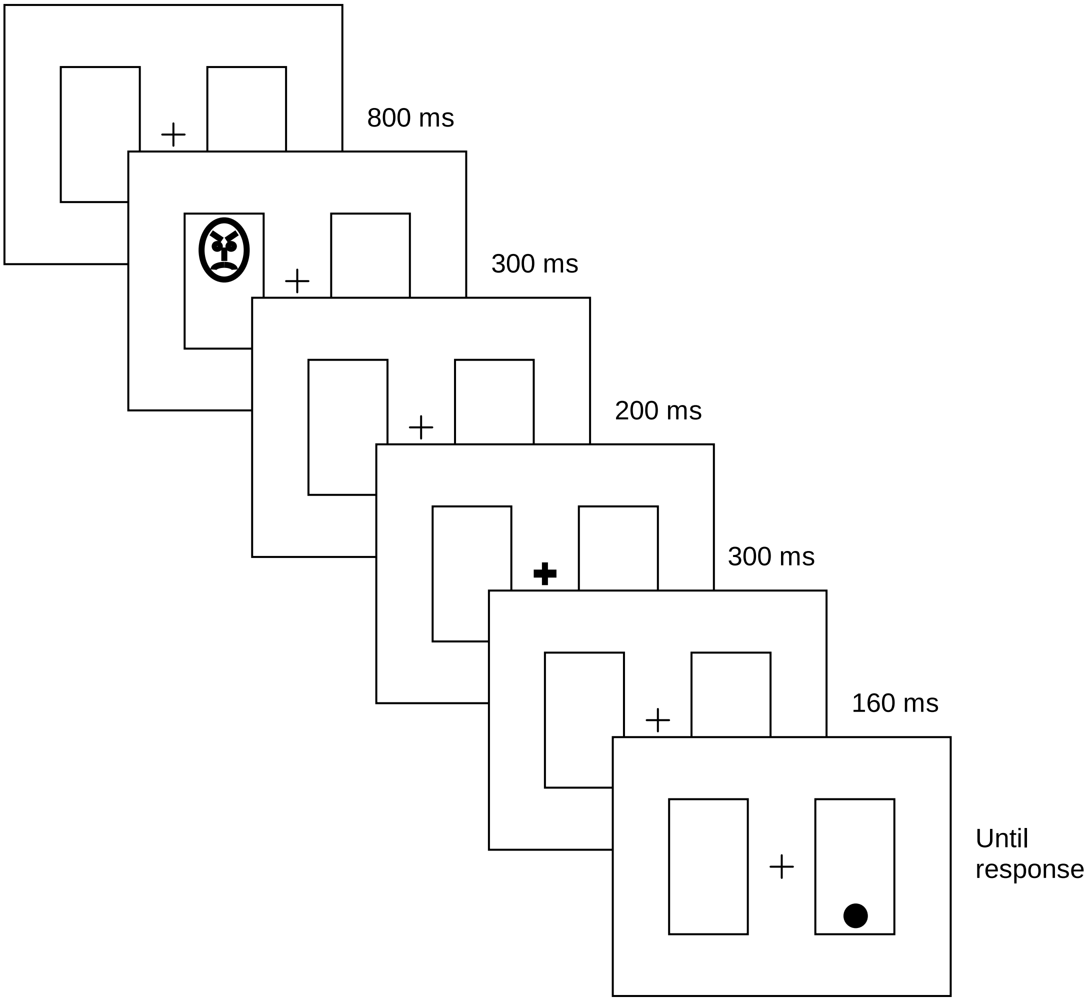


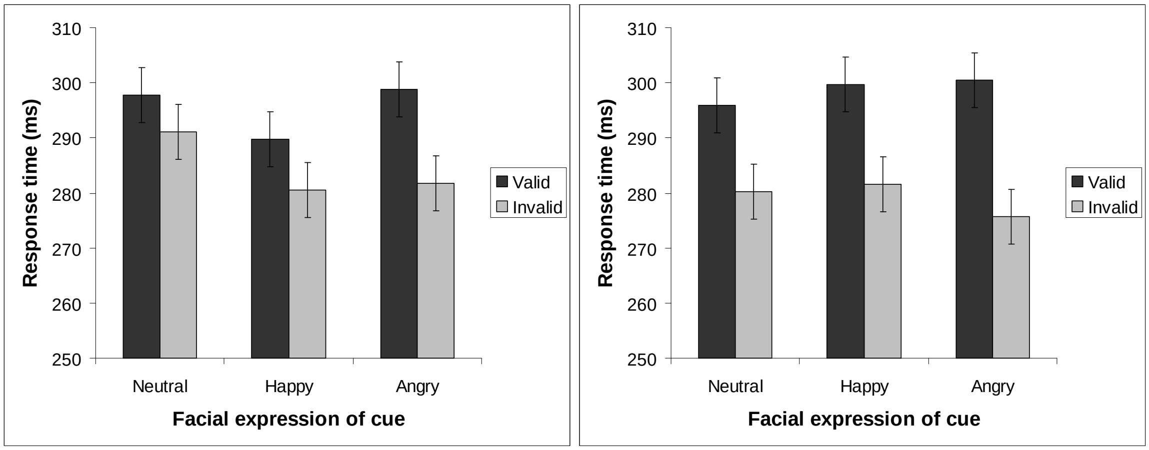
Figure 13. An example of the trial events of Experiment 3. Participants were briefly presented with a face of varying emotional valence, followed by a blank interval, followed by a brief brightening of the central cross, followed by the appearance of the target. Not to scale.

other half, the circle appeared in the box that did not previously contain the face (invalidly cued trials). Participants' task on each trial was to respond as quickly and as accurately as possible to the location of the circle (in accordance with the task used by Fox et al., 2002). Responses to circles in the left box were made using the left response button, and responses to circles in the right box were made using the right response button. The circle remained onscreen until response or until 2 s had passed. Error messages were presented if participants pressed the wrong button, responded too quickly (< 100 ms), or did not respond within 2 s. There was a 1 s inter-trial interval. Importantly, participants were told that the location of the cue was not predictive of the location of the target, so it was in their best interest to try to ignore the cue.

A 3 (facial expression of cue: neutral, happy, angry) x 2 (cue location: left box, right box) x 2 (cue validity: valid, invalid) x 2 (hand-posture: near, far) within-subjects design was used. Participants completed three blocks of 60 trials each per hand-posture, for a total of 360 experimental trials (30 observations per unique condition). There was a break at the end of each block. Participants received 10 practice trials at the beginning of the experiment.

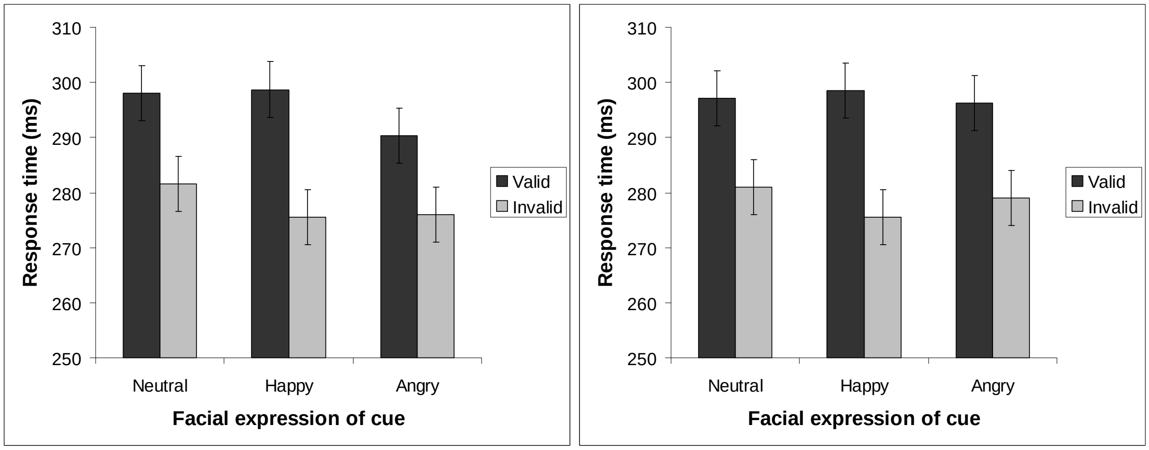
Results & Discussion

One participant was excluded from the analysis because of an equipment malfunction. Mean response times can be seen in Figure 14. The response time data were submitted to a 3 (facial expression of cue: angry, happy, neutral) x 2 (cue location: left, right) x 2 (cue validity: valid, invalid) x 2 (hand-posture: near, far) repeated-measures ANOVA. Participants were faster to respond to targets in invalidly compared to validly cued locations, $F(1, 28) = 94.76$, $p < .001$, $\eta_p^2 = .77$. This finding is indicative of the standard IOR effect (e.g., Klein, 2000). There was no main effect of cue location on response time ($F < 1$), nor did cue location significantly interact with any other factor (Fs(1, 28) < 1.70, ps > .20; Fs(2, 56) < 1.80, ps > .175). Response times did not differ across hand-posture, $F < 1$,



Hands-near, left cue

Hands-near, right cue



Hands-far, left cue

Hands-far, right cue

Figure 14. Mean response times for Experiment 3. Data points for all combinations of facial expression, cue location, cue validity, and hand-posture are shown. Error bars represent the within-subjects 95% confidence intervals.

consistent with the findings of Abrams et al. (2008) who used the present hand-posture manipulation in an IOR task.

The ANOVA did not reveal a hand-posture x cue validity interaction, *F*(1, 28) = 2.34, *p* = .14, $\eta_p^2 = .05$: The overall IOR effect in the hands-near posture (15.28 ms) was not significantly different from that in the hands-far posture

(18.44 ms). However, a significant facial expression x cue validity x hand-posture interaction was observed, $F(2, 56) = 5.07$, $p < .01$, $\eta_p^2 = .15$. This interaction can be most easily conceptualized by using the IOR effect (mean validly cued response time – mean invalidly cued response time, for each posture x facial expression combination) as the dependent variable and can be seen in Figure 15. Hand-nearness significantly reduced IOR to happy cues $t(28) = 3.43$, $p < .005$, $\eta_p^2 = .64$ (a moderate-to-large effect size), but not to angry cues, $t(28) = -1.22$, $p = .23$ (a small effect size). Indeed there was a numerical, though non-significant, increase in IOR to angry cues in the hands-near condition. A trend of reduced IOR near the hands was observed for neutral cues, $t(28) = 1.66$, $p = .11$, $\eta_p^2 = .31$ (a small-to-moderate effect size). The reduced IOR found near the hands for happy and neutral cues—cue valences that themselves should not have been expected to influence IOR (Fox et al., 2002)—replicates the finding of Abrams et al. (2008) of reduced IOR near the hands. Indeed, when the response time data from the angry facial expression condition were removed from the analysis, the overall IOR effect was smaller near to (12.47 ms) compared to far from (19.77 ms) the hands, $F(1, 28) = 8.46$, $p < .01$, $\eta_p^2 = .23$.

A comparison of IOR effects across facial expressions for only the hands-far condition was performed to determine whether those results replicated Fox et al. (2002), who (in essence using a hands-far posture) found substantially reduced IOR for the angry compared to the happy or neutral expressions. A repeated-measures ANOVA on IOR effects showed a non-significant trend of a difference between expressions, $F(2, 56) = 2.34$, $p = .11$, $\eta_p^2 = .08$. More

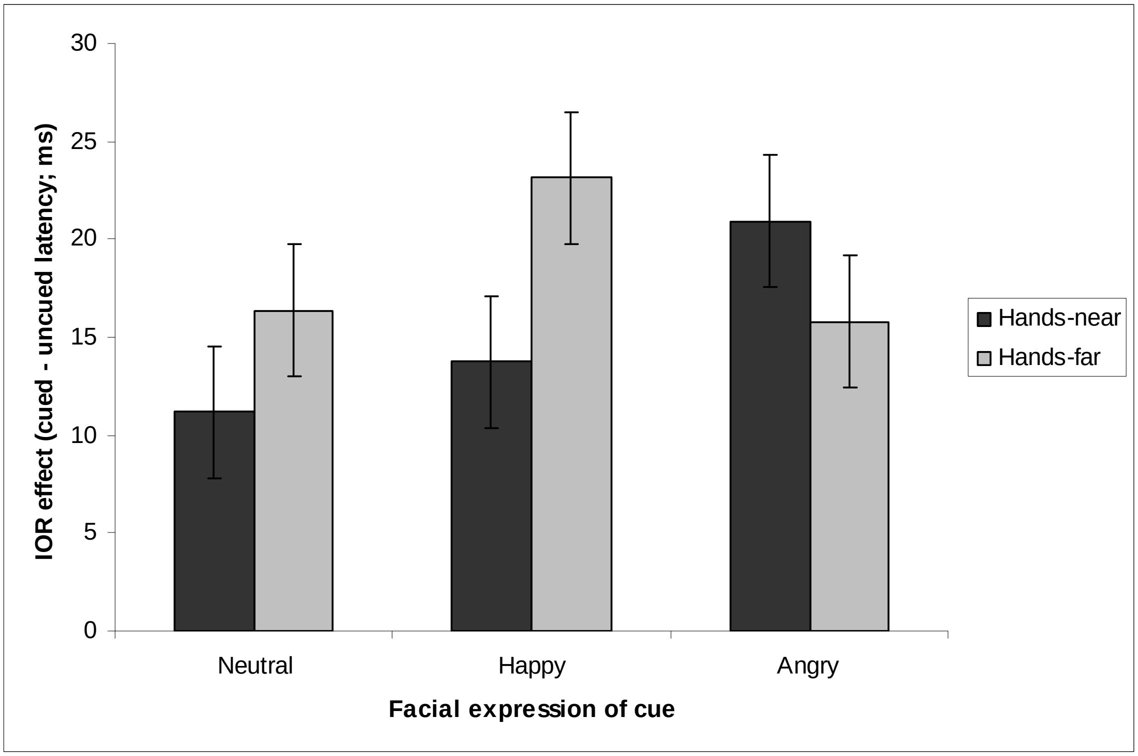
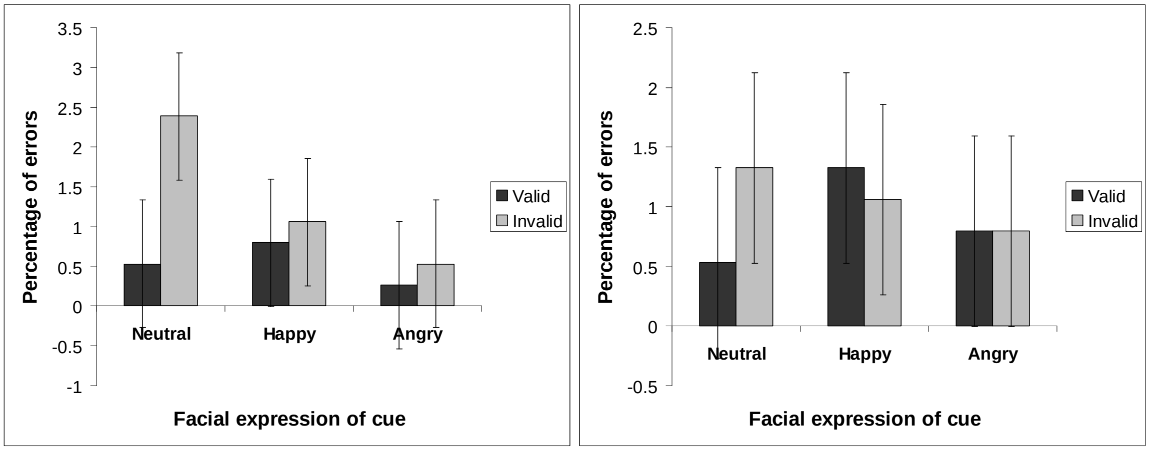


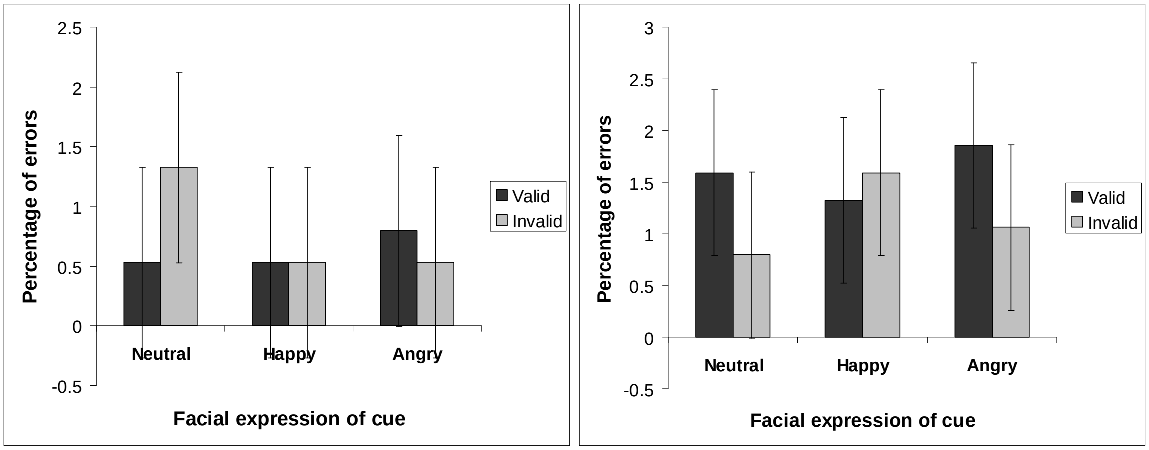
Figure 15. IOR effects as a function of facial expression of the cue for the hands-near and hands-far postures; Experiment 3. Error bars represent the within-subjects 95% confidence intervals.

specifically, there was a trend in the data showing that IOR effects for angry expressions (15.80 ms) were smaller than those for happy expressions (23.16 ms), $t(28) = 1.80$, $p = .083$, $\eta_p^2 = .33$ (a small-to-moderate effect size).

Mean error percentages are shown in Figure 16. The error percentage data were submitted to a 3 (facial expression of cue: angry, happy, neutral) x 2 (cue location: left, right) x 2 (cue validity: valid, invalid) x 2 (hand-posture: near, far) repeated-measures ANOVA. The overall error rate was 1.0%. There was a non-significant trend towards lower error percentages when the cue appeared in the left compared to the right box, $F(1, 28) = 3.68$, $p = .065$, $\eta_p^2 = .12$. However, this main effect occurred within a marginally significant hand-posture x cue



Hands-near, left cue Hands-near, right cue



Hands-far, left cue Hands-far, right cue

Figure 16. Mean error percentages for Experiment 3. Data points for all combinations of facial expression, cue location, cue validity, and hand-posture are shown. Error bars represent the within-subjects 95% confidence intervals.

location interaction, *F*(1, 28) = 4.18, *p* = .050, η_p^2 = .13. In the hands-near posture, error percentage did not change regardless of whether the cue appeared in the left or the right box. In the hands-far posture, however, error percentage was lower when the cue appeared in the left compared to the right box. The only other non-significant trend was observed in the hand-posture x cue validity interaction, *F*(1, 28) = 3.31, *p* = .080, η_p^2 = .11. In the hands-far posture, error percentage did not change regardless of whether the cue was valid or invalid. In the hands-near posture, however, error percentage was lower when the cue was valid compared to invalid. That finding is consistent with previous findings of reduced IOR near the hands: If disengagement of spatial attention from cued locations is delayed near the hands, then participants should make fewer errors to validly-cued targets near the hands, as presumably attention is “stuck” at the cued location. No other main effects or interactions reached significance (*F*s(1, 28) < 2.50, *p* > .125; *F*s(2, 56) < 2.30, *p* > .110).

Fox et al. (2002) found significant IOR effects following happy (19 ms) and neutral (14 ms) cues, but found no IOR effect following angry cues (2 ms). In the present study, IOR was found at all levels of facial expression (angry: 15.8 ms; happy: 23.2 ms; neutral: 16.4 ms) in the hands-far condition (analogous to the posture assumed by the participants of Fox et al., 2002). There was a marginally significant reduction in IOR to angry cues compared to happy cues, thus preserving the trend found by Fox et al. (2002).

Holding the hands near the stimuli reduced IOR to happy and neutral cues. That result is in agreement with the findings of Abrams et al. (2008), who showed reduced IOR near the hands. However, IOR was not further reduced to angry cues in the hands-near condition. That result is what would be expected if indeed hand-nearness activates the emotional processing mechanism. This is because the emotional processing mechanism that causes reduced IOR when aroused is presumably already activated by hand-nearness. Thus all stimuli, regardless of their inherent emotional valence, are processed through that mechanism. Curiously, IOR to angry cues near the hands actually showed a numerical increase compared to that for happy and neutral cues. At this point it is unclear why that pattern of results was observed, but further research should be conducted to determine the reliability of that pattern and what it could mean.

Chapter 7: General Discussion

The relationship between hand-nearness, emotional arousal, and visual processing was explored in the present dissertation. The reason that one may even care to study such a relationship is because of a number of similar effects that hand-nearness and emotional arousal have on visual processing. Are those similarities merely a coincidence, or is it possible that hand-nearness and emotional arousal affect visual processing through a shared mechanism? Could it be the case that hand-nearness activates the same visual processing mechanism that is engaged during arousal?

To explore those questions, three experiments were conducted in which subjects made judgments about visual stimuli while both hand-posture and emotional arousal were manipulated. Specifically, experiments that have previously shown clear effects of emotional arousal on visual processing in a conventional (hands-far) experimental posture were replicated (directly or conceptually) with the addition of a hands-near condition to each experiment.

The results of Experiment 1 showed slower rates of visual search (1) near the hands (replicating Abrams et al., 2008) and (2) for a positive face amongst negative faces than for a negative face amongst positive faces (replicating Fox et al., 2000). However, the results did not reveal an interaction between hand-posture and emotional arousal, indicating that those factors exerted their effects independently of one another. On the other hand, the findings of Experiment 2 showed an interaction between hand-posture and emotional arousal: Response times were faster following angry compared to happy faces in the hands-far condition, but did not differ in the hands-near condition. Experiment 3 used a standard IOR paradigm with emotional face-cues (Fox et al., 2002). As in Experiment 2, the findings of Experiment 3 showed an interaction between hand-posture and emotional arousal. The IOR effect was reduced for angry face cues in the hands-far condition (replicating the findings of Fox et al., 2002), but not in the hands-near condition. Importantly, hand-posture did not have a main effect on response times or errors in any of the experiments. Thus, the results that were obtained cannot be due merely to the ease of responding in one posture, or to one posture being more comfortable than the other. That absence of main effects of hand-posture is in agreement with several other studies that have shown that hand-proximity effects are not attributable to differences in comfort between the two postures (Abrams et al., 2008; Davoli & Abrams, 2009; Davoli, Abrams, & Bloesch, 2009; Davoli et al., 2010; Reed et al., 2006).

The interactions between hand-posture and emotional arousal observed in the present dissertation indicate that hand-nearness and emotional arousal affect some aspects of visual processing through a shared mechanism, but other aspects uniquely. Why might there be a shared mechanism for two conditions—hand-nearness and being emotionally aroused—that on the surface seem unrelated? Why did hand-nearness modulate the effect of arousal following the presence and removal of an emotional stimulus (Experiments 2 and 3), but not during the presence of emotional stimuli (Exp. 1)? Those questions will be addressed below.

A shared mechanism for hand-nearness and emotional arousal: Building a theory of survival-relevant processing

Objects near the hands and emotionally arousing stimuli have high salience for the observer. Objects near the hands often consist of items with which we wish to interact, such as tools, food, or even other humans. Additionally, to successfully and safely perform several actions, we must avoid collisions with nearby objects, like a hot stove while we are cooking. In that sense, the peripersonal representation acts as a “last line” of defense between the body and the physical world (e.g., Graziano & Cooke, 2006). Emotionally arousing stimuli are especially effective at provoking an appropriate response: Negative stimuli (e.g., an angry face) can communicate danger and thus induce an avoidance response, while positive stimuli (e.g., a happy face) can communicate reward and thus induce an approach response. Indeed, nearby objects and emotional stimuli, by virtue of what such things afford us and may symbolize, are more pertinent to our well-being than objects that are far away and non-emotional. Thus, objects near the hands and emotionally arousing stimuli may be considered to be survival-relevant.

Perhaps the many similar effects that have been observed when people view objects near the hands and view emotionally arousing stimuli are reflective of a unitary mechanism responsible for processing all things relevant to survival. There is precedent for the existence of such a mechanism, described next.

Survival processing in memory. Nairne and colleagues (Nairne, Pandeirada, & Thompson, 2008; Nairne, Thompson, & Pandeirada, 2007) have found evidence of a survival processing mechanism for memory. In their basic paradigm, subjects are given a list of words and are asked to remember the words for a later memory test. Some subjects are told to think about the words in terms of their relevance to survival, while others are told to think about the words in other ways that are known to produce deep encoding (e.g., pleasantness, relevance to the self, relevance to moving to a foreign land, etc.). Impressively, there is a robust, reliable mnemonic advantage for items processed in terms of survival relevance, and this effect has been replicated by other laboratories (e.g., Kang, McDermott, & Cohen, 2008; Weinstein, Bugg, & Roediger, 2008).

Existing theories of visual processing mechanisms. There is evidence that an analogous survival-processing mechanism exists for visual processing. LeDoux (1995; 2000) and Öhman and Mineka (2001; 2003) have contended that the brain is equipped with a “fear module” that constantly monitors the environment for stimuli that are threatening or implicate danger. That kind of mechanism is supported by findings (reviewed in Chapter 2) that show processing advantages for threatening items over non-threatening items (e.g., Blanchette, 2006; Harber et al., 2009) and for fearful faces over happy (e.g., Becker, 2009; Fox et al., 2000; Mogg & Bradley, 1999) or neutral (e.g., Bocanegra & Zeelenberg, 2009; Phelps et al., 2006) faces. The fear module also appears to be sensitive to negative *internal* states, in which our vulnerability is heightened. In such states, visual processing changes in ways that best serve protection, such as narrowing the scope of attention to a “tunnel vision” for the most relevant parts of the environment (Fredrickson & Branigan, 2005), or perceiving threats to be closer or more perilous than they truly are (Harber et al., 2009), which would presumably facilitate an avoidance response.

However, in contrast to a mechanism that only monitors the environment for fear-relevant stimuli, there is evidence that non-negative stimuli that are nevertheless survival-relevant receive the same processing benefits allocated to negative stimuli. For instance, Brosch, Sander, Pourtois, and Scherer (2008) found that attention could orient just as rapidly to nurturance-relevant (i.e., baby) faces as to fear-relevant (i.e., angry) faces. In general, biologically relevant events, regardless of their valence, seem to be given special preference by the brain. Several studies have shown perceptual sensitivity for biological compared to non-biological motion (e.g., Johansson, 1973; Pratt, Radulescu, Guo, & Abrams, in press; Shiffrar, Lichtey, & Chatterjee, 1997). Furthermore, there are regions of the brain that specifically respond to biological motion (e.g., Grossman et al., 2000) and to ambiguous stimuli when interpreted as humanoid instead of artificial (Tipper, Handy, Giesbrecht, & Kingstone, 2008). Importantly, activation in those regions is not dependent on whether a stimulus is “good” or “bad,” just that it is biological, and by extension relevant to survival.

A new survival processing theory for vision. Given the evidence of processing advantages for survival-relevant stimuli, it is possible that there exists a survival-processing mechanism for vision that functions in consistent ways for situations that are relevant to survival. Under such a survival-processing theory of vision, stimuli that are particularly survival-relevant receive a processing advantage. That could of course include stimuli that are threatening or implicate danger, but could also include positive things, such as food, tools, or affirming social cues like a smiling face. It is the contention here that emotional arousal engages the survival processing mechanism. Thus, the collection of effects that have been observed during emotional arousal, such as altered rates of visual search (Becker, 2009; Fox et al., 2000), delayed disengagement of attention (e.g., Fox et al., 2002, Mathewson et al., 2008), and enhanced spatial analysis (Bocanegra & Zeelenberg, 2009; Phelps et al., 2006), are reflective of changes in processing that occur when that mechanism is engaged.

Survival-relevant situations are not merely limited to the presence of certain types of stimuli, however. The assumption of particular postures or the performance of certain actions can also be relevant to survival, and thus would also engage the proposed survival-processing mechanism. For example, hand-nearness—a posture that brings objects into peripersonal space—is survival-relevant because nearby objects could be threats we should not touch or tools we must use to achieve our goals[1]. Thus, it is the contention here that the reason that hand-nearness and emotional arousal share so many of the same effects on visual processing is because the same mechanism is activated in both circumstances.

In addition to hand-nearness, a standing posture has been found to produce changes in visual processing that are similar to those of hand-nearness and emotional arousal. Recent evidence from our laboratory (Davoli, Knapp, & Abrams, 2009) has shown that standing changes visual processing in distinct ways compared to sitting. In our study, we found that standing compared to sitting produced slower rates of visual search through a display of items and a reduced Stroop interference effect[2]. Those effects are in fact the same as those observed near the hands (Abrams et al., 2008; Davoli et al., 2010) and when emotionally aroused (e.g., Fox et al., 2000; Huguet et al., 1999; Ihssen et al., 2007; Kuhl & Kazén, 1999). Importantly, standing has strong ties to survival: It is from a standing posture that we can most easily engage in the quintessential survival response—fight-or-flight. And, in a way that is similar to how hand-proximity is used as a linguistic device for expressing our emotional/evaluative relationships with the world, the relationship between standing and survival is repeatedly acknowledged throughout the English language (e.g., “taking a stand”). If standing and hand-nearness are both survival-relevant postures, then necessarily those postures should affect vision similarly if a unitary survival-processing mechanism exists.

In further support of a unitary survival-processing mechanism, survival-relevant actions can alter visual processing in ways that have been encountered previously with emotional arousal and survival-relevant postures. Specifically, Koch, Holland, Hengstler, and van Knippenberg (2009) had their participants take steps forwards, backwards, or sideways prior to performing a Stroop task. They found a marked reduction in Stroop interference following steps backwards compared to steps taken in the other directions. Koch et al. argued that stepping backwards induced an avoidance mindset, as this is an action that often is taken when confronted with danger. Consequently, that mindset recruited resources devoted to cognitive control, a process that is necessary when presented with a threatening situation (e.g., being able to take action instead of becoming distracted by other thoughts). Incidentally, cognitive control is also employed to override the automatic tendency to read a color-word stimulus in the Stroop task, allowing participants to better respond to the color of the stimulus. Thus, performing an action related to self-preservation (i.e., stepping backwards) had the same behavioral consequence as assuming survival-relevant postures (hand-nearness: Davoli et al., 2010; standing: Davoli, Knapp et al., 2009) and as performing a task in the presence of others (Huguet et al., 1999).

Processing during the presence versus following the removal of an arousing stimulus

Hand-nearness and emotional arousal seem to affect some aspects of visual processing through a shared mechanism. An outstanding question, however, is why hand-posture modulated the effect of arousal following the presence and removal of an emotional stimulus (Experiments 2 and 3), but not during the presence of emotional stimuli (Exp. 1). It has been proposed here that hand-nearness activates a survival-processing mechanism such that all nearby stimuli, regardless of their inherent emotional valence, are processed as arousing. If that were entirely true, however, then a different pattern of results should have been found in Experiment 1. Specifically, search near the hands should have been conducted at the same rate for a negative face amongst positive distractors as for a positive face amongst negative distractors. However, that was not the observed result.

A critical methodological distinction between Experiment 1 and Experiments 2 and 3 was whether or not the emotionally arousing stimuli were present during the primary task. In Experiment 1, the arousing stimuli were themselves present during the search, whereas in Experiments 2 and 3, the arousing stimulus was presented and then removed prior to the appearance of the target. Hand-nearness did not modulate the effect of emotional arousal on processing in the presence of arousing stimuli, but did modulate how an emotionally neutral environment was processed following the presence and removal of an arousing stimulus. The differing conclusions from the experiments suggest that that methodological distinction is important in understanding when and how hand-nearness interacts with arousal.

It appears that visual permanence of emotional stimuli (at least throughout the duration of a trial) preempts hand-nearness in the hierarchy of factors that activate the emotional processing mechanism. That is, when one is presented with a neutral environment, hand-nearness can allow objects in that environment to be processed through the emotional processing mechanism; thus hand-nearness can perhaps make neutral objects appear emotionally significant. However, when one is presented with an emotionally arousing environment, visual processing of that environment is altered through the emotional processing mechanism, regardless of the proximity of the hands to objects in that environment. This perhaps makes sense: Presumably it would be advantageous to process objects near the hands as emotionally significant as such objects often are of high importance; likewise, it would be advantageous to process emotionally arousing objects in a consistent, special way regardless of where those objects are located in the environment.

Limitations, implications, and future studies

All experiments of the present dissertation could benefit from larger sample sizes, which would presumably allow marginal or close-to-marginal differences to reach statistical significance. Importantly, those differences occurred in the predicted directions with substantive effect sizes, indicating the presence of true differences but not enough power to detect them.

In Experiments 2 and 3, neutral faces produced somewhat ambiguous patterns of behavior. Rather than yielding data that were quantitatively between those produced by happy and angry faces, data from neutral face conditions tended to resemble either happy- or angry-face data. That suggests that the neutral faces used in the present dissertation may not have been interpreted as truly neutral (i.e., emotion-less) by participants (albeit the neutral face used in Experiment 3 simulated that used by Fox et al., 2002). Thus in future studies it would be beneficial to conduct pilot work to ascertain a valid neutral face.

If visual processing of objects near the hands occurs through the emotional processing mechanism, then that suggests that holding the hands near some thing is a way to render that thing emotionally significant (assuming it otherwise is not). This notion could have strong implications for our understanding of abstractions like intimacy and love, aesthetic experience and appreciation, personal boundaries and interpersonal relationships, and the formation, understanding, and mutability of self-concept.

Conclusion

The results of the present dissertation suggest that hand-nearness and emotional arousal affect some aspects of visual processing through a shared mechanism. It has been proposed that this mechanism is specifically tuned for survival processing and is engaged when presented with stimuli or situations that are relevant to survival, such as objects near the hands. Holding the hands near an object may be a way to render that object emotionally significant if it otherwise is not.

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Footnotes

[1] Of course, not all objects in peripersonal space are ultimately survival-relevant. However, it would presumably make sense that, by default, nearby objects are initially processed as being relevant to survival until identified as otherwise. Clearly, once a two-dimensional letter that appears near the hands in a visual search task has been inspected and identified, it can be regarded as non-threatening. Prior to identification, however, it is an unspecified peripersonal object, and given the importance of the space around the body, it would be advantageous to presume this object to be of high relevance and to thus award it attentional priority.

[2] Viewing distance and geometry were equivalent across standing and seated postures. Thus, the effects observed while standing could not be due to differences in retinal information across the two postures. Furthermore, there was no main effect of posture, indicating that the observed effects could not be attributable to standing simply being a more uncomfortable or awkward posture than sitting.