Behavioral and Physiological Attention Biases to Positive Emotional Stimuli

Elisa Duell

Oklahoma State University

Abstract

Prior research has examined attention to emotional stimuli with the conclusion that fear-relevant information automatically facilitates attention and autonomic nervous system activity. While appraisal theories of emotion suggest that all classes of biologically relevant stimuli capture attention, few studies have explored the interface between attention and biologically relevant *positive* emotional stimuli, such as infants. The survival of nascent offspring is essential to the continuance of any species, which makes attending to such stimuli of high adaptive value. Furthermore, Lorenz (1943) observed that infants elicit positive emotions, such as warmth and fondness. This study examines behavioral and physiological attention biases to infants, a form of biologically relevant positive emotional stimuli. Results confirm attention capture by infant images when presented in the right visual field, suggesting a left cerebral hemisphere advantage in the perception of infant faces. Sex differences in autonomic reactivity to the positive stimuli indicate that females were more responsive to the infants. Overall findings support the notion of automatic attention capture by biologically relevant positive emotional stimuli.

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Humans are constantly faced with environmental stimulation and must be able to rapidly extract pertinent information from their surroundings. As suggested by Pessoa, Kastner, and Ungerleider (2002), the limited processing capacity of the human visual system necessitates environmental stimuli to compete for neural representation. Brosch and colleagues extend this notion by positing that human perception is shaped by categorization processes that organize external items into conscious and identifiable representations (Brosch, Pourtois, & Sander, 2010). Object categorization rapidly guides and constrains environmental stimuli with little cognitive effort (Thorpe, Fize, & Marlot, 1996), thus filtering information available in the external world and facilitating object discrimination (Brosch et al., 2010). The purpose of the current investigation is to examine human visual attention processing in relation to positive emotional stimuli, and to investigate physiological correlates of attentional arousal.

One important topic in psychological science pertains to the mechanism by which humans filter information for further perceptual processing (Anderson, 2005). Research suggests the arousal value of objects or events plays a key role in the allocation of attentional resources. For instance, emotional information is more readily discerned than non-emotional information. Indeed, research suggests fear-relevant emotional stimuli are instinctively prioritized over less salient material (e.g., Dimberg & Ohman, 1996; Ohman, Flykt, & Esteves, 2001). This is illustrated by the finding that faces displaying anger are detected faster than neutral faces (Eastwood, Smilek, & Merikle, 2001), spiders and snakes are identified more quickly than flowers or mushrooms (Ohman et al., 2001), and in a variant of the Stroop task, negatively valenced words interfere with color naming (Algom, Chajut, & Lev, 2004).

Researchers have speculated that this phenomenon occurs due to the relevance of emotional stimuli. Certain emotional objects, such as spiders, snakes, and angry faces, may signal danger or threat, and thereby convey greater survival relevance than emotionally neutral stimuli (Brosch et al., 2010). Such pertinent emotional information requires swift attention to ensure the wellbeing of an organism, and thus receives priority cognitive processing.

Responses to stimuli with significant emotional value necessitate an approach or avoidance reaction involving both behavioral and physiological responses (Brosch et al., 2010). Many researchers have examined autonomic nervous system activity as an indicator of biologically predisposed fear reactions to objects and situations. For example, electrocortical indices of fear conditioning have been evaluated to compare autonomic affective responses to fear-relevant and fear-irrelevant stimuli (e.g., Regan & Howard, 1995), and finger-pulse volume and heart rate have also been used to examine fear responses (e.g., Fredrikson & Ohman, 1979). Most research on fear indicates broad sympathetic activation, with heart rate measures most commonly reported (Kreibig, 2010).

The majority of psychophysiological measures are reflective of general emotional arousal and also attentional processes (Ohman & Mineka, 2001; Kreibig, 2010). For instance, heart rate is routinely examined to indicate both orienting and sustained attention (Bradley, 2009; Richards, 2010), and event related potentials (ERPs) can be used to track the time course of attention allocation and allow researchers to examine facilitated attention toward emotional stimuli (Hajcak et al., 2008). Salivary biomarkers can also be used to measure psychophysiological responses to highly relevant stimuli (Nater & Rohleder, 2009). Concentrations of salivary alpha-amylase, for example, reflect sympathetic nervous system activity and provide a fast-reacting biological response that can indicate attention toward psychological stressors (e.g., emotional

images; Rohleder & Nater, 2009). According to Lang, Bradley, and Cuthbert (1997),

physiological responses index the motivational significance of visual cues and co-vary with

pleasant and unpleasant emotional arousal.

Of course, behavioral responses can also be considered when evaluating responses to

emotional stimuli. One well-established behavioral method of examining attention biases to

emotional stimuli is the dot-probe task. During this task, two visual stimuli are briefly presented

simultaneously, and participants indicate the location of a target (e.g., a dot) that replaces one of

the two stimuli. Their reaction time in pinpointing the location of the target signifies attention

biases to the stimulus that had occupied that location. For instance, in a dot-probe task conducted

by MacLeod, Mathews, and Tata (1986), emotionally threatening words (e.g., cancer, failure,

hazard) were paired with neutral words. Probes preceded by a threatening word were detected

more quickly than probes that followed a neutral word, suggesting that attention was shifted

toward the threatening terms.

Subsequent studies support the notion of attention capture by threatening stimuli. In two

experiments, Mogg and Bradley (1999) used another dot-probe paradigm to investigate whether

angry faces selectively capture attention. When participants were shown pairs of threatening,

happy, and neutral faces, response latencies were fastest for probes that replaced the threatening

faces in both experiments, while response times were not significantly different for happy faces

compared with neutral faces.

These behavioral results are consistent with studies utilizing ERPs. In an attempt to

clarify electrophysiological correlates of attention biases to emotional objects, Pourtois,

Grandjean, Sander, and Vuilleumier (2004) recorded participants' EEG during a dot-probe task

in which they viewed emotional (fearful, happy) and neutral faces. Pourtois et al. observed a

selective increase in P1 amplitude for probes replacing the fearful face, indicating that fearful, but not happy faces, involuntarily oriented participants' spatial attention.

All of these results, and more (see Vuilleumier, 2005 for a review), indicate that attention is preconsciously restricted to fear-relevant stimuli. Ohman and colleagues (2001) speculate that this preferential processing of threatening stimuli is due to an evolutionarily adaptive fear module that facilitates rapid behavioral and neural responses to danger. These modulatory effects have theoretically been tailored by so great a lineage of recurrently encountered adaptive problems that they are no longer under voluntary control. Rather, these attentional mechanisms can subliminally trigger responses that are outside of conscious awareness (Tooby & Cosmides, 1990; Ohman et al., 2001).

Although many researchers in the past have favored an evolutionarily adaptive fear module of attention, alternative appraisal theories of emotion suggest that attentional preference is dictated by the relevance of a stimulus to survival, not necessarily its emotional valence (Sherer, Schorr, & Johnstone, 2001; Ellsworth & Sherer, 2003; Brosch, Sander, Pourtois, & Scherer, 2008). According to appraisal theories, stimuli with high biological relevance receive preferential cognitive processing and attentional resources (Scherer et al., 2001; Brosch et al., 2008). Furthermore, in contrast to fear-module interpretations, biologically relevant emotional stimuli may include a variety of information, including both positive *and* negative emotions (Brosch et al., 2008).

Appraisal theories may, at first glance, appear to lack credence given the substantial number of studies showing attention capture by only negative, threatening stimuli. However, as noted by Brosch et al. (2008), the majority of such research has only examined attention to negative stimuli in relation to either neutral stimuli or happy facial expressions. Such paradigms

may not be suitable representations of positive emotional stimuli. In fact, smiles may instead

signal one to relax by conveying safety. As such, the comparisons utilized in prior research do

not offer a critical examination of attention to positive emotional stimuli, and a more suitable

experimental comparison is needed to truly examine attention capture by biologically relevant

positive emotional stimuli.

Newborn infants represent one category of highly relevant stimuli that has been

particularly neglected in attention research. The survival of nascent offspring is essential to the

continuance of any species, which makes attending to such stimuli of high adaptive value.

Lorenz (1943) observed that the configuration of facial features of newborns (e.g., large eyes,

rounded cheeks, a high, slightly-bulging forehead) elicits positive emotions (e.g., warmth,

fondness) and behaviors associated with parental care. Furthermore, a recent study by Brosch,

Sander, and Scherer (2007) suggests that adults preferentially attend to such positive images of

infants as opposed to neutral adult images. However, scarcely any studies exist to substantiate

these results, and only a few studies to date have examined the interface between attention and

biologically relevant *positive* emotional stimuli.

The current study seeks to remedy this gap in experimental literature by further

examining attention biases to biologically relevant positive emotional stimuli. Similar to Brosch

et al. (2007), participants' automatic attention to both positive and neutral emotional stimuli was

assessed through the use of a dot-probe paradigm. Given that the physiological stress response is

a significant factor in attending to threatening stimuli (e.g., Fredrikson et al., 1979; Regan et al.,

1995; Kreibig, 2010), we also examined the stress response in regard to our *positive* stimuli.

Thus, participants' pre- and post-task salivary alpha-amylase was assessed as an indicator of

autonomic nervous system activity. Alpha-amylase is a biomarker that is indicative of

sympathetic nervous system activation and is associated with attentional focus (Rohleder et al., 2009). In addition, considering the maternal role of women in childbearing, we further predicted that the infant stimuli would bias the attentional responses of women more so than men.

Method

Participants

Sixty-six healthy adult participants (35 male, 31 female, M_{age} = 19.54 years, age range: 18-36 years) were recruited at Oklahoma State University through an online subject pool recruitment website. All participants had normal or corrected-to-normal vision and received course credit for participation. Exclusion criteria were parents, nicotine use, caffeine consumption, and vigorous exercise one hour prior to participation. This study was approved by the Institutional Review Board at Oklahoma State University.

Materials and Procedure

Salivary alpha-amylase. Fifteen participants provided saliva using a passive drool technique and fifty-one participants provided saliva using an absorbent swab. The first saliva sample was collected immediately upon arrival to establish a baseline measure of alpha-amylase. A second saliva sample was collected immediately following the dot-probe task. Next, participants continued to sit quietly at the computer while completing a series of questionnaires concerning demographic information, mating strategies, state-trait anxiety, and life history for 20 minutes. After completing the questionnaires, participants provided a third and final saliva sample. All three samples were stored at -20 degrees Celsius, and were subsequently assayed for alpha-amylase at Oklahoma State University using an enzyme immunoassay technique (Salimetrics, State College, PA, USA). All data were square-root transformed prior to analysis to correct a strong positive skew. Alpha-amylase was analyzed in a 3 X 2 analysis of variance

including the repeated factor samples (baseline, post-task, follow-up) and between-subjects

factor sex (male or female).

Dot-probe task. The task used the same eight black-and-white photos from the

categories babies, human adults, kittens, adult cats, puppies, and adult dogs employed by Brosch

et al. (2007). The human stimuli all showed neutral facial expressions. All images were rated for

pleasantness and arousal in a preliminary study conducted by Brosch and colleagues, with higher

positivity and arousal ratings obtained for images that depicted infants rather than adults. The

images measured 7 X 7 cm on the screen and were presented at a distance of 15 cm between

fixation cross and image center. The photo set was analyzed by Brosch et al. for category

differences in luminance, contrast, and mean energy in spatial frequency bands. No significant

differences were found.

Participants were instructed to sit in front of a computer and face the monitor, which

appeared black except for a small fixation cross displayed in the center of the screen. The cross

was shown for a random interval of 250-750 milliseconds (ms). Then the cue, which consisted of

two images presented in the left and right parts of the screen, was presented for 100 ms.

Participants viewed images that were either "positive" (infants) or "neutral" (adults). The two

images belonged either to the same category (adult-adult; e.g., dog vs. dog) or to two categories

(baby-adult; e.g., puppy vs. dog) of the same species (humans, dogs, or cats). Immediately after

the picture display was terminated, a small dot-probe appeared in the spatial location of one of

the images for 200 ms. Participants indicated the location of the dot as quickly as possible by

pressing one of two specified computer keys: "C" with their left index finger if the dot appeared

on the left, "M" with their right index finger if the dot appeared on the right, and no key if there

was no dot. Participants had a maximum of 2,000 ms to respond before the next trial began, and were given a 30-second break after every 128 trials.

Trials were divided into three conditions: valid, invalid, and neutral. In a valid trial, the dot replaced the infant image. In an invalid trial, the dot replaced the adult. In a neutral trial, both images were adults. One third of all trials were presented with no dot to prevent the participant from developing response strategies. The images and respective cuing conditions were randomized for each participant. Participants first completed 24 practice trials with neutral cues of household items (e.g., trashcan, chair), then performed a total of 360 experimental trials.

Following the procedure in Brosch et al. (2007), neutral trials were excluded from the analyses. Only response times of correct responses occurring within 3 standard deviations of the mean for each individual were analyzed. Response times were analyzed in a 3 X 2 X 2 X 2 analysis of variance with repeated factors of species (humans, cats, dogs), visual hemifield (left or right), cue validity (valid or invalid), and the between-subjects factor sex (male or female). Planned comparisons were made regardless of ANOVA outcome.

Results

Salivary alpha-amylase. The main effect for alpha-amylase Sample was significant, $F(2,23) = 3.46$, $p = .049$. As seen in Figure 1, alpha-amylase levels tended to decrease from baseline to post-task, and then increase from post-task to follow-up. Pairwise comparisons showed that male alpha-amylase levels significantly decreased from baseline to post-task (mean difference = 1.69, $p = .057$; Figure 1). For females, alpha-amylase did not change significantly from baseline to post-task, but increased from post-task to follow-up (mean difference = 1.49, $p = .033$; Figure 1).

Dot-probe task. Behavioral data from three men were excluded due to technical error, and nine men and four women were further excluded from the analysis because of error rates greater than 25 %. Overall response times for males (218 ms) were slightly slower than females (209 ms). When comparing Hemifield and Cue Validity, the simple effects for invalid trials, F(1,47) = 9.21, p = .004, and right hemifield, F(1,47) = 3.71, p = .06, were significant. Pairwise comparisons showed that when the target was presented in the right visual field, response times for targets that replaced infants (i.e., valid trials) were marginally faster than targets that replaced adults (i.e., invalid trials; mean difference = 7.95, p = .06; Figure 2). Response times for valid and invalid targets presented in the left hemifield did not differ.

The Sex X Species interaction was not significant, but pairwise comparisons showed that females responded faster for humans than dogs (mean difference = 9.3, p = .039; Figure 3). When comparing Sex and Hemifield, the simple effect for males was significant, F(1,47) = 9.03, p = .004. Pairwise comparisons showed that males exhibited faster response times for targets presented in the left visual field (mean difference = 7.95, p = .06; Figure 4). One intriguing finding, although irrelevant to the purpose of this study, was that females responded more quickly to cats than dogs (mean difference = 6.9, p = .004). Contrary to our hypothesis, there were no significant sex differences in attention to the infants.

Discussion

The results of this study are congruent with the hypothesis that infants, an example of a biologically relevant positive emotional stimulus, automatically capture attention, but only when viewed in the right visual field, and thus the left cerebral hemisphere. These findings stand in contrast to Brosch et al. (2007), who employed the same dot-probe paradigm and found that human infants elicited faster response times when presented in the *left* visual field. Similar to

Brosch et al. (2007), prior research has suggested that the right cerebral hemisphere, which

corresponds to the left visual field, plays a dominant role in the processing of faces (Farah,

Wilson, Drain, & Tanaka, 1998) and emotional stimuli (Borod, 2000). However, other studies

have found that the proposed right hemispheric advantage is most prevalent for the processing of

negative emotional stimuli (Gainotti, 2012; Smith & Bulman-Fleming, 2005), and may thus not

be applicable to all behavioral research. The present findings show hemispheric asymmetries in

the unconscious processing of positive emotional stimuli, and suggest a left hemisphere

superiority in the perception of infant faces. Furthermore, the observation that males responded

more quickly to targets presented in the left visual field is consistent with substantial research

indicating that male brains are more lateralized than female brains (e.g., Tomasi & Volkow,

2011).

      Contrary to the hypothesis that women may be biologically disposed to attend to infants

more quickly than men, no significant behavioral sex differences in attention to the infant stimuli

were found. However, salivary alpha-amylase revealed sex differences in sympathetic nervous

system reactivity following the dot-probe task, with females showing elevated sAA levels from

post-task to follow-up. Male sAA levels did not significantly increase throughout the paradigm.

This difference in autonomic activity may reflect motivational differences in responding to the

infant stimuli (Lang et al., 1997). However, the occurrence of sAA increase *after* the dot-probe

task prevents any conclusions concerning this effect, and further research is needed to isolate the

impact of positive stimuli on autonomic reactivity.

      The arousal potential of a stimulus is thought to play a key role in the allocation of

attentional resources. Appraisal theories of emotion predict that stimuli with high biological

relevance receive priority processing and facilitate autonomic system changes to enable a rapid

adaptive response. The observed finding that biologically relevant positive emotional stimuli elicit quicker response times than neutral stimuli in the right hemifield supports the notion that positive arousing stimuli, similar to threatening stimuli, are more readily discerned than non-emotional stimuli.

Taken together, our results highlight the need for further examination of attention to biologically relevant positive emotional stimuli. Considering the mean age of this study's participants (19 years), and the fact that all were undergraduate students, an additional issue that might be addressed in future research is attention biases in populations where infants may represent a more salient stimulus, such as parents. Little is currently known about attention to this particular category of positive emotional stimuli, and additional research is needed to understand the perceptual processing of infant faces, as well as other biologically relevant emotional stimuli that are positive in nature.

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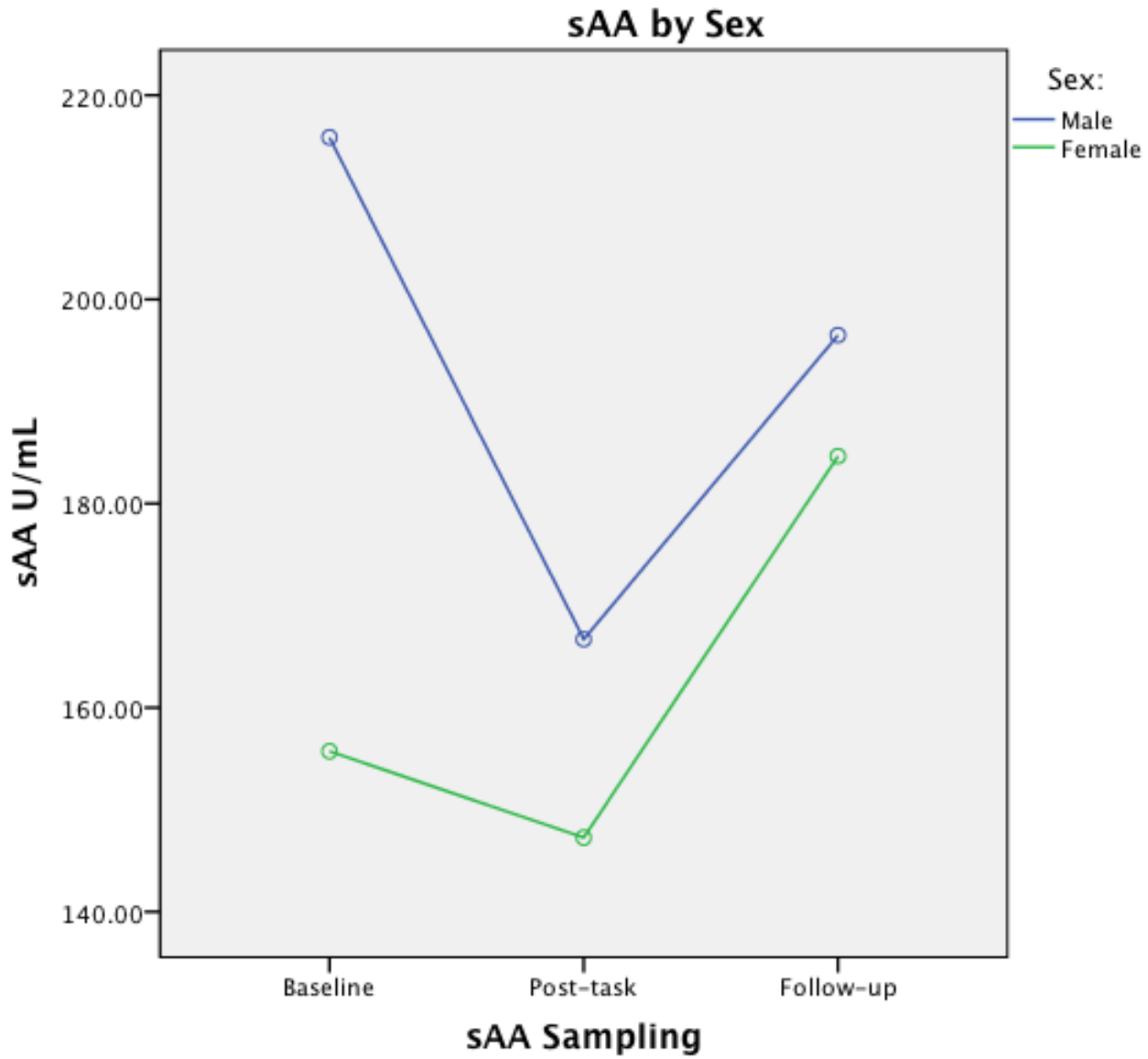
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Figure 1. Male and female alpha-amylase levels at baseline, post-task, and follow-up. Male sAA levels significantly decreased from baseline to post-task. Female sAA levels significantly increased from post-task to follow-up.
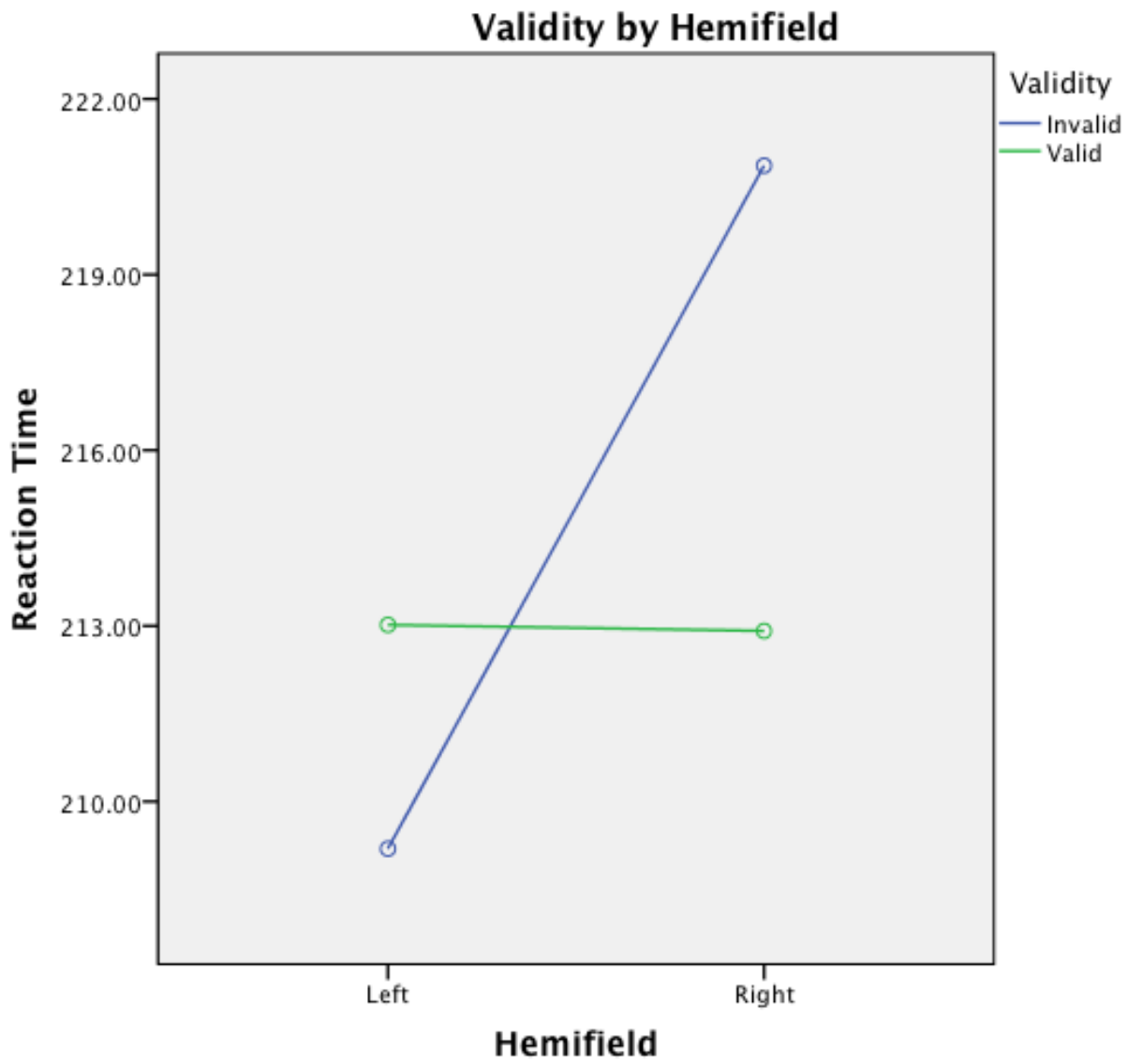
Figure 2. Significant interaction for Validity X Hemifield. Valid response times were marginally faster than invalid response times when the target was shown in the right hemifield.
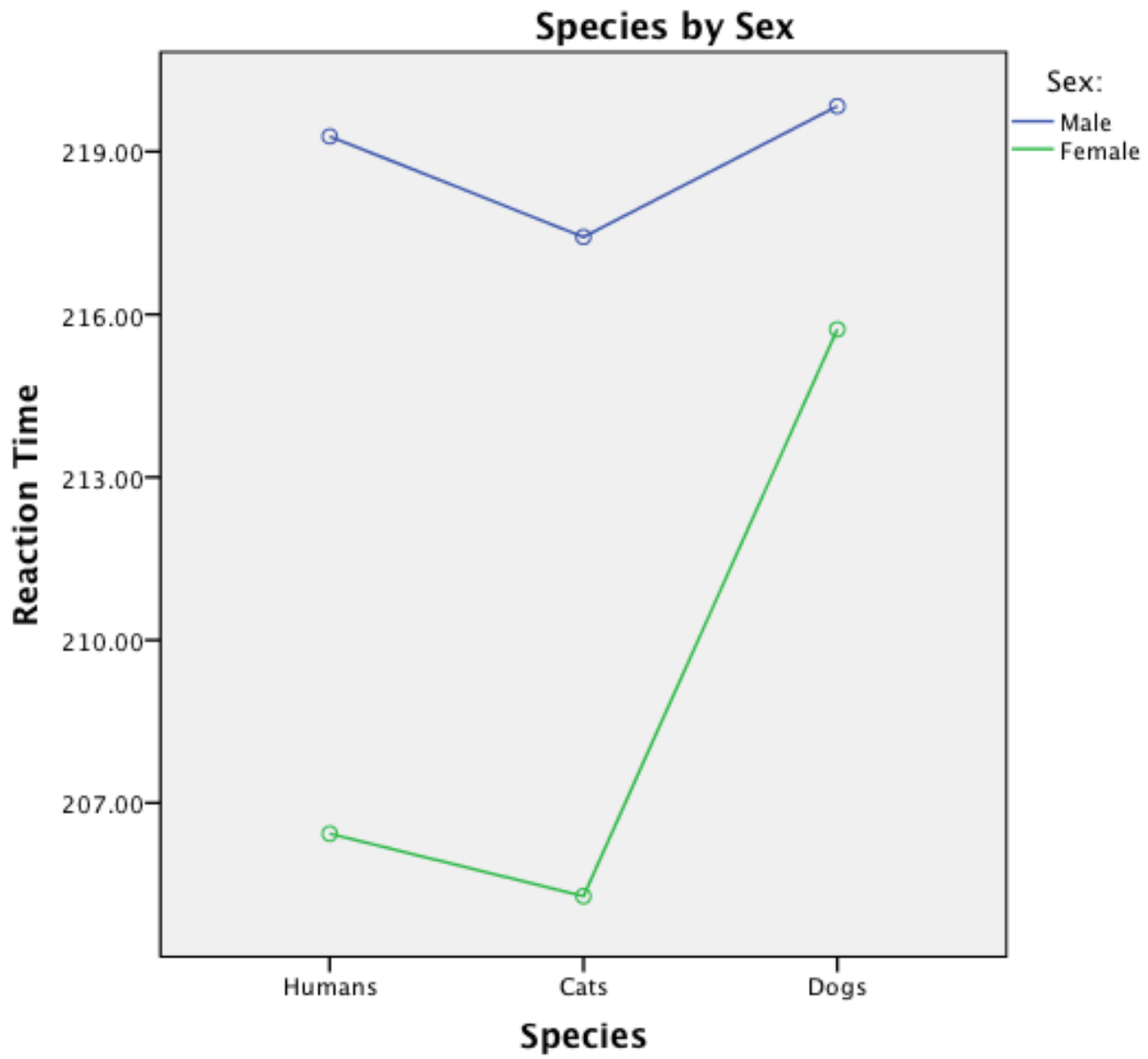
Figure 3. Although the Sex X Species interaction was not significant, females reacted more quickly to humans than dogs.
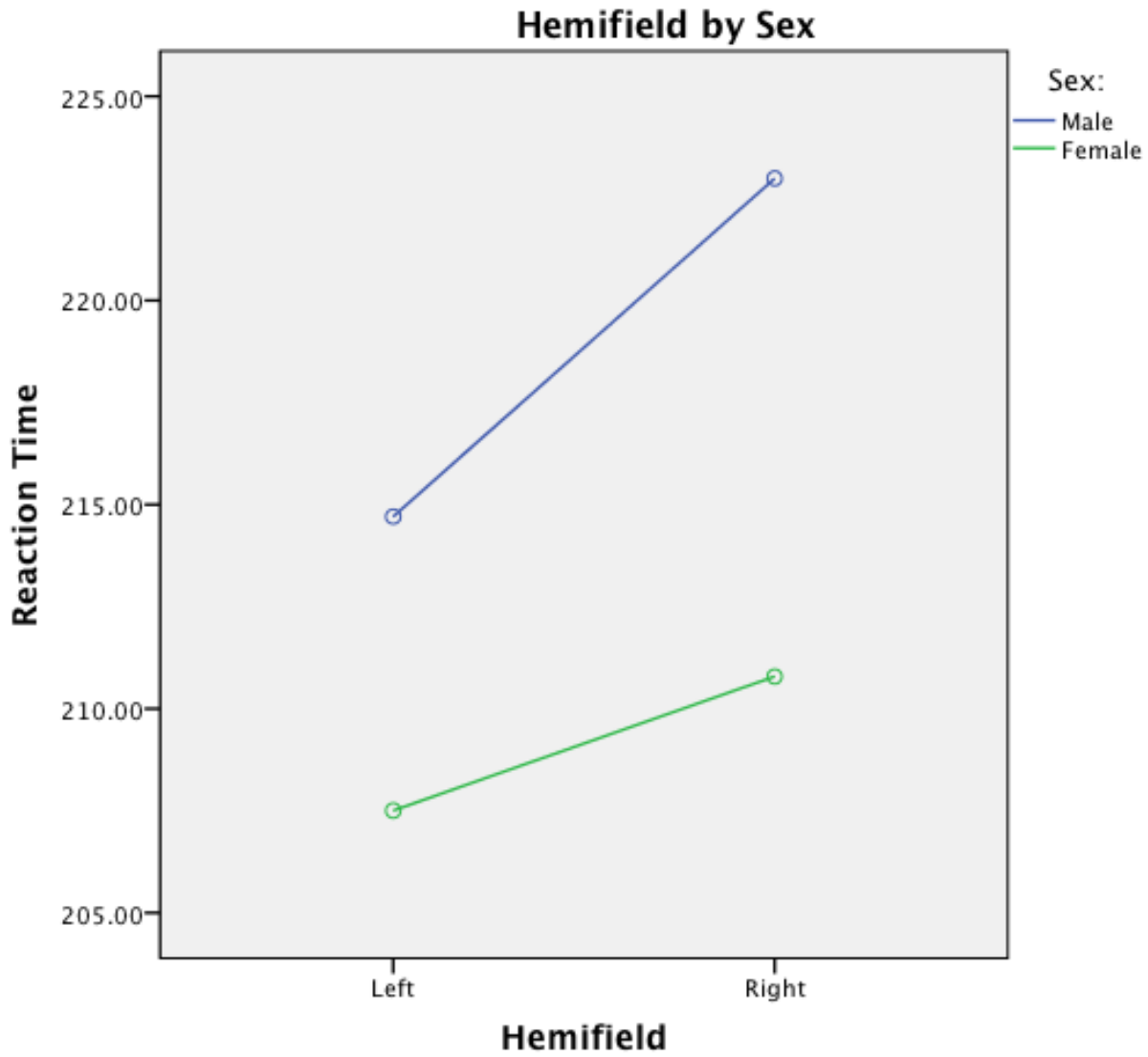
Figure 4. Hemifield X Sex interaction. Males responded more quickly to targets presented in the left visual field.