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Can Hand Position Enhance Target Detection in a Complex, Real-World Visual Search Task?

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CAN HAND POSITION ENHANCE TARGET DETECTION IN A COMPLEX, REAL-WORLD VISUAL SEARCH TASK?

By

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ABSTRACT

Previous research has shown that holding, or placing one's hands near, an object can alter visual processing of that object in a variety of ways, including enhancing the detection of change, reducing the effect of distraction, and boosting sensitivity to low-spatial frequency information. These studies have mostly used abstract laboratory cuing and search paradigms to demonstrate a near-hands advantage. In the current study we explored whether enhanced visual analysis in the space near one's hands confers an advantage when applied to a real-world visual search task. We asked participants to search for knives in X-ray images of luggage (a TSA baggage screening task). Stimuli were presented on a tablet computer. In one experiment participants performed the task by pressing response boxes at the edge of the screen, which forced them to grip the display within their hands. Alternatively, they responded with button press on a mouse held within their lap. There was no effect of hand placement on speed or accuracy. In a second experiment, participants were asked to use their finger to trace along the image of the bag to ensure that all potential target locations were inspected. In addition to any effect of hand proximity to the target, it was anticipated that this strategy would encourage a more systematic search strategy, potentially improving accuracy. Participants inspected bags substantially longer when using this strategy (1,238 ms longer for target present trials, 2,590 ms for target absent trials). Interestingly, this additional time spent viewing the image did not result in improved accuracy. While basic research suggests that hand proximity can influence visual processing, these benefits may not scale-up to more complex search situations.

INTRODUCTION

Visual Search

Visual search is the process of detecting or locating a particular stimulus (target) in an environment containing one or more non-target items (distractors), and it is one of the most common tasks that we perform each day (see Wolfe, 1994; for review). Examples include searching for a car in a parking lot, a friend's face in a crowd, a pen on a desk, or a specific book on a shelf. These visual environments are often too complex to instantly recognize the presence and location of the target item. Search can be conceptualized as the process of successively allocating limited visual processing resources from location to location in a scene until the target is found and recognized, or until it can be confidently concluded that the target is not present. Efficient and effective visual search is important for survival (e.g., a primate searching for berries to eat), and failures of the visual search process can have disastrous consequences in modern life (e.g., a TSA baggage screener who searches unsuccessfully for a threat item, or a radiologist who fails to detect a suspicious tissue mass). Search is a fundamental process worthy of exploration, as are various methods with which to improve visual search accuracy given that failures to find targets can have major implications for performance and safety outside of the laboratory.

Determinants of Search Efficiency

A variety of factors influence visual search efficiency and success. The majority of this work has focused on how the visual properties of target and distractor items influence search efficiency, which is typically assessed by measuring how much longer the search process takes when additional distractors are added to the display (i.e., set size by response time functions, typically referred to as search slope). When the target is distinct from distractors, adding more distractors to the display (increasing set size) produces little increase in the time needed to find the target, producing a shallow search slope. However, as the target becomes increasingly similar to distractors, each additional distractor added to the display results in some cost to response time, producing a steeper set size x response time function.

Whether the detection of the target requires attention was proposed by early search models as the primary factor distinguishing easy from hard searches (Treisman & Gelade, 1980). A target that differs from distractors based on just one feature (e.g., color or orientation) doesn't require attention to detect. These basic visual differences are computed early in vision (preattentively) and no additional processing is required to resolve the target from distractor items. However, when the target differs from non-targets based on the conjunction of two or more features (e.g., color and orientation), attention needs to be shifted serially from item to item to integrate different features into stable object representations. Only after this integration process can an individual item be identified as the target or rejected as a distractor. This is why it is easy to detect a red circle among green circles, but harder to find a red vertical line among red horizontal lines and green vertical and horizontal lines. Other models propose that search efficiency depends not just on the similarity between the target and distractors, but also the similarity among distractor items (Duncan & Humphreys, 1989). As distractors become more similar, they are more easily rejected en masse, increasing the efficiency with which the target can be found. Wolfe (1994), on the other hand, primarily attributes search efficiency to the efficiency with which attention can be guided to the target based on known features that distinguish the target from distractors. This leads to the correct prediction, contrary to Treisman and Gelade (1980), that a target defined by the conjunction of three features should be relatively easy to find because guidance can be based on three sources of information (e.g., color, orientation, size). These studies typically use targets and distractors that are distinct from the background. However, the similarity between the target and the background (camouflage) also plays an important role in some situations (Boot, Neider, & Kramer, 2009).

Boot, Neider, and Kramer (2009) also demonstrated another important factor that determines search performance: practice. In their camouflage search paradigm, participants greatly improved their performance after a few hours of visual search practice. Practice differentially benefited harder searches (camouflage search) compared to easier searches (non-camouflage search). Interestingly, search training transferred to novel targets that participants had not seen before. Both younger adults and older adults can, with practice, greatly improve the speed and accuracy with which they can improve in camouflage search situations (Neider, Boot, & Kramer, 2010). In simpler search tasks it has been demonstrated that with enough practice, finding the search target can resemble an automatic process (Schneider & Shiffrin, 1977). That is, with enough practice search slopes can go from very steep to virtually flat. Practice can also have an impact on real-world, safety-related search tasks such as a TSA baggage screening task (McCarley et al., 2004). In addition to the visual properties of search targets, distractors, and the search background, previous experience can exert a large influence on search performance.

Hand Position and Visual Processing

This paper will explore a novel method through which visual search performance might be improved in safety-critical real-world tasks: manipulating hand position. Over the past decade numerous studies have suggested that the position of one's hands can enhance visual processing (Brockmole, Davoli, Abrams, & Witt, 2013). If true, hand position might provide some advantage to searchers as they perform real-world search tasks. Next, I provide a brief review of the evidence that hand position can change the way we process visual information.

Reed, Grubb, and Steele (2006) explored the effect that hand position could have on the visual processing of information in peripersonal space (the space around one's body). Participants were asked to maintain fixation on a cross at the center of the screen that was flanked by two boxes (one on each side of the screen). The task was to respond with a mouse click whenever a target (black dot) appeared in the left or right box. A cue, the brightening of one of the boxes, preceded the target, and this cue coincided with the target's location 70% of the time. In this type of paradigm, typically there is an advantage (faster responses) on trials on which the target and cue coincide spatially (valid trials), and a cost when the cue and the target do not coincide (invalid trials). Reed et al. (2006) instructed participants to hold one of their hands to the computer screen near one of the boxes while they performed the detection task. Regardless of the validity of the cue, facilitation (in terms of response time) was observed when the target occurred on the side of the screen near the hand.[1] This pattern suggests a general attentional prioritization of space near one's hand. A control experiment that placed a board the same size as an arm and hand near one of the boxes found no effect on response times, confirming that the effect was unlikely to be driven by purely visual factors (i.e., the effect of a salient visual landmark). Further, an effect was observed when participants' hands touched the screen but their view of their hand was blocked. The authors propose that targets near the hand

[1] Note that the response time pattern was complex. A general left-bias was observed in which there was a tendency for faster responses to targets on the left. This bias was increased when the left hand was near the left target location, and this bias was eliminated when the right hand was near the right target location.

may be perceived as more salient, and point to evidence that some neurons respond selectively to visual stimuli that occur near the hands.

In subsequent experiments, Reed, Betz, Garza, and Roberts (2010) observed a response time benefit only when the target appeared near the participant's palm rather than the back of his or her hand. Results suggest a modulation of visual processing for objects within one's grasping space. Interestingly, this study found that tools placed near the target produced a similar effect. Reed and colleagues gave participants a tiny rake (for use in Zen gardens) to hold up to the computer monitor. When the rake was positioned as if it could sweep up the target, facilitation was observed. However, when the rake faced away from the target no benefit was observed.

Abrams et al. (2008) explored the effect of hand position on attentional allocation within a variety of tasks. For these tasks, participants either pushed buttons on the side of the computer monitor (meaning the monitor was between their hands) or on a board placed in their laps. In general, it was found that when the display was flanked by the participant's hands, items in the display received more scrutiny. In a visual search task, participants searched for an H or an S among Es and Us. Set size varied from 4 to 8 items. Search slopes were steeper when the participants' hands were near the display, consistent with each item receiving more attention and analysis during search. In a cuing paradigm similar to the one already described, Abrams and colleagues explored both the facilitation and inhibition caused by a non-predictive cue. When a cue and target occur on the same side of the display, response times are typically fast. However, after approximately 350 ms of the cue's appearance, detection of the target is actually faster on the side of the screen opposite the cue. This effect is known as inhibition of return (IOR) and is thought to reflect an inhibitory mechanism that prevents attention from sampling the same locations over and over again once attention has been disengaged (for reviews see Wang &

Klein, 2010). According to the visual search results, hands near the screen appear to delay the disengagement of attention from objects. Since inhibition of return requires the disengagement of attention from the cue location for inhibition to occur, there should be a smaller IOR effect when participants had their hands near the display. This was exactly what was observed. This again is consistent with objects receiving more attention when they occur between the hands. Finally, a separate experiment examined how hand proximity influenced performance in an attention blink task. In this task, participants viewed a rapid series characters and had to report two things 1) the digit that appeared among letters (odd or even), and 2) whether an A or B occurred some time after this digit. What is typically found is an “attention blink.” When the second target (A or B) appears close in time to the first, it is often missed. In other words, the second item is not processed when attentional resources are still occupied processing the first target. If hand proximity results in a deeper processing of objects near the hands, then the attention blink effect should be larger because of the first target receiving a more detailed analysis. Consistent with predictions, accuracy was lower for the second target when the hands were near the monitor. In general, Abrams and colleagues (2008) report these studies as supporting the fact that objects near the hands receive more detailed analysis by the visual system, in part through a tendency to disengage attention more slowly.

Tseng and Bridgeman (2011) provided further evidence that stimuli near the hands receive enhanced processing. Methods were largely modelled off of those by Abrams et al. (2008), except Tseng and Bridgeman (2011) had participants complete a challenging change detection task. Participants were presented with 8-12 colored squares briefly. After a delay, they were presented the same display again except one square might change color. The task was to decide whether or not a change occurred. These set sizes substantially exceed the capacity of visual short term memory (typically estimated as 4). Sensitivity to change (regardless of set size) was significantly better in the condition in which participants' hands were near the monitor. This resulted in participants being able to expand their memory capacity by .6 to .75 items. Further, this facilitation appeared to be present regardless of whether the actual change was near the hands or far from the hands, as long as the change occurred between the hands.

Hand position has also been found to prevent distraction from objects outside of one's hands. This was demonstrated elegantly by Davoli and Brockmole (2012). Participants completed a flanker task in which they had to identify a letter at the center of the screen surrounded by two large flanking letters. Typically when the center letter's response matches that of the flanking letters, participants are fast. When the flanking letters suggest a different response compared to the center letter, responses are slowed (a flanker effects). The critical manipulation was whether or not the center letter appeared between the participant's cupped hands. When the center letter appeared within the participant's hands, they were able to completely ignore the flanking items compared to a large flanker effect when their hands were away from the display. Hand-shaped barriers made of wood placed around the center letter did not have the same effect, suggesting that that decreased distraction was not the result of simply having a visual barrier between target and distractor items. Benefits were only observed when the object appeared within a participant's cupped hands, and not just when their hands were near the center letter. In addition to enhancing visual processing, these results also suggest that holding an object can reduce distraction from objects not within one's hands.

Other Hand Position Effects

In addition to influencing visual attention, largely drawing attention to objects within reach or within the hands, preventing distraction, and encouraging more thorough processing of these objects, a number of other hand effects have been observed. For example, Cosman and Vecera (2010) found that in displays containing ambiguous figures, regions that were reached for were more likely to be interpreted as figure rather than ground. Davoli, Brockmole, Du, and Abrams (2012) had participants complete a task-switching task for stimuli between their hands. This task required participants to change the scope of their attention to report either global or local features of a stimulus. It was more difficult for participants to switch from one task to another when stimuli occurred between the hands, suggesting that attention may become "locked in" on relevant aspects of an object when that object occurs between the hands. Interestingly, semantic processing for words presented between the hands appears to be impaired, consistent with less of a holistic analysis and a greater focus on visual detail. Davoli, Du, Montana, Gaverick, and Abrams (2010) presented sentences between participants' hands and had them judge whether the sentences made sense or not. Detection of nonsensical sentences was worse when the sentence occurred between the hands compared to when sentences did not occur near the hands. In a follow up experiment, participants completed a Stroop task. In this task, participants must perform the difficult task of naming the font color of a word when the meaning of the word is incongruent (e.g., saying "blue" when the word "red" is printed in blue ink). Interference was less when the Stroop stimulus occurred between the hands compared to outside of the hands.

Neurobiology of the Near-Hand Advantage

The neural mechanisms responsible for changes in visual processing based on hand proximity are not fully understood (Brockmole et al., 2013). Many explanations implicate multimodal neurons. Unlike unimodal neurons which only respond to one stimulus modality (e.g., taste, sound, touch, sight, smell), multimodal neurons distributed throughout the brain receive and integrate information from two or more modalities (Stein & Stanford, 2008). For example, bimodal visuotactile neurons respond to both visual and tactile stimulation (Graziano & Gross, 1998; Bresciani, Dammeier, & Ernst, 2006). Bimodal neurons in premotor and parietal cortex in particular respond to objects near the hands and have hand-centric receptive fields (Tseng, Bridgeman, & Juan, 2012). These neurons can even exhibit a graded response, with greater activation as the distance between a hand and an object decreases. It is possible bimodal neurons may provide an additional neural signal with which to quickly detect visual target items that are close to one's hands. When one's hands are away from an object this signal may be reduced or absent. The presence of these neurons specifically in parietal cortex, which plays a large role spatial attention, further links hand position to potential differences in visual processing and attentional disengagement. While the exact neural mechanisms have not conclusively been identified, various interactions between neurons and brain regions that represent visual, tactile, and body position information, and that also appear to play a role in attention, provide a biologically plausible mechanism for near-hand effects.

The Current Study

The reviewed literature suggests that 1) objects within the hands receive a more careful analysis compared to objects outside of the hand, 2) attention is biased to locations near the hands, 3) distraction can better be prevented for objects held within one's hands, and 4) that processing can become more detail oriented for objects within one's hands. However, all of these studies have used relatively simple, abstract tasks and stimuli and it is not clear 1) how well such effects might scale up to complex, real-world tasks, and 2) whether these effects might be powerful enough to improve performance on these important real-world tasks. This thesis explored these questions in the context of a difficult real-world task: Transportation Security Administration (TSA) baggage screening. TSA baggage screeners inspect cluttered X-ray images of baggage in an attempt to detect threat items (e.g., guns, knives, explosives). This is an extremely challenging task. In fact, Homeland Security recently found that TSA agents failed tests in which contraband items were introduced into baggage 67 times out of 70 tests (Fischel, Thomas, Levine, & Date, 2015).

McCarley et al. (2004) examined performance on this task over time in an undergraduate population. Over several sessions, participants were asked to search for different knives within X-ray baggage images. With practice performance improved substantially in terms of response time and target sensitivity. However, at the end of training 11% of misses occurred because participants fixated the threat item but did not recognize it. If hand position can increase scrutiny of objects between the hands, and can facilitate more detailed processing, it is possible that these types of errors can be reduced. We examine whether the search for threat items might be improved for participants when they hold the baggage image within their hands.

EXPERIMENT 1

Methods

Participants

Sixty-eight undergraduate students with self-reported normal color vision participated for course credit (*M* age = 18, *SD* = 1.03; 11 males). This sample size is sufficient to detect a small-medium within-participant effect (Cohen's *f* = .175) with a probability of .90 at an alpha level of .05 (G*Power v. 3.1.9.2). We anticipated a correlation of .62 between repeated measures based on pilot data.

Materials

All stimuli were presented on a 12-inch Microsoft Surface Pro 3 tablet PC (1280 x 768 resolution). Response latency and accuracy data were collected using a mouse or touch screen responses.

Stimuli

Stimulus sets were created using images from a previous study (McCarley et al., 2004). This original set included 900 X-ray images of baggage. Smaller bags were excluded in the present study to enhance the perception that the full extent of the bag was between participants' hands. This process identified 229 images of bags with a target (knife) present, and 292 bags with no target (Figure 1). In a pilot study, five participants searched these image and responded whether a knife was present or absent. We used accuracy data from these participants to create two sets of 120 images of equal difficulty to be counterbalanced across conditions. We will refer to these image sets as Set A and Set B. Each set had 60 target present images and 60 target absent images.

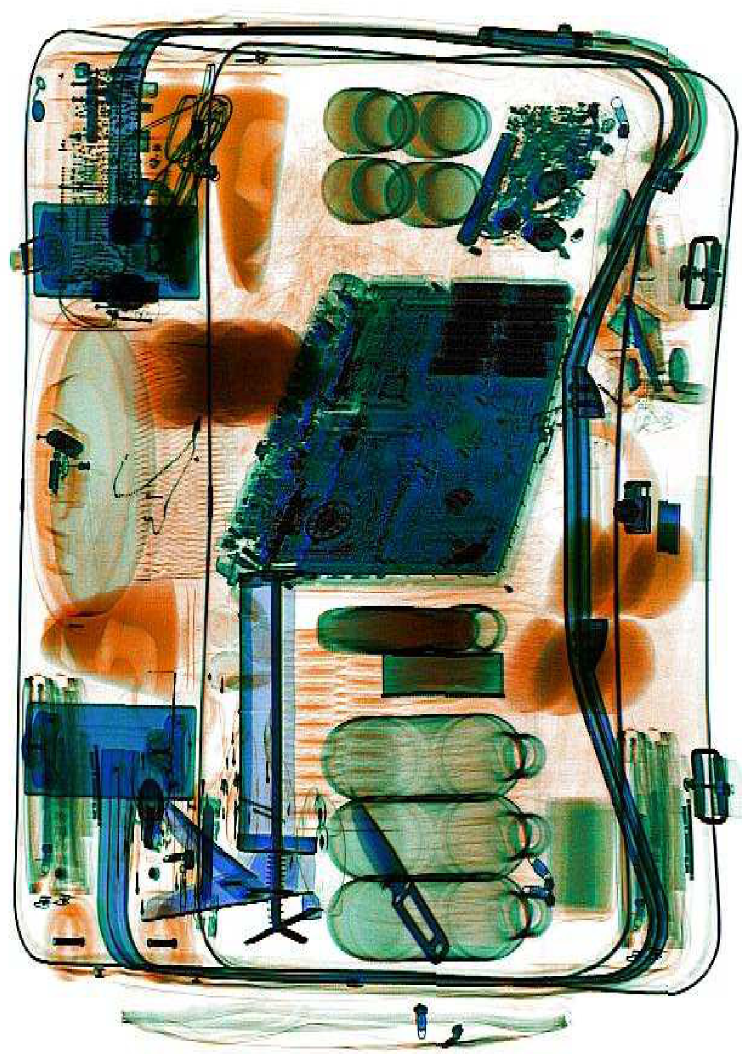

Figure 1. Example of a threat present image. The knife is in the lower portion of the image, at center.

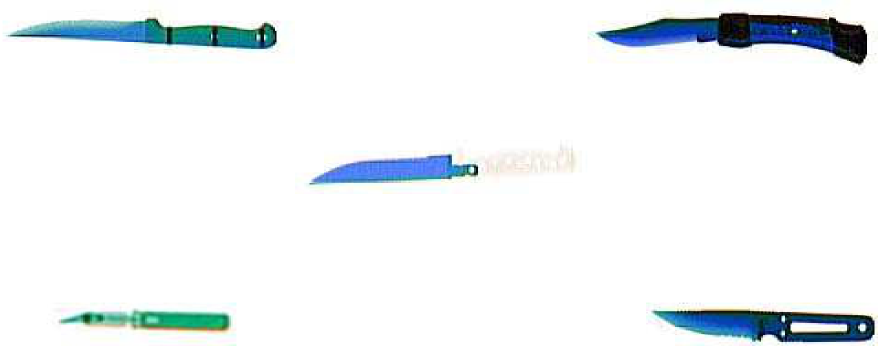

Figure 2. Image of the five knives that could appear in bags. Before each block, participants were shown this image to familiarize them with potential targets.

TSA Baggage Paradigm

The TSA baggage paradigm was created using OpenSesame (Mathôt, Schreij, & Theeuwes, 2012). Participants were asked to search for one of five knives within each bag and report whether a knife was present or absent by making one of two responses. Participants were familiarized with all five knives before each block of trials (Figure 2), and completed one version of the task using response buttons (Threat Present, Threat Absent) at the side of the screen of the tablet. These buttons were implemented through the touchscreen interface. The position of these response buttons required that the tablet be held between the hands of the participant (Hands Near condition, Figure 3). In another version, images of these response buttons remained on the screen, but instead of responding using the touchscreen participants responded by pressing the left or right mouse button of a mouse held in their lap (Hands Away condition, Figure 3). No feedback was provided regarding accuracy.

Figure 3. Depiction of the Experiment setup and hand positions from all 2 experiments.

Procedure

Upon entering the lab and giving consent, participants completed both tasks listed in the Materials section. Hand Position and Image Set order were counterbalanced. In each condition, participants were told to imagine that they were a worker at an airport-security station, and their job was to search for hidden knives in images of luggage. If participants saw a bag containing a knife, participants were instructed to "stop the bag" from passing through inspection and responded by pressing the Threat Present Button. If participants did not see a knife, participants were instructed to "pass the bag" allowing it the pass through inspection and responded by pressing the Threat Absent Button. In the Hands Near condition participants responded by pressing the Threat Present Button on the screen with their left thumb and Threat absent Button on the screen with the right thumb. In the Hands Away condition participants responded by pressing the left mouse button for a Threat Present response with the left thumb and pressed the right mouse button for a Threat Absent response with the right thumb. For each condition, the experimenter read instructions directly from the screen, word for word, emphasizing the idea that participants should respond accurately, but not take any more time than necessary (similar to the demands of TSA baggage screeners). Each block of 120 trials were preceded by 10 practice trials.

Results

Trial Exclusion

Response time analyses only included trials on which participants made a correct response.

Response Time

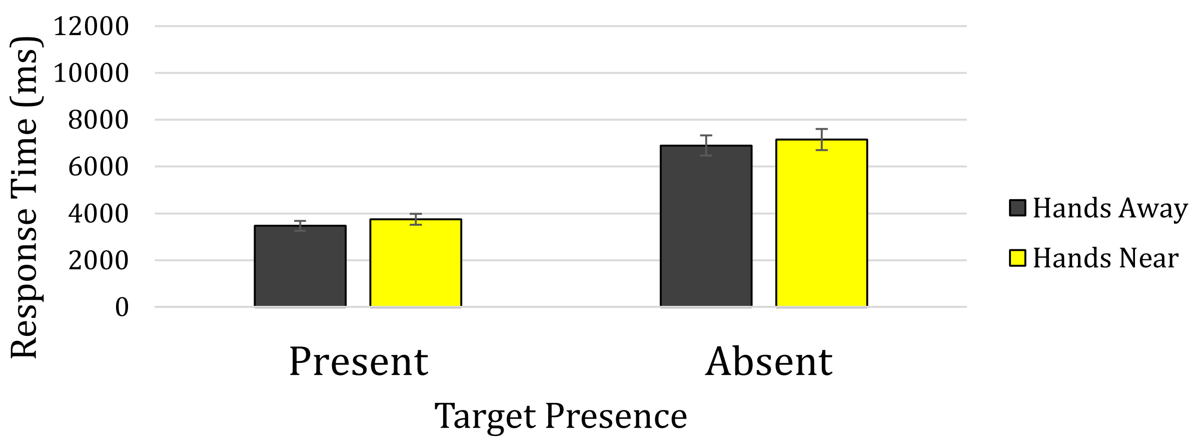

Figure 4. Response Time as a function of Target Presence and Hand Condition in Experiment 1. Error bars represent +/- one standard error of the mean.

We would expect participants' response times in the Hands Near condition to be longer if hand proximity increases visual processing and delays attentional disengagement. Participants' response times were entered into an ANOVA with Target Presence (Present vs. Absent) and Hand Position (Hands Near vs. Hands Away) as within-participants factors. Consistent with most visual search results, a main effect of Target Presence was found, F (1, 67) = 138.05, $p <$ .001 (See Figure 4). Participants were slower to respond in trials on which threat items were absent compared to present. Contrary to predictions, Hand Position had no effect on response times, $F(1,67) = 1.50$, $p = .31$ and there was no interaction between Hand Position and Target Presence, $F(1, 67) = 0.009$, $p = .93$.

Accuracy

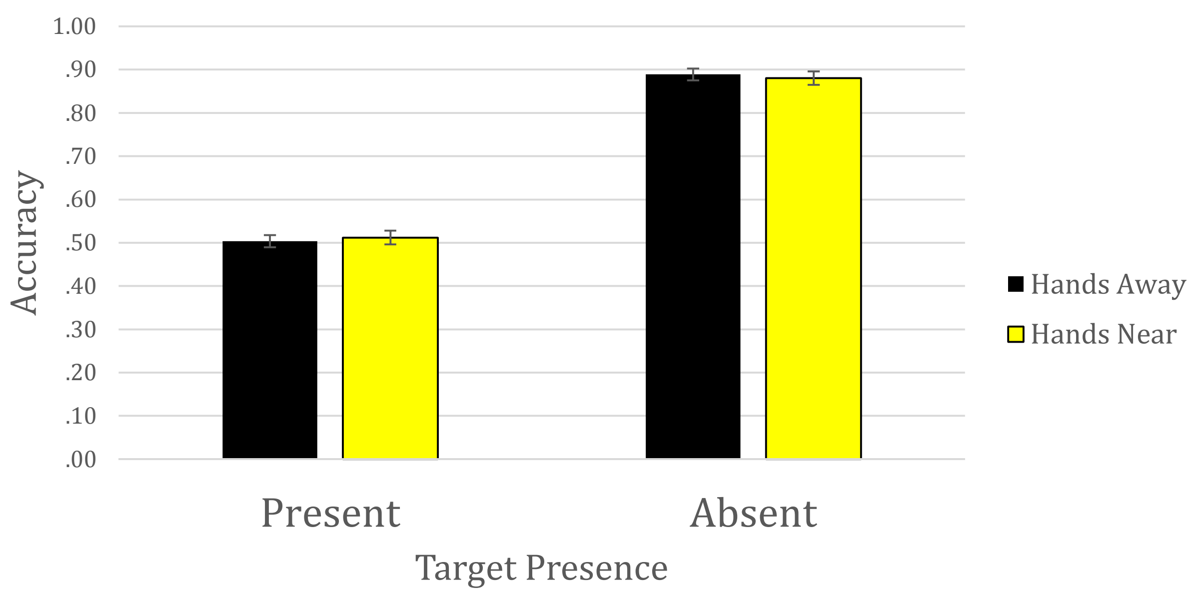

Figure 5. Accuracy as a function of Target Presence and Hand Condition in Experiment 1. Error bars represent +/- one standard error of the mean.

Accuracy data were entered into an ANOVA with Target Presence (Present vs. Absent) and Hand Position (Hands Near vs. Hands Away) as within-participants factors. A main effect of Target Presence was found, F (1, 67) = 256.98, $p < .001$(See Figure 5). Participants were more accurate in trials on which threats were absent compared to present. Contrary to predictions, Hand Position had no effect on accuracy, $F(1,67) = 0.003$, $p = .96$) and there was no interaction between Hand Position and Target Presence, $F(1, 67) = 0.27$, $p = .61$.

Sensitivity

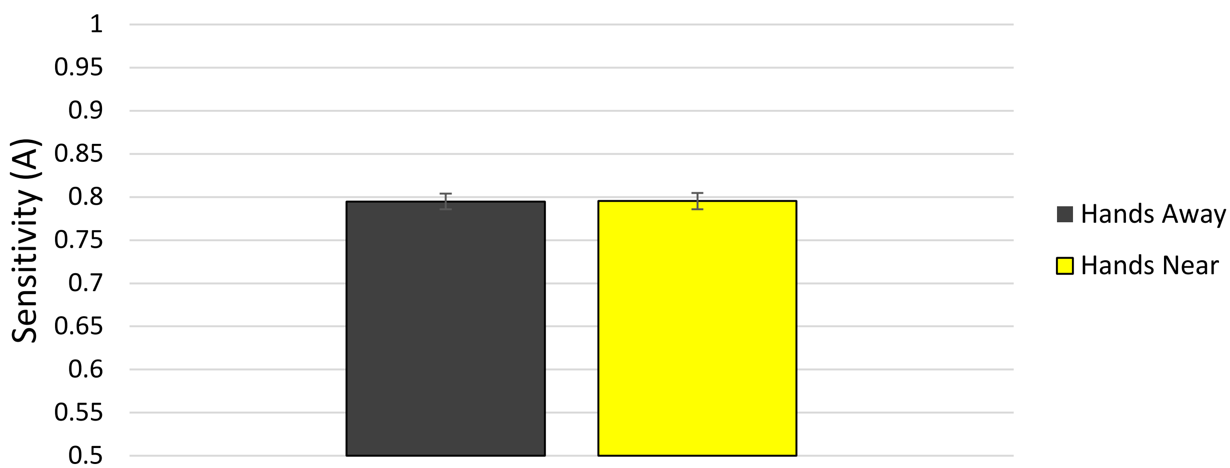

Figure 6. Sensitivity as a function of Hand Condition for Experiment 1. A ranges from .5 to 1. Error bars represent +/- one standard error of the mean.

Target sensitivity (*A*) was the primary measure of performance. *A* is a corrected measure of sensitivity measure *A'* (Zhang and Mueller, 2005). It is an alternative to *d'* and is useful in cases in which hit rates are sometimes 100% and/or false alarm rates are zero. It was predicted that, if hand position encourages more thorough and detailed visual processing, that sensitivity would be higher in the Hands Near condition. Sensitivity data were entered into an ANOVA with Hand Position (Hands Near vs. Hands Away) as a within-participants factor. Contrary to predictions, there was no effect of Hand Position, $F(1,67) = .004$, $p = .95$ (See Figure 6).

Bias

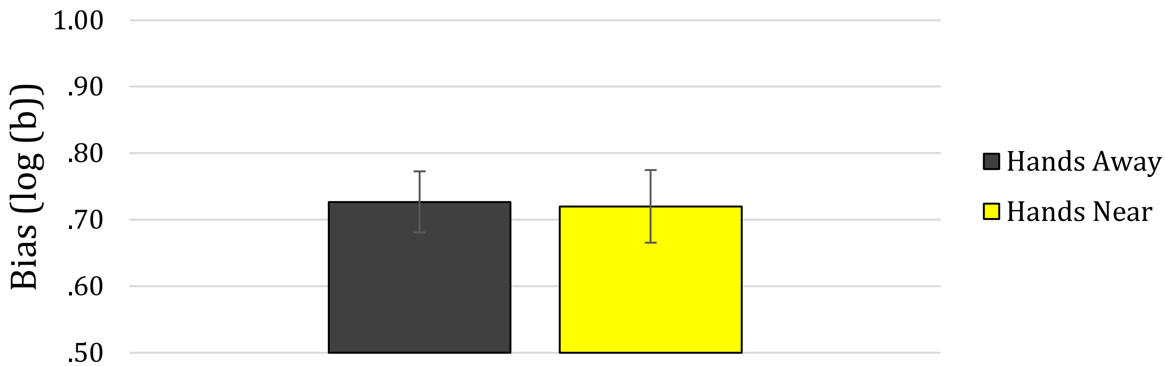

Figure 7. Bias as a function of Hand Condition in Experiment 1. Bias is reported as log (*b*), a symmetric bias measure (0=unbiased). Error bars represent +/- one standard error of the mean.

In addition to sensitivity, we also explored whether Hand Position might influence bias (making participants either more liberal or conservative in their response). Log (*b*) served as a measure of bias, and is a symmetric bias measure associated with *A* (Zhang and Mueller, 2005). Bias data were entered into an ANOVA with Hand Position (Hands Near vs. Hands Away) as a within-participants factor. There was no effect of Hand Position on Bias, $F(1,67) = .04$, $p = .85$ (See Figure 7).

Summary

We predicted that participants in the Hands Near condition would exhibit enhanced visual processing and delayed disengagement of attention that would produce slower response times, increased accuracy, and greater sensitivity to threat items. Contrary to predictions, when participants had their hands near the search display performance did not differ compared to when their hands were away from the display.

EXPERIMENT 2

One potential reason for a lack of a hands-near effect might be that the search targets were too far from the participants' hands. At least some effects require the hand to be near the target for benefits to be observed (e.g., Reed et al., 2006). A second experiment was conducted with the purpose of decreasing the distance between participants' hands and the search target. We asked participants to perform the task using a "Finger Sweep" strategy in which they traced the finger of one hand systematically along the image during search to ensure the proximity of their hand to the search target on each trial. Participants used their finger to sweep along the display, left to right, top to bottom. We anticipated that this strategy might benefit search for two reasons. In addition to any potential benefit in terms of visual processing resulting from hand proximity, we predicted that this strategy would also encourage a more systematic search in which all potential target locations were searched.

Methods

Participants

Thirty-two undergraduate students with self-reported normal color vision participated in this study for course credit (*M* age = 19, *SD* = 1.45; 9 males).

Materials

Same as Experiment 1.

TSA Baggage Paradigm

The paradigm was identical to the one used in Experiment 1, but the response method and Hand Positions differed. Participants in both tasks responded to whether a target was present or absent using one of two keys on the keyboard. In one condition a "Finger sweep" strategy was introduced in which participants were encouraged to trace their left finger along the image, left to right, top to bottom (Hand Near condition, Figure 3). In another condition participants placed their left hand on the table away from the display (Hand Away condition, Figure 3).

Procedure

Hand Position and Image Set order were counterbalanced. For each condition, participants were told to complete two search tasks using two different strategies. In the Hand Near condition participants were told to complete the current section of the experiment with a specific strategy, to search for a knife in the luggage by scanning the image with their finger. The strategy involved putting the left index finger on the screen and sweeping the screen from left to right to make sure all possible locations were searched. Starting at the upper left-hand corner of the bag, participants would sweep their finger from left to right across the bag making a line across the bag and would then start again below the previously traced line. Participants were told to search the bag where the finger was located and to move their attention as the finger moved. Participants were told the aim of this strategy was to help systematically search the bag and make sure that all potential locations a knife could be located received attention. If a knife was found participants were told to stop scanning the bag with the finger and make a response. A video of the "Finger Sweep" strategy was displayed for the participant and participants were told to emulate the video for each image. Participants responded with the right hand using keyboard responses for Threat Present and Threat absent. If a knife was present participants responded by pressing the left arrow key and if a knife was absent participants responded by pressing the right arrow key. In the Hand Away condition participants were told to search for a knife while the left hand was held flat against the table to the left of the keyboard. For each condition, experimenters read instructions directly from the screen, word for word, emphasizing the idea that participants should respond accurately, but not to take any more time than necessary (similar to the demands of TSA baggage screeners). Each block was preceded by 10 practice trials.

Results

Trial Exclusion

Only response times from accurate trials were considered in analyses of response time.

Response Time

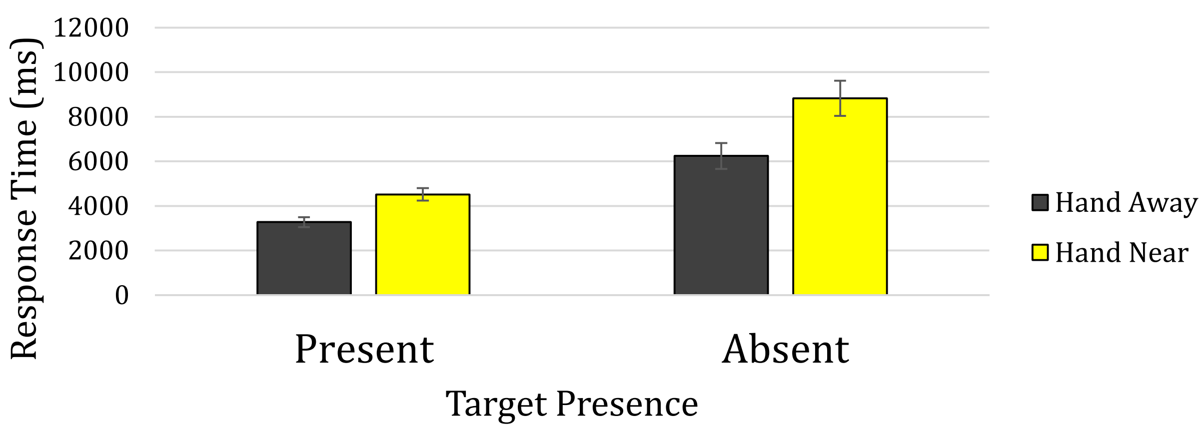

Figure 8. Response Time as a function of Target Presence and Hand Condition in Experiment 2. Error bars represent +/- one standard error of the mean.

Response times were entered into an ANOVA with Target Presence (Present vs. Absent) and Hand Position (Hand Near vs. Hand Away) as within-participants factors. This analysis indicated a significant effect of Target Presence, F (1, 31) = 67.52, $p < .001$, Hand Position, $F(1,31) = 27.14$, $p < .001$, and a significant interaction between Hand Position and Target Presence, $F(1, 31) = 8.36$, $p < .01$. The finger sweep condition prolonged inspection times, and this was especially true for target absent trials (1238 ms for target present trials, 2590 ms for target absent trials; Figure 8).

Accuracy

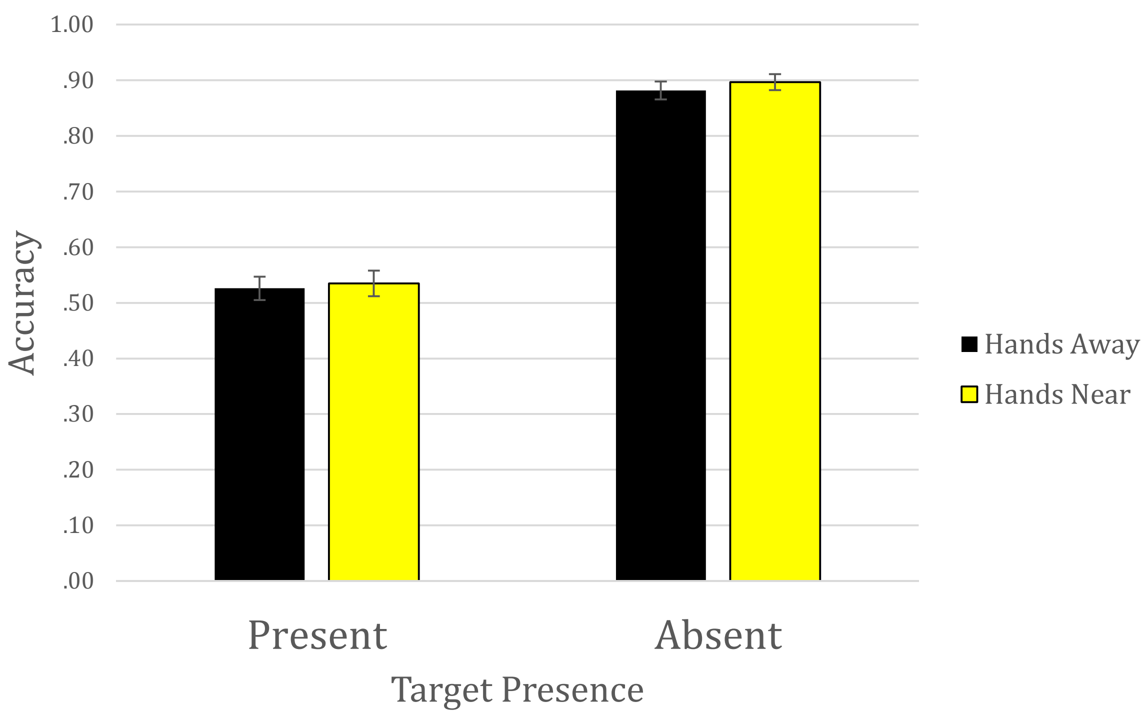

Figure 9. Accuracy as a function of Target Presence and Hand Condition in Experiment 2. Error bars represent +/- one standard error of the mean.

Accuracy data were entered into an ANOVA with Target Presence (Present or Absent) and Hand Position (Hand Near vs. Hand Away) as within-participants factors. A main effect of Target Presence was found, F (1, 31) = 143.96, $p < .001$ (Figure 9). Participants were more accurate on trials on which threats were absent compared to when threats were present. However, contrary to prediction, Hand Position had no effect on accuracy, $F(1,31) = 1.06$, $p = .31$, and there was no interaction between Hand Position and Target Presence, $F(1, 31) = 1.79$, $p = .19$.

Sensitivity

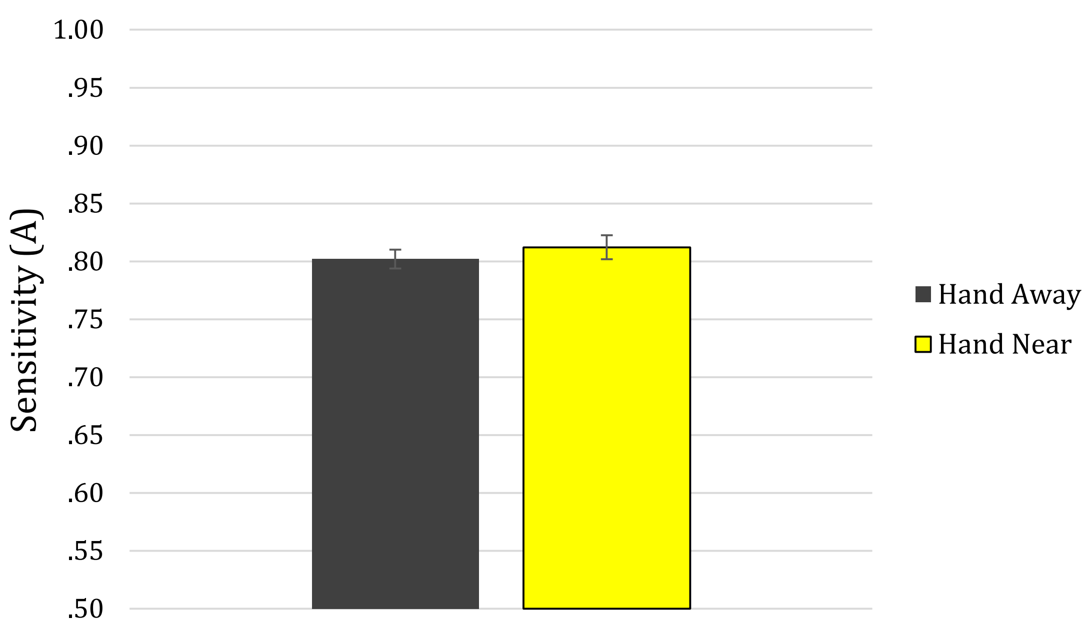

Figure 10. Sensitivity as a function of Hand Condition in Experiment 2. *A* ranges from .5 to 1. Error bars represent +/- one standard error of the mean.

Sensitivity data (*A*) were entered into an ANOVA with Hand Position (Hand Near vs. Hand Away) as a within-participants factor. Contrary to a near-hand advantage, there was no effect of Hand Position on sensitivity, $F(1,31) = .84$, $p = .37$(Figure 10).

Bias

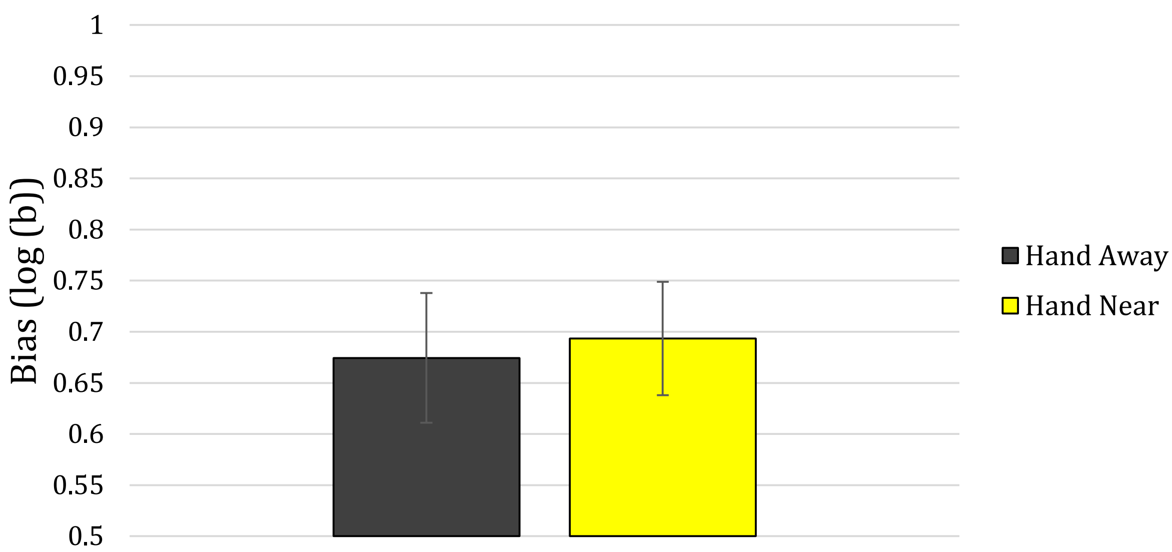

Figure 11. Bias as a function of Hand Condition for Experiment 2. Bias is reported as log (**b**), a symmetric bias measure (0=unbiased). Error bars represent +/- one standard error of the mean.

Bias data (log *b*) were entered into an ANOVA with Hand Position (Hand Near vs. Hand Away) as a within-participants factor. There was no effect of Hand Position on Bias, $F(1,31) = .14$, $p = .71$(See Figure 11).

Summary

Participants were asked to sweep the screen with a finger to make sure all possible locations were searched. This made participants substantially slower, especially on target absent trials. Contrary to our expectations, this extra time viewing each image did not improve performance.

DISCUSSION

Previous research has demonstrated that, in a variety of contexts, hand position can influence visual processing, including enhancing change detection, reducing the effect of distraction, and boosting sensitivity to low-spatial frequency information (e.g., Brockmole et al., 2013; Davoli & Brockmole, 2012; Tseng & Bridgeman, 2011; Reed et al., 2006). We aimed to explore whether hand position could enhance visual processing and benefit the performance of a "real world" search task. TSA baggage screening is a difficult and error-prone task, and discovering methods through which accuracy might be improved could have significant consequences.

One type of error in particular might benefit from a near-hands advantage. McCarley et al. (2004) found that even when participants fixated threat items in a TSA screening task they failed to recognize them 23% of the time. We predicted that, since objects between the hands receive more detailed scrutiny, these errors might be reduced. However, hand position has also been shown to bias participants toward a more detail-oriented analysis. A less holistic, more detail-oriented visual analysis might also provide a better guidance signal by which attention can be directed to potential threat items. In two experiments, hand position was manipulated as participants searched for knives within X-ray images of baggage. In Experiment 1, on-screen buttons required participants to hold the display between their hands in order to respond. In Experiment 2, participants were asked to sweep the display with their finger to encourage proximity between the target and the participant's hand on each trial. Contrary to expectations, hand position did not result in any performance differences with respect to accuracy or target sensitivity. The instructed strategy in Experiment 2 resulted in longer inspection times that produced no advantage with respect to finding threat items.

Why might we have observed no effect of hand positon? Methodological differences may play a role. Previous studies have often asked participants to push physical buttons on the sides of the search display instead of virtual buttons on the screen. While this may seem like a minor difference, some evidence suggests that variations in hand grip posture can have different effects (Thomas, 2015). However, Abrams et al. (2008) found a near-hands benefit when participants held the display between their hands but made their responses with foot pedals. So minor differences in how participants made their responses between the current study and previous studies may not fully explain why no near-hands advantage was observed. An alternative explanation is that the effect of hand position is relatively small, and when participants are searching through much more complex displays any effect of hand position is masked by the many other factors that influence search performance (e.g., search strategy, individual differences in visual processing ability, visual clutter, etc.).

Future research will be necessary to isolate whether task/image complexity or differences in methodology are responsible for the lack of an effect observed here. However, these two studies appear to demonstrate that such effects may be too small or context specific to benefit real-world search performance. It should also be noted, though, that an analysis of previous studies reporting a near-hands advantage suggests that effects may be less robust than originally thought (Francis, 2012). This analysis compared the number of significant findings in the literature to the average power of these studies. More positive findings are reported than one would expect from the low power of most experiments, suggesting that the literature represents a biased estimate of the robustness and replicability of near-hand effects.

In sum, hand position does not seem to be a fruitful direction of investigation to boost threat detection in important search tasks. Errors in TSA baggage screening are stubborn and difficult to eradicate. Since the terrorist attacks on September 11th, 2001 a great deal of research has been conducted with respect to training threat detection, yet TSA baggage screeners continue to fail tests of their ability to detect threat items in the field. This is a problem that is unlikely to be solved through training alone, and technology (e.g., computer vision algorithms) may play an important role in supplementing human performance to ensure that contraband items do not make it through the screening process undetected.

APPENDIX A

IRB APPROVAL

Florida State UNIVERSITY

Office of the Vice President For Research
Human Subjects Committee
P. O. Box 3062742
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

RE-APPROVAL MEMORANDUM

Date: 01/26/2016

To: Walter Boot <[redacted]>

Address: Department of Psychology, [redacted]

Dept.: PSYCHOLOGY DEPARTMENT

From: Thomas L. Jacobson, Chair

Re: Re-approval of Use of Human subjects in Research:
The Guidance of Attention During Visual Search

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 01/24/2017 , you are must request renewed approval by the Committee.

If you submitted a proposed consent form with your renewal request, the approved stamped consent form is attached to this re-approval notice. Only the stamped version of the consent form may be used in recruiting of research subjects. You are reminded that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report in writing, any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chairman of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc:
HSC No. 2016.17423

Go back

1. Project Title and Identification

1.1 Project Title

The Guidance of Attention During Visual Search

Project is: ongoing student and PI research

1.2 Principal Investigator (PI)

Name(Last name, First name MI):

Boot, Walter Richard

Highest Earned Degree:

Doctorate

Mailing Address:

Department of Psychology [redacted]

Phone Number:

850

Fax:

University Department:

PSYCHOLOGY DEPARTMENT

Email:

@psy.fsu.edu

The training and education completed in the protection of human subjects or human subjects records:

NIH CITI

Occupational Position:

Faculty

1.3 Co-Investigators/Research Staff

Name(Last name, First name MI):

Roque, Nelson ; Co-Investigator

Highest Earned Degree:

Bachelor's Degree

Mailing Address:

[redacted]

Phone Number:

Fax:

University Department:

PSYCHOLOGY DEPARTMENT

Email:

@psy.fsu.edu

The training and education completed in the protection of human subjects or human subjects records:

NIH

Occupational Position:

Student

Name(Last name, First name MI):

Andringa, Ronald ; Co-Investigator

Highest Earned Degree:

Bachelor's Degree

Mailing Address:

[redacted]

Phone Number:

Fax:

University Department:

PSYCHOLOGY DEPARTMENT

Email:

@psy.fsu.edu

APPENDIX B

SAMPLE CONSENT FORM

FSU Behavioral Consent Form

The Guidance of Attention During Visual Search

You are invited to be in a research study of how people find what they are looking for. You were selected as a possible participant because you contacted our laboratory. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by Walter Boot, Ph.D., from the Department of Psychology at Florida State University.

Background Information:

The purpose of this study is to learn about how people find what they are looking for in visual environments that are often cluttered and complex. Specifically, we are interested in what you pay attention to while you search for a target.

Procedures:

If you agree to be in this study, we would ask you to do the following things: You will view on a computer monitor pictures containing many items. These items include letters, numbers, shapes, and household items. None of these items are anticipated to induce discomfort; they are items you encounter every day. You will be looking for a specific item (e.g., the letter H among other letters, or a teddy bear among other toys). You will be told before each trial which item you are looking for. Depending on whether or not the target is present, or which target is present, you will press one of two keys on the keyboard. Your response time and accuracy will be recorded.

You may also be asked to listen to a string of digits at the same time and make judgments about what you hear. Specifically, you may be asked to count the number of times the same digit repeats. You will report the number of repetitions after you have completed the search task using the keyboard.

The entire experiment will last no longer than 1 hour and you will be given the opportunity to take breaks during the experiment.

Risks and benefits of being in the Study:

The study has few risks. There are no anticipated risks beyond those of normal everyday computerbased activity. There is a possibility that you may experience some mild frustration if you are unable to perform the task as well as you want. We wish to remind you that you are only to complete the task as best as you can, and that there are no good or bad scores.

There are no direct benefits to you by participating in this study. However, your participation will serve to enhance our understanding of the mechanisms that underlie visual search.

Compensation:

You will receive compensation: You will either receive 1 hour of Psychology Subject Pool credit for your participation **OR** 8 dollars for 1 hour of participation. If you are uncomfortable performing the task and decide to withdraw from the study, you will not be penalized (i.e., you will receive full payment or credit).

FSU Human Subjects Committee approved on 1/26/2016. Void after 1/24/2017. HSC # 2016.17423

Confidentiality:

The records of this study will be kept private and confidential to the extent permitted by law. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records.

Voluntary Nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researcher conducting this study is Dr. Walter Boot. You may ask any question you have now. If you have a question later, you are encouraged to contact Dr. Boot at the Psychology Building (B*** PD*), *** *** ****, ****@psy.fsu.edu. You may also contact ****** ******** (******@psy.fsu.edu).

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), you are encouraged to contact the FSU IRB at 2010 Levy Street, Research Building B, Suite 276, Tallahassee, FL 32306-2742, or 850-644-7900, or by email at humansubjects@fsu.edu.

You will be given a copy of this information to keep for your records.

Statement of Consent:

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

_________________ _________________

Signature Date

_________________ _________________

Signature of Investigator Date

Would you like to be contacted for the opportunity to participate in paid experiments in the future?
(Please check one)

YES _____ NO _____

FSU Human Subjects Committee approved on 1/26/2016. Void after 1/24/2017. HSC # 2016.17423

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BIOGRAPHICAL SKETCH

Ronald Andringa is currently in his 3rd year of study in the Cognitive Psychology program at Florida State University. In July 2016, he will graduate with a Master of Science in Psychology degree, with a focus on visual cognition. Mr. Andringa is an aspiring vision scientist.