Enhanced visual processing for objects in perihand space: Does it matter which hand acts on the object or will any hand do?

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UREAP Write Up

Abstract

Peri-hand space is described as the area immediately surrounding a person's hands. This area has been shown to lead to enhanced visual processing, demonstrated in studies involving a visual search task. The functions of peri-hand space and its neurological development suggest that it evolved to facilitate fine hand movements - this pilot study set out to investigate this. To date, no research using a visual search task has had participants define peri-hand space and act on target objects with the same hand; we hypothesized that this methodology would show greater peri-hand space effects than when defining peri-hand space with one hand and acting on the object with another hand. Our results showed that: 1) participants accurately identified significantly more target objects with their non-dominant hand compared to their dominant hand, 2) participants found the target objects significantly faster when the object was graspable compared to ungraspable, 3) when participant's hands were near the screen they had a significantly longer total fixation duration than when their hand was away from the screen, 4) Participant's target fixation duration was significantly shorter when using their dominant hand to act on the object compared to their non-dominant hand, and 5) participants fixated on the target for a significantly shorter amount of time when the object was graspable compared to non-graspable. These results partially support our hypothesis. This pilot study pioneered a novel way to study peri-hand space and its effects. In the future, we will collect more participants (n=30) as well as add extra conditions to minimize handedness effects.

Enhanced visual processing for objects in peri-hand space: Does it matter which hand acts on the object or will any hand do?

The area immediately surrounding a person's hand, known as peri-hand space, has been shown to receive enhanced attentional focus compared to areas away from the hands. This greater attentional focus also leads to greater object recognition and improved working memory for objects in near-hand space (Reed, Grubb, & Steele, 2006; Adams et al., 2012; Du et al., 2017; Tseng & Bridgeman, 2011). Research measuring late positive potentials (LPP)—which serve as neural markers to record attention to emotional stimuli—revealed that participants show stronger LPP's when viewing unpleasant stimuli in near-hand space compared to viewing it away from the hands (Dennis & Hajcak, 2009; Du et al., 2017). Together, the research surrounding peri-hand space suggests that it is evolutionarily advantageous; enhanced visual attention near the hands allows people to be able to improve processing of unpleasant stimuli to avoid it, and enhanced working memory allows for people to better recall hazardous stimuli that are in their peri-hand space.

Peri-hand space effects on visual processing appear to be plastic and can adapt based on people's routines. Literature suggests that both left-handed and right-handed people are better at detecting objects in right-hand space compared to left hand space; this has been attributed to societal norms, such as door handles generally being on the right side of doors (Colman et al., 2017). It was also found that participants have more accurate object discrimination near their right hand compared to their left hand, which implies that there are visuomotor biases in the left hemisphere of the brain, which controls the right hand (Colman et al., 2017). These handedness effects likely emerged through repeated use of one hand over another during development, leading to greater perihand space effects surrounding people's dominant hands, thereby allowing for more efficient object manipulation to occur with that hand.

In addition to handedness, a person's hand postures appear to influence peri-hand space effects. Literature has shown that open palmed grasp postures with the palms facing the objects — known as collected hand postures — yield enhanced visual processing compared to pincer posture grips (Thomas, 2013). Further evidence to support this comes from Dosso and Kingstone (2018), which did not find peri-hand space effects when participants positioned their hands with their palms perpendicular to the object on a screen but did so when their hands rested in a collected posture on the screen. Participants also show greater attentional prioritization when physical objects, such as tools, are placed near their palm compared to the back of their hands (Reed et al., 2010). This likely occurs for two reasons. First, neurons with overlapping visual and somatosensory receptive fields around the hands result in bimodal neurons firing more in the parietal cortex when a visual stimuli is in peri-hand space (Kastner et al., 2017, Ladavas & Serino, 2008). Second, there may be a top-down expectation to manipulate objects near the hand, and you are more likely to manipulate an object with an open palm facing the objects than a pincer grip or a hand posture in which the palms face away from the objects.

The neural processing of objects in peri-hand space appears to follow a separate pathway than when objects are viewed away from the hands. Normally, visual information flows through the geniculostriate pathway from the retina to the lateral geniculate body, to the primary visual areas (V1, area V2, and then to area V5; Born & Bradley, 2005; Makin et al., 2012); however, visual information near the hand appears to have evolved to take a more efficient route through the brain, and seems to flow from the retina to the superior colliculus, to the pulvinar, bypassing area V1 and V2 and going directly to area V5, through which flows to the ventral portion of the intraparietal sulcus, where it then reaches the premotor cortex (Makin et al., 2012; Perry, Amarasooriya, & Fallah, 2016; Rizzolatti & Matelli, 2003). This more efficient route of visual processing for objects near the hands allows for crude visual information to integrate with sensory information of hand position, which could enable more rapid actions with objects near the hands (Makin et al., 2012).

Research has found that visual area V2 is involved in orientation selectivity when hands are close to an object, which suggests that a feedback loops exists from reaching and grasping networks in parietofrontal cortex back to the early cortical visual areas (Motter, 1993; Perry, Sergio, Crawford, & Fallah, 2015). Evidence to support this assumption comes from participants with blindness from an injury to the primary visual cortex—also known as cortical blindness. Damage to the geniculostriate pathway prevents visual information from travelling to the cortical visual areas. Therefore, participants with this injury should not be able to accurately process the size of an object. However, research that has investigated these participants finds that when they placed their hand near an object they were able to accurately estimate the target object using their other hand, which suggests the visual information takes a separate route to get to the primary visual areas enabling a unique phenomenon known as blindsight (Brown et al., 2008; Pellegrino & Frassinetti, 2000; Schendel & Robertson, 2004).

A common way to study alterations in visual perception in peri-hand space involves using a visual search task, in which participants look at a target image, then try to find that same imagine in an array of distractor images with their hand either near the screen or away from the screen (Le Bigot & Grosjean, 2016; Abrams & Weidler, 2014; Thomas, 2013). Using a visual search task can yield measures such as search time—the time it takes for the participant to find the target object, and accuracy—how many target objects participants correctly identified out of the forty trials. This measure was used by Abrams et al. (2008) and is able to identify altered visual processing near hands, as a slower shift in attention between items on the screen, which suggests that more visual attention is given to each item on the screen. To date, previous literature involving a visual search task has had one hand (generally the dominant hand) rest on the side of the screen in a collected open palm posture with the palm facing the screen to test peri-hand space. Although this method is sound, there is a troubling gap in the literature. If peri-hand space truly did evolve to facilitate fine hand movements with objects near the hands, then it would make sense that using the same hand to both define peri-hand space and to act on the object would yield greater near-hand space effects than using separate hands to define peri-hand space and act on the object.

The current study aimed to close this gap in the research by requiring participants to use their dominant hand to both define peri-hand space and to act on the object in the array to determine whether this would yield greater peri-hand space effects than conventional methods. Each participant completed a visual search task in which they had to find a target image from a 12-object visual array. The participant was to first find the object in the array and then reach out and touch it as quickly as possible. Participants completed four conditions: dominant hand near the screen and point to target, dominant hand far from the screen and point to target, dominant hand near the screen and non-dominant hand point to target, dominant hand far from the screen and non-dominant hand point to the target. When the participant's hand was near the screen they maintained a collected palm posture and their palms were directed towards the array of objects. This allowed us to examine the effect of three independent variables in this study. First, the variable of hand position was manipulated by positioning the participant's dominant hand either near the screen or in the participant's lap. The second independent variable, acting hand, looked at whether peri-hand space effects were stronger when participants used their dominant hand to define peri-hand space, and another to touch the object on the screen, or when participants established peri-hand space and acted on the object with the same hand. Finally, we presented objects that were graspable and objects that were not graspable to examine the effects of object graspability. There were three different dependent variables in this study: accuracy, the amount of times participants correctly identified the target object out of the 40 trials; visual search time, the amount of time it took participants to visually fixate on the target image after appearing in an array of distractor images, and; target fixation duration, the amount of time participants visually fixated on the target object before releasing their hand from the button. using a Positive Science eye tracker, we examined participant's visual attention, which included average pre-fixation duration, target fixation duration, and number of fixations. We hypothesized that when participants placed their dominant hand near the visual search array and used the same hand to reach out and touch the target objects that they would show the greatest peri-hand space effects—measured by a slower visual search time, greater accuracy, and shorter total fixation duration—compared to all other conditions.

Participants

Adult participants were recruited from lower level psychology classes at Thompson Rivers University (n =12). Participants ranged from 19 – 32 years old. Each participant had normal or corrected to normal vision, and any participant with a sensory, motor, or neurobiological disorder was excluded. Ethics approval was received in preparation for this pilot study. Prior to the study beginning, participants signed an informed consent form and a photo release form, as required by the Thompson Rivers University human ethics committee. Each participant received a letter of information about the study to take home and received 2% credit towards their Introduction to Psychology class for participating.

Materials and Apparatus

Visual Search Task

The current study used an E230t HP touch screen monitor to display a custom-made visual search task. The visual search task was programmed using Unity game engine and was coded in Visual Studio which used C# programming language. An external button from P.I. Engineering was connected to the computer via USB and either rested on the right-hand side of the computer screen or on the participant's right thigh, depending on the condition. Pressing and holding the button resulted in a fixation cross appearing on the center of the screen for 1 second — this cross would disappear and then a single target object would appear for 2 seconds. Following this, a visual array appeared which contained 11 distractor objects and 1 target object, which was the same as the previously displayed object. There were 8 different visual arrays, made up of 4 non-graspable arrays (horses, houses, cars, people) and 4 graspable arrays (fruits, toys, tools, balls). The computer program recorded 5 measures: the time from when the visual search array appeared to when the button was released; the time from when the button was released to when the participant touched the screen with their finger; whether the touch on the screen matched the location of the target; precision of the touch on the target; and total time required to complete the task. The order in which the location of the objects appeared on the array, and the order in which the arrays appeared were randomized and counterbalanced. Also, each array was not presented more than 5 times per 40 trials. The two center spots in the array never contained the target location because it was too close to where the viewer was looking before the array appeared. The location of the target in the array was randomized so each target location did not occur more than 4 times per 40 trials, and the target image was randomized with a limit so that each target object would only ever appear once within the 40 trials.

Eye Tacking System

The experiment used eye tracking software by Positive Science. LiveCapture software tracked participant eye movements during the visual search task. The eye tracking video was calibrated offline after the participants left the lab using the program Yarbus to create a rendered video that showed where participants looked during the visual search task.

Procedure

Each participant signed an informed consent form and a photo release form when they entered the lab. Then, the participant was instructed on how to complete a visual search task using a script describing the task and was fitted with a head mounted eye tracker. They sat facing a touch screen monitor with both their hands on their lap. The touchscreen monitor was adjusted to the participant's eye level, and the button was either placed on the right side of the touch screen monitor or in the participant's lap, depending on the condition.

The participant's information was entered into the custom software, then participants completed a training condition to practice the visual search task and ensure they understood how to complete the task. Participants had to successfully complete 5 training trials before beginning the task. Before beginning the task, the participants either put their dominant hand on the button on the screen in a collected hand posture with their palms facing the screen, and their non-dominant hand in their lap or put both their hands in their lap with either their dominant or non-dominant hand resting on the button on their corresponding upper thigh. The order of conditions was partially counterbalanced using a Latin Square design. Once the participant was in position to begin the study, they pressed the button with their hand and held the button down. After holding down the button the trial was initiated, and the participant was required to look for the target image in an array of distractor images. Once the participant found the target object, they released the button and either touched it with their dominant or non-dominant hand using their index finger, depending on the condition. After the participant touched the object, the screen went blank and the participant pressed and held the button again to begin the next trial. At the end of 40 trials, the computer screen would read “Thank you for completing this testing session”. The participant would get into position to begin the next condition and completed 40 trials under the new condition until all four conditions were complete.

When all conditions were complete the data was saved and the eye tracker was removed from the participant. The participant was given a debriefing form, which explained our hypothesis, and they were offered a Human Ethics Feedback Form and were told they could complete it if they would like to. Finally, participants were given a copy of the Letter of Information to take with them.

Data Analysis

This study used a 2x2x2 within subjects design. Hand position (dominant hand close vs. far from the screen), acting hand (dominant vs. non-dominant hand touching the screen), and object type (Graspable vs. Non-graspable) were the independent within-subjects variables. The dependent variables were: accuracy, which was defined as how many targets participants correctly identified out of the 40 trials; visual search time, which was how long it took for participants to visually fixate on the target image, and; total fixation duration, which was defined as how long the participant visually fixated on the target image before releasing their hand from the button. Accuracy was calculated by dividing the number of correct trials with the number of incorrect trials for each condition. Visual search time was calculated as the difference between the frame number of when the array appeared and the frame number in which the participants visually fixated on the target object. To calculate total fixation duration, we took the frame number that the participants visually fixated on the target object and the frame number that the participant released their hand from the button.

Following data collection, the participants rendered videos were analyzed frame-by-frame using Kinovea software. Frame numbers were recorded for the time that the array fully appeared (when the images were fully contrasted on the screen), the frame number that participants visually fixated on the target object, and the frame number in which the participants touched the target object (defined as the frame number when the images completely faded from the screen). The frame numbers were input into an Excel spreadsheet containing additional measures recorded from the custom visual search task software to be analyzed. The raw scores were converted to mean scores for each dependent variable. The data was then analyzed in separate repeated measures analyses of variance (ANOVAs) via the program SPSS.

Results

This study made use of a repeated measures ANOVA to examine the effect of hand position, acting hand, and object graspability on accuracy, visual search time, and target fixation duration in a visual search task. Participant trials were excluded for the following reasons: the participant released their hand before fixating on the target image, the participant blinked between locating the target image and releasing their hand to touch the object, the eye tracker had a calibration issue, or the participant incorrectly identified the target image.

Accuracy

Accuracy was defined as the proportion of total trials that the participants correctly identified the target image. The statistical analysis revealed that here was no significant effect of hand position on accuracy $F(1, 11) = 1.59$, p = n.s There was a significant effect of acting hand on accuracy $F(1, 11) = 13.10$, $p = 0.004$ $\eta_p^2 = 0.54$, in that participants were significantly more accurate when they touched the target with their non-dominant hand compared to their dominant hand (**Figure 1)**. There was no significant effect of graspability $F(1, 11) = 0.40$, p = n.s. There were no significant interactions between hand position and acting hand $F(1, 11) = 0.07$, p = n.s., hand position and graspability $F(1, 11) = 0.61$, p = n.s., acting hand and graspability $F(1, 11) = 0.51$, p = n.s., or hand position, acting hand, and graspability on accuracy $F(1, 11) = 0.81$, p = n.s. Thus, when participants used their non-dominant hand to act on the target object they were significantly more accurate than when using their dominant hand to act on the target object regardless of whether their dominant hand was positioned near or far from the array.

Visual Search Time

Visual search time refers to the amount of time it took the participant to visually fixate on the target object after it appeared in an array of distractor objects. There was not a significant effect of hand position on visual search time $F(1, 11) = 0.93$, p = n.s. There was, however, a significant effect of graspability on visual search time $F(1, 11) = 133.04$, $p = > 0.001$, $\eta_p^2 = 0.92$. Participants had a significantly faster visual search time when the objects were graspable compared to ungraspable (**Figure 2**). There was not a significant effect of acting hand $F(1, 11) = 0.001$, p = n.s. No significant interactions were found for hand position and acting hand $F(1,11) = 2.49$, p = n.s., hand position and graspability $F(1, 11) = 0.41$, p = n.s., acting hand and graspability $F(1, 11) = 0.004$, p = n.s., or hand position, acting hand, graspability on visual search time $F(1, 11) = 1.02$, p = n.s. Thus, when the target object was graspable participants identified the target object significantly faster compared to when the target object was non-graspable regardless of which hand acted on the object and regardless of whether the dominant hand was positioned near or far from the screen.

Total Fixation Duration

Total fixation duration was defined as the time from when the participant visually fixated on the target object to when they released their hand from the button. There was a significant effect of hand position on target fixation duration F (1, 11) = 5.41, p = 0.04, $\eta_p^2 = 0.33$. Participants had a significantly longer target fixation duration when their hand was near the screen compared to away from the screen (**Figure 3**). A significant effect of acting hand on target fixation duration was found F (1, 11) = 16.76, p = 0.002, $\eta_p^2 = 0.60$ in that participants had a significantly shorter total fixation duration when using their dominant hand to act on the object compared to their non-dominant hand (**Figure 4**). There was also a significant effect of graspablility on total fixation duration F (1, 11) = 42.85, p = <0.001, $\eta_p^2 = 0.80$. Participants had a significantly shorter target fixation duration when the object was graspable compared to non-graspable (**Figure 5**). No significant interactions were found for hand position and acting hand F (1, 11) = 0.55, p = n.s., hand position and graspability F (1, 11) = 3.95, p = n.s., acting hand and graspability, F (1, 11) = 1.83, p = n.s., or acting hand, hand position, and graspability F (1, 11) = 0.01, p = n.s. When the participant's hand was near the screen they fixated on the target object for longer before releasing the button compared to when their hand was far from the screen. Participants fixated on the target image for less time when using their dominant hand to act on the image compared to their non-dominant hand. Lastly, when the target object was graspable, participants fixated on the target image for less time before acting on it compared to when the target image was non-graspable.

Discussion

This pilot study set out to investigate a novel way to study perihand space in which participants used the same hand to both define peri-hand space and act on the object on the screen. This method was based off of the idea that peri-hand space evolved to facilitate fine hand movements. Therefore, it makes sense that using the same hand to define peri-hand space and act on the object would yield greater peri-hand space effects compared to traditional methods used in a visual search task. To do this, participants wore an eye tracker and completed a visual search task under four conditions: dominant hand near the computer and acting on the object, dominant hand far and acting on the objects, dominant hand near and opposite hand acting on the objects, dominant hand far and opposite hand acting on the object. In all hands close conditions, the participant rested their dominant hand on the right side of the monitor in a collected hand posture with their palm facing the screen. We hypothesized that when participants placed their dominant hand near the visual search array and used the same hand to reach out and act on the target object in the visual array that they would show the greatest peri-hand space effects— greater accuracy, slower visual search time, and shorter target fixation duration—compared to all other conditions. Based on findings from Colman et al. (2017) we also predicted that participants would show greater peri-hand space effects when the target object was graspable compared to non-graspable. Our results partially support our hypothesis.

A number of sophisticated techniques were used to analyze peri-hand space effects in human adults. First, a visual search task was used to investigated peri-hand space because it is a reliable task for studying peri-hand space and has been used previously (Le Bigot & Grosjean, 2016; Abrams & Weidler, 2014; Thomas, 2013). Second for the hands close conditions, participants maintained an open palmed, collected hand posture, as this position has been shown to yield enhanced peri-hand space effects compared to other hand postures (Thomas, 2013; Dosso & Kingstone, 2018). This previous literature served as the foundation of our methodology in hopes of producing noticeable peri-hand space effects in participants.

Even though our pilot study used previous literature as a rationale for our methods, limitations still existed in this research. First, this research had twelve participants, and the power of the findings were low. Future research will need to address this issue by recruiting more participants to increase the power and replicability of the results. In addition to this, a confound is present. In this study, participants are acting on the object with their dominant and non-dominant hands. Previous literature has found that participants show enhanced peri-hand space effects for their dominant hand compared to their non-dominant hand (Colman et al., 2017; Laura Elizabeth Thomas, 2013; Le Bigot, Grosjean, & De Lange, 2012). Because of this, it is difficult to discern if our results are due to enhanced peri-hand space effects or a result of participants using their dominant hand to act on the object. Future research will address this confound by adding two more conditions: Non-dominant hand near the screen + act on the object; non-dominant hand near the screen + dominant hand act on the object. These two extra conditions will help rule out any handedness confounds.

Our measure of accuracy was defined as how many times participants correctly identified the target image out of forty trials. Previous literature suggests that participants are more accurate when identifying objects near the hands compared to objects away from the hands (Thomas, 2013). In addition to this, past research has found that participants show more accurate object discrimination near their right hand compared to their left hand (Colman et al, 2017). Therefore, we hypothesized that participants would show the greatest peri-hand space effects when using their dominant hand to both define peri-hand space and act on the target object. After analysis, our data showed a significant effect of acting hand on accuracy—participants were significantly more accurate when they touched the target object with their non-dominant hand compared to their dominant hand. This finding is surprising, because it opposes an abundance of previous literature suggesting that peri-hand space effects are greater when participants used their dominant hand to define peri-hand space compared to when they used their dominant hand (Colman et al., 2017; Laura Elizabeth Thomas, 2013; Le Bigot, Grosjean, & De Lange, 2012). These results may have been obtained due to the small sample size; with only twelve participants, it is hard to fully interpret the results. Before these results can bear any weight, data collection with more participants is necessary.

Our measure of visual search time refers to the amount of time participants took to find the target object after it appears in an array of distractor objects. Previous research by Abrams et al. (2008) found that participants showed greater peri-hand space effects—denoted by a slower shift in attention between the objects on the screen—when their hand was near the screen compared to away from the screen. Therefore, we predicted that participants would show a slower shift in attention between the objects when using the same hand to define peri-hand space and act on the object, compared to using one hand to define peri-hand space and another to act on the object. We did not find this, but we did find a significant main effect of graspability; participants were significantly faster at identifying a target object in an array of distractor objects when the target was graspable compared to non-graspable. These results are similar to findings by Colman et al. (2017) showing that peri-hand space effects are more pronounced when the target object is graspable compared to non-graspable.

Total fixation duration was defined as the amount of time from when the participants fixated on the target object to when they released their hand from the button in order to reach out and touch the object. Past literature has shown that participants have faster object recognition times when their hand is near the object compared to away from the object (Adams et al., 2012; Reed, Grubb, & Steele, 2006). Because of this, we hypothesized that participants would have a faster object recognition time—target fixation duration—when using the same hand to define peri-hand space and act on the target object. Participants had a significantly shorter total fixation duration when the object was graspable compared to non-graspable. Further, our results also demonstrated that participants had a significantly shorter target fixation duration when using their dominant hand to act on the target object compared to using their non-dominant hand to act on the object; concurring with previous literature (Colman et al., 2017; Laura Elizabeth Thomas, 2013; Le Bigot, Grosjean, & De Lange, 2012). However, due to a confound of handedness effects, the significant effect of acting hand on total fixation duration may be a result of participants simply being more well adapted with their dominant hand compared to their non-dominant hand. Future research will need to incorporate extra conditions to address the potential handedness confound.

Surprisingly, our findings show a significantly longer target fixation when the participant’s hand was near the screen compared to away from the screen, which is the opposite of what is expected in peri-hand space. This may be due to a trending interaction between hand position and graspability. When the objects were non-graspable participants had a substantially longer target fixation duration in the hands close condition compared to the hands far condition; when the objects were graspable, there was only a slight difference in target fixation duration between the hands close and hands far conditions (**Figure 6**). This may be because ungraspable objects could bias visual processing towards the ventral (parvocellular) pathways, whereas the graspable objects may bias visual processing towards the dorsal (magnocellular) pathways. The magnocellular pathway has also been shown to be involved in "gist" or fast processing of images, which may explain why the graspable objects produce notably faster target fixation duration times than the ungraspable objects, which would not have "gist" processing (Chan, Peterson, Barense, & Pratt, 2013). Because the magnocellular pathway—which is involved in gist processing—and the parvocellular pathway—involved in more detailed processing—inhibit each other, the large discrepancy between non-graspable objects and graspable objects may be because "gist" processing was unavailable for non-graspable objects, leading to a significantly longer target fixation duration time, and influencing the main effect of hand position (Yeshurun & Levy, 2003).

Conclusion and Recommendations

To conclude, this pilot study set out to test a novel way to study peri-hand space. If peri-hand space did in fact evolve to facilitate fine hand movements, then it would make sense that using the same hand to define peri-hand space and act on the object would yield greater near-hand effects than using one hand to define the space and another hand to act on objects in that space. Our results revealed that participants were significantly faster at identifying a target object in an array of distractor objects when the target was graspable compared to non-graspable, which supported our hypothesis and previous literature by Colman et al. (2017). Nonetheless, contrary to our hypothesis, participant's showed lower accuracy and shorter target fixation duration when using their dominant hand to identify the target object in the array. However, it is important to acknowledge the limitations and confounds present in this pilot study; at only twelve participants it is hard to confidently conclude our significant results and accept our non-significant outcomes. Further investigation with more participants will be necessary to conclude whether or not this new method of studying peri-hand space is effective or not. In addition to this, adding the following two conditions will help rule out if the acting hand effects found were a result of using the same hand for peri-hand space and acting on the object, or if the effects were because the participants were using their dominant hand: non-dominant hand near the array + point to target, non-dominant hand near array + dominant hand point to target**.**

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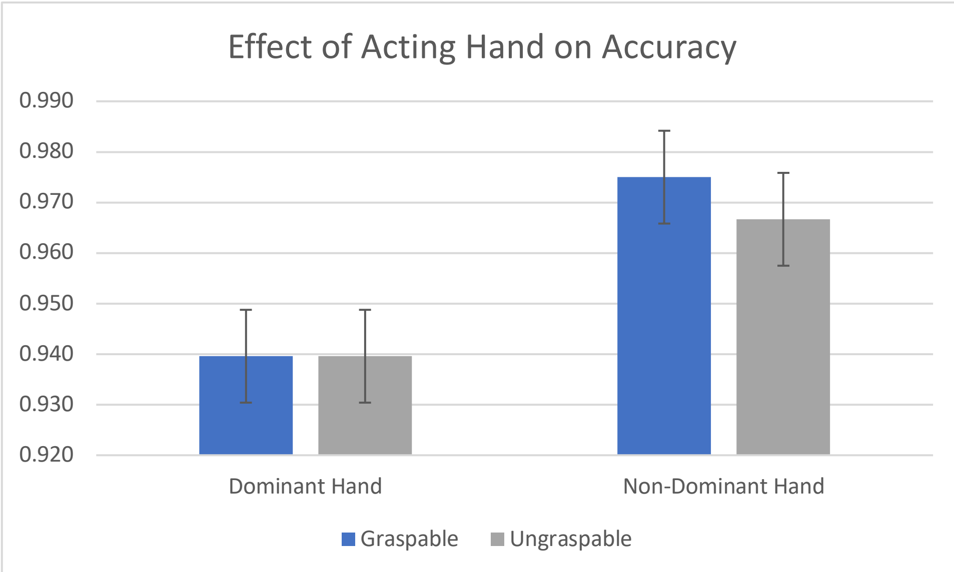

Figure 1. Participants' effect of acting hand on accuracy for graspable and non-graspable objects

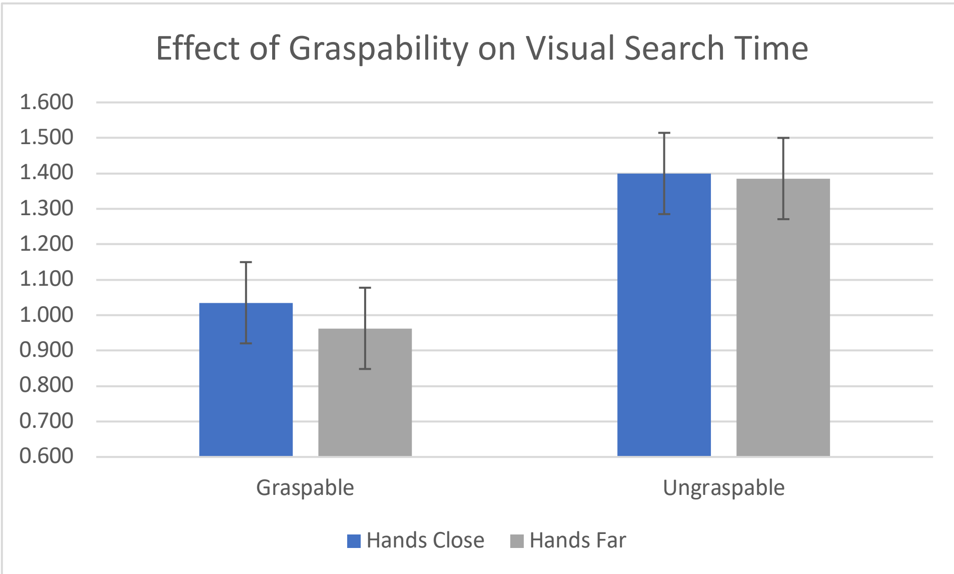

Figure 2. Effect of graspability on visual search time for graspable and non-graspable objects

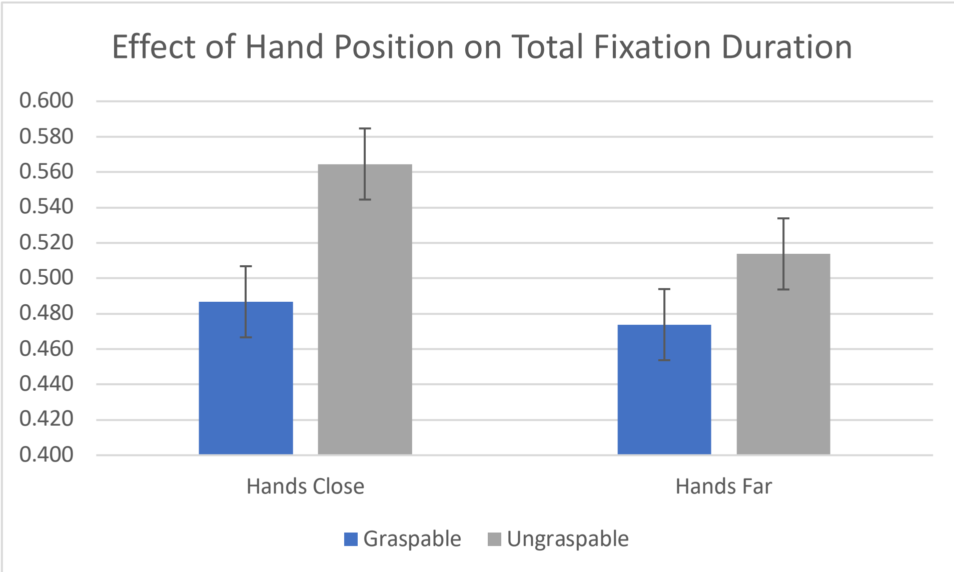

Figure 3. Effect of Hand position on total fixation duration for graspable and non-graspable objects

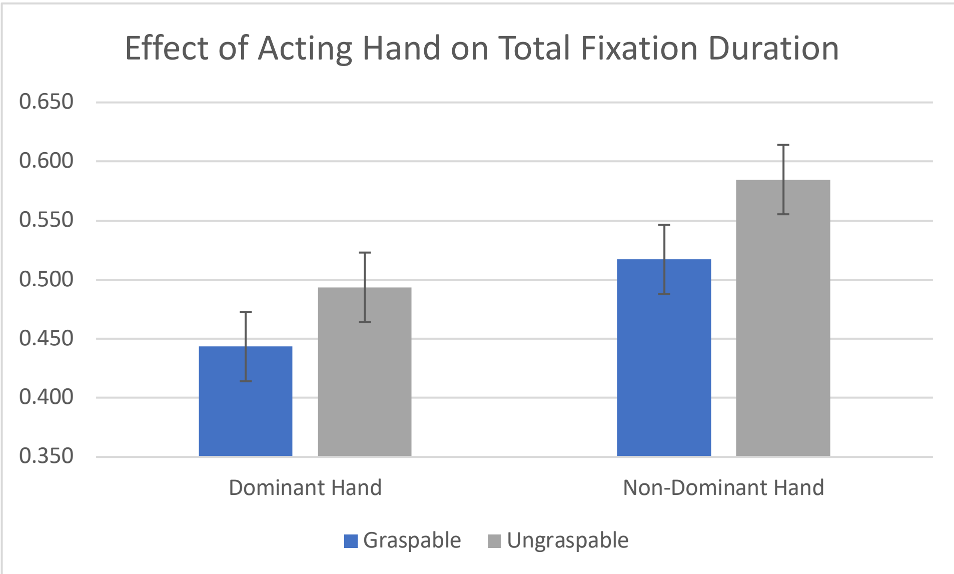

Figure 4. Effect of acting hand on total fixation duration for graspable and non-graspable objects

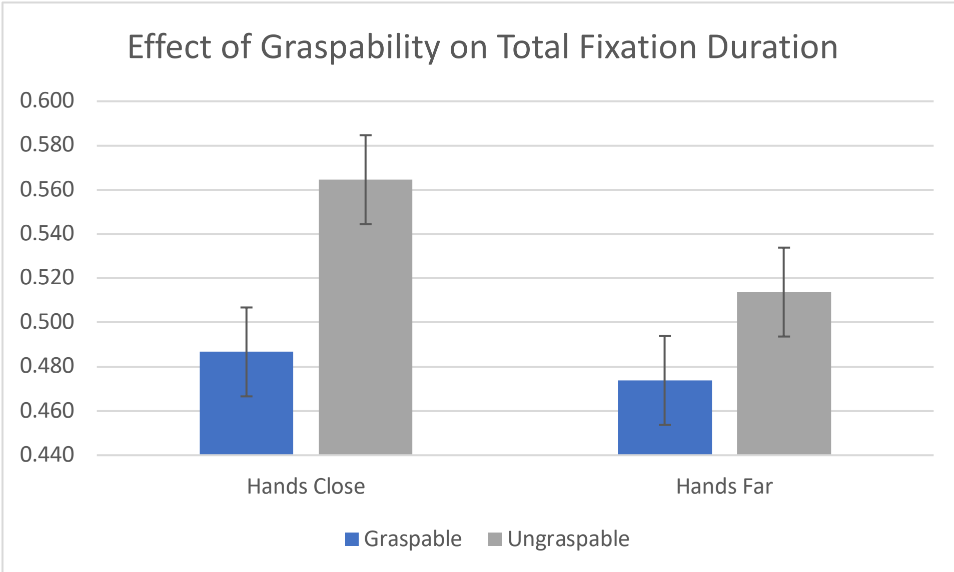

Figure 5. Effect of graspability on total fixation duration for graspable and non-graspable objects

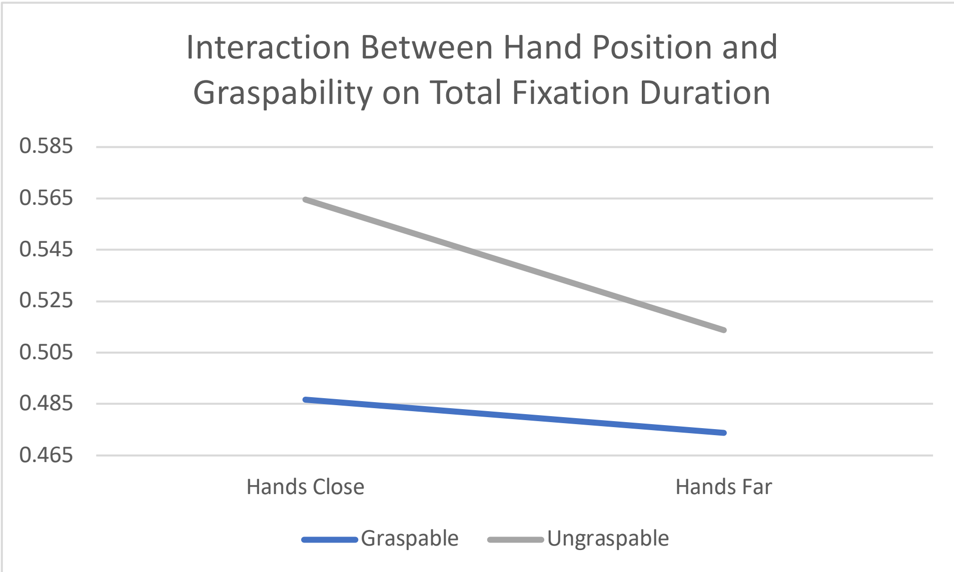

Figure 6. Interaction between hand position and graspability on total fixation duration.