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2017

The Effects of Pointing Gestures on Visual Attention

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The Effects of Pointing Gestures on Visual Attention

An Honors Thesis submitted in partial fulfillment of the requirements for Honors Psychology.

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ABSTRACT

Visual attention is a process that involves concentrating on select features, such as sensory cues, within the complex environment. Sensory cues within the visual field capture and redirect our attention. Previous research on eye gaze revealed that direct gaze captures attention. In the present study, pointing gestures and motion cues were tested together in a visual search task to examine their effects on attention. Participants were instructed to identify a target letter presented on one of four hands. Initially, two hands displayed a pointing gesture while the other two displayed an open gesture. Next, a target letter appeared, one open hand switched to pointing and one pointing hand switched to open, and the other two hands maintained their original gesture. The findings revealed that participants' response times varied across the stimuli, with an interaction between the gesture and motion of the target hand. When the gesture was static before and after the appearance of the target letter, responses were faster to the pointing than open hand gesture. When the gesture of the target hand switched with the presentation of the target letter, however, responses were faster when the hand was initially pointing and switched to open than the reverse. There are two possible explanations for this finding: the pointing hand attracted attention to that location before the switch or the sudden onset of the open gesture attracted attention quicker. These findings reveal that gesture's effect on attentional processes is affected by motion.

Key Words: attention, gestures, visual cues

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April 2017
Department of Psychology
University Honors Program
Georgia Southern University

Acknowledgements

I would like to begin by thanking the University Honors Program for granting me the opportunity to conduct undergraduate research. This has been a privilege that I am extremely grateful for and have learned a great deal from.

To Dr. Ty W. Boyer, thank you for your continued guidance, patience and insight over the past two years. As someone who was new to the research process, I honestly could not have done this without your assistance. The lessons I learned working with you have fully prepared for future research endeavors and will last for a lifetime.

To my fellow members of the Cognitive Development Lab, thank you for your suggestions, feedback and help. It was so refreshing to be constantly surrounded by like-minded individuals who shared a passion similar to mine.

To my parents, thank you for raising me to be the person that I am today. Growing up, you taught me to work hard and to never give up because I can accomplish anything that I set my mind to. As educators, you made it your mission to instill a genuine love for learning in me and I will forever be thankful to you for that.

And finally, to my friends, thank you for your constant support, love and endearment in helping me complete this project. Thank you for believing in me and lifting me up when I didn't believe in myself. Words truly cannot express how grateful and lucky I am to have you all in my life.

The Effect of Pointing Gestures on Visual Attention

When we visualize the world around us, we consciously or unconsciously focus on a small fraction of the total information that we could potentially process. This perceptual selection process is known as attention (Zivony & Lamy, 2016). Without attention, the visual world would be an overwhelming and incomprehensible jumble of information (Tan & Wyble, 2015). Attention refers to the cognitive and behavioral process of directing focus on an individual feature while disregarding any other present factors. Selective visual attention alludes to having difficulty being able to focus on more than one particular feature at one time. The selective component of attention filters out details of less importance in order to be able to focus on more important details. For instance, being at a dinner with a close friend in a busy restaurant makes us susceptible to a vast amount of sensory information such as ongoing conversations, music playing, and the sound of silverware against plates. One must be able to tune out these irrelevant yet disruptive sounds, or stimuli, in order to effectively communicate with and focus on attending to the person they've gone to dinner with.

Visual attention is shifted by things that we see, often referred to as cues. The movement of our eyes from one thing to another, gaze shift, plays a key role in the attention shifting process. Our visual field is made up of the foveal, parafoveal, and peripheral regions. The foveal region, although it only accounts for about 1% of the visual field, constitutes a large portion of what is sent to the brain through the optic nerve (Essen & Anderson, 1995). When we focus on an object, our vision is aligned so that the object is directed onto the fovea (Collins, Heed & Röder, 2010), making this an important region for the processing of information. Attention is able to be directed towards salient environmental features, such as abrupt change, motion, and contrast visible in parafoveal and peripheral vision (Juola, Bouwhuis, Cooper & Warner, 1991). Peripheral vision is the region that has the ability to detect motion and contrasts (Otten, Pinto, Paffen, Seth & Kanai, 2017).

We have the ability to combine the visual field and eye movements to pinpoint target areas of interest. Saccades are eye movements that require a quick movement of the fovea from one target area to another. Saccades acquire information about the complex outside world, causing a sense of competition between sources of information (Tatler, Brockmole & Carpenter, 2017) because we are exposed to large amounts of visual information and we must decipher when and where to look. In order for the visual information of the target to be fully processed, the eye must remain focused on this target for a certain extent of time. This is known as fixation. Saccades and fixation work together for us to focus our attention on a target that is static (i.e., not in motion). When a target is in motion, however, the process changes. We employ smooth pursuit eye movements which allow our fovea to closely follow the target as it is in motion.

Eye movements and attention interact both overtly and covertly. Overt attention is when our gaze directly follows the path of our attention, while covert attention refers to attention that is not associated with eye movements (Tas, Luck & Hollingworth, 2016). Overt and covert attention processes can occur independently or simultaneously. For instance, our overt and covert attention work together simultaneously when we are attempting to notice an indistinguishable feature within our peripheral visual field. Because the feature is not clear, the eyes will need to move to the feature, using solely overt attention, to see it clearly. A single decision process, referred to as “Stay or Go”, involves signals that represent the relative expected benefit associated with different actions that race against each other until one of the decision signals reaches a threshold criterion for making a choice (Tatler et al., 2017). Essentially, gaze control is based on assessing the "expected benefit" of attending to or fixating (stay) on the feature in relation to the expected benefit of saccading (go) to a different location within our periphery.

These targets and features of interest that attract our attention are sensory cues. Sensory cues can be defined as signals or stimuli that will evoke a response or behavior pattern (Jones, 2016). Visual cues, in particular, are received in the eye and are processed by the visual system. Some visual cues include depth, motion onset, color, and contrast. Highlighting motion in particular, a study in which continuous motion and an onset of motion were pitted against each other showed that motion itself does not capture attention, however, the onset of motion does (Abrams & Christ, 2003). Essentially, we notice when objects suddenly move but not when objects have already been moving. Sudden changes in the visual periphery have the ability to draw attention to their locations (White, Lunau & Carrasco, 2014). Additionally, cues that reduce or eliminate positional uncertainty improve stimulus detection, suggesting that when a person can tell where a stimulus is likely to move, they have a higher likelihood of locating it (Juola et al., 1991).

Motion cues allow for enhanced social communication by adding an additional component other than verbal language. Hand gestures, in particular, are extremely common in our everyday lives through communication. A study analyzing the hand gestures of popular TED talk speakers found that popular viral speakers used, on average, 465 hand gestures, which was twice as many used by less popular speakers (Van Edwards & Vaughn, 2015). These findings reveal that there is variability in speakers' effectiveness that covaries with gesture frequency. Studies also reveal that we become highly familiar with gestures throughout our lifespan, beginning in infancy. Gestures directly impact infants' attention during early word learning (Rader & Zukow-Goldring, 2010), and, because they lack the ability to communicate verbally, infants tend to use their hands to make signals (Schutz, 1962). The prevalence of the use of hand gestures in social interactions does not fade as we age. Furthermore, gestures are essential to communication, as they universally accompany language (Abner, Cooperrider & Goldin-Meadow, 2015), , and, some have suggested, not only add emphasis to language, actually fulfill a fundamental purpose (Kelly, Healey, Özyürek, & Holler, 2015). Gestures that occur during speech are best represented through embodied cognition, the idea that the body has the ability to influence the mind (Alibali, Boncoddo & Hostetter, 2014). When communicating, gestures can serve as a mechanism for working out thought processes while speaking. They act as an added language and allow people to say what cannot necessarily be put into words. Moreover, gestures are equally as prominent in nonverbal communication as in verbal communication through the transmission of signals. There is a distinction between informative and communicative signals (Poggi & d'Errico, 2012). For instance, informative signals tend to be unconscious efforts and are more common in our lives. A simple gesture, such as raising a glass to one's mouth to drink water would serve as an informative signal because it *informs* others of thirst, while cupping an empty hand and raising it to one's mouth serves as a communicative signal that consciously *communicates* thirst (Abner, Cooperrider & Goldin-Meadow, 2015).

Studies conducted with human infants reveal that prominent use of gestures tend to work as an indicators of cognitive development (Wu, 2016). Studies with toddlers (e.g., 2-3 year old children) indicate that parents attempt to demonstrate understanding by shaping the toddler's' hands into the gesture that would best aid them in completing the task (Kirk & Lewis, 2017). Gestures such as pointing were used to help the child indicate what it was they needed to accomplish. In young children, gestures facilitate creative thinking and fulfill a critical self-oriented function (Kirk & Lewis, 2017). Children's problem-solving skills are enhanced when adults' speech co-occurs with gesture. For instance, one study revealed that 4.5 to 6 year old children's completion of a puzzle was heavily influenced by their parents' use of gestures during the task (Kirk & Lewis, 2017).

The classic pointing gesture is directed outward at concrete objects, people, or locations in the world (Cooperrider, 2014), and has two main intentions: imperative, to obtain a desired object or action from the other, or declarative, to share attention or interest about a referent with the other (Committeri et al., 2015). Pointing, a goal directed action, can shift attention and allow others to make interpretations of the meaning of the action (Ristic, Friesen & Kingstone, 2002). It is a common gesture that many people are familiar with due to its use in everyday life. We oftentimes purposefully direct our attention to information and stimuli that we are interested in, but also rely on others' points to guide our attention in cued directions (Ristic, Friesen & Kingstone, 2002).

Sudden gaze to a new location has the ability to draw participants' attention to the new location (Driver et al., 1999). This finding is represented in a study done on eye gaze of pairs while eating. Findings showed that when one person looked away from the other to eat, the other person tended to look away as well. When one person looked up, the other person tended to make eye contact, supporting the idea that we use other's' eyes as external cues of where we might want to direct our attention next (Wu, Bischof, and Kingstone, 2013). Visual cues have the ability to capture and direct attention. Particularly, visual cues such as motion and eye contact were observed to capture attention (Böckler, van der Wel, & Welsh, 2014), and results supported the idea that direct eye contact captured attention faster than averted eye gaze. Participants' responses when a target letter was presented on a face displaying direct gaze were faster than when a target was presented on a face displaying averted gaze. Participants were to identify a target letter ('S' or 'H') that was randomly presented on one of four faces among three distractor letters ('E' or 'U'). Initially, two faces had direct gaze, two faces had averted gaze, and each image contained a figure-8 overlaid on the center of the face working as a placeholder. This transitioned and each of the figure-8 placeholders were replaced with three of the same "distractor letters" and one "target letter". Simultaneously, two of the faces eye gaze changed, from averted to direct (sudden direct) and from direct to averted (sudden averted), while two of the faces eye gaze remained unchanged, static averted and static direct (Böckler et al., 2014).

It has been shown that attention can be measured by examining where someone is looking. In other words, where one directs their eyes can, quite literally, serve as an indicator of to what they are attending to. The eyes possess the ability to both gather information (i.e., act as a channel) and communicate information to others (i.e., act as a signal) (Risko, Richardson & Kingstone, 2016). The use of direct eye gaze functions to draw an individual's attention. Like eye gaze, pointing is a powerful and common visual referential signal (Enfield, Kita & de Ruiter, 2007), but could pointing work as efficiently as direct eye gaze in grasping others' attention? Compared with a neutral hand, could pointing function to draw attention quicker?

This current experiment is a modified version of the visual search task study reported by Böckler et al. (2014), in that the visual cue of eye contact (direct and averted) was adapted and replaced with hand gestures (pointing and open). The cue of eye gaze was changed to gesture, because we aim to determine if pointing gestures function similarly to direct gaze. This study also aims to determine if and to what extent motion onset and hand gesture play a role in capturing and directing one's attention. Visual search tasks require participants to locate a target object with a known identity amongst task-irrelevant distractors in the visual field. Models of visual search suggest that, when involved in goal-directed explorations of visual scenes, attention is allocated sequentially to various different objects until the target is found (Ristic et al., 2002).

We hypothesized that pointing gestures would capture attention. Specifically, we predicted that when the target letter was placed on a pointing hand, rather than an open hand, response times for the sudden onset of motion to the pointing gesture (dynamic-point) would be lower compared to the open hand gesture (dynamic-open). This is largely based on findings of previous research that assert that certain hand gestures and motion onset both influence attentional processes. We also hypothesized that, for the motion condition, response times in the dynamic conditions would be faster than those in the static conditions. Previous findings noted that effects of motion and gaze cues did not interact (Böckler, van der Wel, & Welsh, 2014), so this study also aims to determine if a cue, such as gesture, would interact with motion.

Method

Participants

Participants were 19 undergraduate students (11 female, 8 male) all between the ages of 18 and 22 years old (M_{age} = 19.2, *SD* = 1.01). An additional participant was run but excluded from the reported analyses due to a failure to respond on > 50% of all trials. Participants were recruited from Psychology courses at Georgia Southern University using an online participant recruitment software. All participants in the study received course credit. Participants completed an informed consent form and were provided background information on the study.

Apparatus

This study required a desktop computer equipped with a Tobii TX-300 eye-tracking device in order to collect gaze data. This device is equipped with a 22” LCD screen capable of recording binocular x- and y-gaze coordinates, pupil diameter, screen to eye distances and estimates of sample validity at 60 Hz. Participants sat within a cubicle within a research lab. E-Prime software (Psychology Software Tools, Pittsburgh, PA) was used for stimulus presentation and data collection. Participants used a keyboard to respond to each trial.

Stimuli

As represented in Figure 1 in Appendix A, stimuli were presented in each of the cardinal directions against a white background with a central black fixation cross. All four images were 200 x 250 pixels and were created using Adobe Photoshop CC 2015. The letters, ‘S’, ‘H’, ‘E’, ‘U’ and the figure ‘8’ were created using Microsoft Paint. Each were created to have the same dimensions (17 x 26 pixels) and be placed at the center of the hand image. All of the hands in the first and second display were images taken of the same hand.

Procedure

When participants entered the lab, they were told that they would be taking part in a computerized experiment in which they would have to respond using a keyboard. In addition to that, participants were informed that this study utilized an eye-tracking system and that the system would need to be calibrated to their eyes before they could begin. Participants were asked to adjust their position so as to maximize the functionality of the eye-tracking system while maintaining comfort. Calibration of the Tobii eye tracker involved following a red dot in a series of movements about the screen. Next, participants completed ten practice trials in order to verify that they understood the instructions and how to complete the study.

Each trial consisted of two separate displays. As shown in Figure 1 in Appendix A, the first display was a cue display and had four placeholder locations with the number ‘8’ overlaid and centered on the image of a hand. In each of the displays, from the perspective of the participants, two hands were pointing and two hands were open.

The second display was a target-distractor display and appeared 1,500 ms following the presentation of the first cue display. Several changes occurred with the transition from the cue display to the target-distractor display. One hand changed from pointing to open (dynamic-open condition) while another hand suddenly changed from an open hand to pointing (dynamic-pointing condition). Two of the hands’ gesture remained unchanged, static-open and static-pointing. Simultaneously, all of the “8” placeholders changed with the transition from the cue display to the target-distractor display. One figure-8 was replaced with a target letter, either “H” or “S”, and the other three figure-8s were replaced with distractor letters “E” or “U”, as depicted in the target-distractor display in Figure 1. In each trial, the distractor letters were all the same.

The participants’ task was to identify the target letter among the three distractors, and to generate a response by pressing “S” or “H” on a keyboard with their left or right index fingers. There were 384 possible combinations of the factors of gesture, image location, and target-distractor combination. This was determined after combining components of target letter (“H” or “S”), distractor letter (“E” or “U”), target point (pointing or open), target motion (static or dynamic), target image (1,2,3,4) and distractor image location (6 different combinations). Each participant completed each combination in random orders. Participants were offered short breaks after completing 192 trials and instructed to continue with the study when they were ready.

Results

To analyze the data, 2 x 2 repeated measures analyses of variance (ANOVA) were conducted for response time and accuracy with motion (dynamic, static) and gesture (open, point) as within-subjects variables. The stimuli were created through the combination of these two factors, resulting in dynamic-open, dynamic-pointing, static-open, and static-pointing conditions. Response time (RT) was measured from the introduction of the target-distractor display until the participant responded by pressing a key on the keyboard. Trials in which participants responded incorrectly to the target letter (3.79% of data) were removed from all RT analyses. Additionally, individual trials that exceeded 10 seconds were eliminated from the data set as outliers. Remaining response times were within three standard deviations of the group mean.

Analysis of RTs revealed a main effect of motion, $F(1, 18) = 10.807$, $p = .004$, $\eta_p^2 = .375$. As seen in Figure 2 in Appendix B, RTs to targets with dynamic motion, (*M* = 924.01 ms, *SEM* = 34.87 ms) were shorter than those to static targets (i.e., no motion) (*M*= 976.78 ms, *SEM* = 33.24 ms), supporting previous findings that motion onset of a stimulus captures attention (Abrams & Christ, 2003). RTs did not vary between gestures, $F(1, 18) = 0.280$, $p = .603$, $\eta_p^2 = .015$. There was no statistical difference in RTs to the open hand (*M* = 948.413 ms, *SEM* = 32.49 ms) and the pointing hand (*M* = 952.38 ms, *SEM* = 34.11 ms). The interaction between gesture and motion was significant, $F(1, 18) = 9.527$, $p = .006$, $\eta_p^2 = .346$. As seen in Figure 2 in Appendix B, when motion was dynamic, RTs to the open hand (dynamic-open; *M* = 910.03 ms, *SEM* = 34.34 ms) were faster than RTs to the pointing hand (dynamic-point) (*M* = 938 ms, *SEM* = 36.33 ms). In the static motion condition, however, RTs to the openhand, static-open, (*M* = 986.80 ms, *SEM* = 33.30 ms) were slower than those to the pointing hand (*M* = 966.75 ms, *SEM* = 33.90 ms).

Accuracy was measured by determining the trials in which the correct target (‘S’ or ‘H’) was selected by the participant on the keyboard. The main effect of gesture on accuracy was not significant, $F(1,18) = .087$, $p = .772$, $\eta_p^2 = .005$, revealing no statistical difference between the open hand, (*M* = .964, *SEM* = .011) and pointing hand, (*M* = .963, *SEM* = .012). Motion also was not significant, $F(1,18) = 1.317$, $p = .266$, $\eta_p^2 = .068$, revealing no statistical difference between the dynamic condition (*M* = .966, *SEM* = .011) and the static condition (*M* = .961, *SEM* = .012 ms). Additionally, the interaction between motion and gesture, $F(1,18) = .240$, $p = .240$, $\eta_p^2 = .076$, was not significant. Dynamic-open (*M* = .968, *SEM* = .011), static-open (*M* = .960, *SEM* = .013), dynamic-point (*M* =

.964, *SEM* = .012) and static-point (*M* = .962, *SEM* = .012) all showed no statistical difference in accuracy. Eye-tracking data were not analyzed due to programming error.

Discussion

This study explored the relationship between gesture and motion cues and their effect on an individual's attention. As an adapted study on eye gaze and motion, gesture was employed to determine if it has similar effects on visual attention. Direct eye gaze captures attention more quickly than averted eye gaze (Böckler et al., 2014), and this study aimed to determine if pointing worked to the same effect. While the results showed that there were no main effects of gesture, there was an interaction between gesture and motion hinting at a more complex overall finding. These findings on gesture imply that gesture and eye gaze may function differently in attention processing. While it was hypothesized that direct eye gaze and pointing might function similarly, there seems to be a difference among the two cues, and, thus, it might be beneficial to further study the differences between gesture and eye gaze to determine how they interact with visual attention.

The findings showed that motion plays a role in capturing attention. The sudden onset of motion in the dynamic condition produced the largest effect on the individual's attention processing, supporting the hypothesis and previous assertions that sudden movements capture our attention more quickly (Abrams & Christ, 2003). Previous findings have noted that a motion onset to a new location has the ability to draw an individual's attention to that area (Driver et al., 1999; Abrams & Christ, 2003; Böckler et al., 2014) which is also supported in the present study since the dynamic condition was able to capture attention at a quicker rate.

The interaction indicates that there is a complex effect of gestures and motion in capturing attention. In the dynamic condition, participants responded faster when the target appeared on an open hand, however, in the static condition, participants responded faster when the target appeared on a pointing hand stimulus. In the static condition, the findings are consistent with the hypothesis that a pointing hand would capture attention quicker than an open hand. Direct eye gaze also captured attention quicker than averted gaze in the static condition (Böckler et al., 2014), suggesting that, when motion is static, direct gestures such as direct eye contact and pointing, are faster to draw one's attention. In previous research, direct eye gaze functioned as the primary cue that was able to capture attention whether motion was static or dynamic, however with gesture the cue varies depending on motion. This interaction would benefit from more research to better understand why motion onset and gesture affect attention processes differently than eye gaze.

Unlike the static condition, the dynamic condition consisted of a quick transition from one hand gesture to another. When the hand gesture changed from pointing to open, response times were faster than when the hand gesture changed from open to pointing. We hypothesized that sudden motion onset to a pointing hand would draw attention quicker than an open hand since pointing is a cue that has been shown to capture attention (Abrams & Christ, 2003). We also predicted this because, in a previous study, sudden direct eye gaze captured attention quicker than sudden averted eye gaze (Böckler et al., 2014). However, in that study, motion and eye gaze produced statistical main effects, but did not interact, which led to the interpretation that motion cues and gaze cues have independent effects. Because this study revealed a significant interaction between gesture and motion, the findings are subject to a different interpretation.

One possibility is that when participants saw the pointing hand on the cue display, their attention was drawn to the location of the pointing hand. When the display transitioned and there was a sudden change to open gesture, responses to the target letter in that location may have been quicker because the participants' attention was already drawn in that direction, and they did not have to search for the target letter on the screen because the pointing hand had already drawn their attention in the right direction. Our initial prediction was that a sudden motion onset of a pointing hand would attract the participants' attention; however, it seems feasible that the presence of the pointing hand as the cue in the dynamic-open condition attracted participants' attention before the display transitioned. It is also possible, however, that the sudden appearance of an open hand may have captured participants' attention. Additional research on this gesture could provide more insight into whether or not the pointing cue played a role in the faster response times for the dynamic-open condition. Moreover, additional research utilizing different gestures as neutral stimuli tested against a pointing gesture should be done to determine if pointing works as effectively.

Limitations

Eye tracking data was unable to be analyzed due to programming errors. This study aimed to use eye tracking data to potentially reveal gaze patterns of participants and indicate which gesture they tended to look at first and for longer periods of time. Specifically, in terms of the interaction between motion and gesture, we would know if the significantly shorter response times in the dynamic motion condition from pointing to open was a result of participants' attention already being captured in that direction by the pointing hand, thus leading to a shorter response time to the open hand target. We would be able to see the participants' eye gaze and know how long they looked at that location before responding to the target with the keyboard and have a more definite and conclusive answer to the results of the dynamic condition. Ultimately, eye tracking data would have allowed for more informed and conclusive answers to the results. For future research, we suggest utilizing eye tracking software in hopes of better investigating pointing and its effect on visual attention.

Conclusion

The current experiment examined visual attention in undergraduate Psychology students at Georgia Southern University with relation to gesture and motion. Findings showed that with static motion, pointing gestures capture attention quicker. For dynamic motion, it is possible that a pointing cue attracts attention to a location allowing for faster target detection. It is also possible that an open hand gesture attracts attention quicker with sudden motion onset. Further research should be done with eye tracking techniques in order to further explore gaze patterns to gestures in relation to motion. In addition to that, different gestures should be tested as neutral stimuli in the event that it is discovered that the open hand gesture indeed does capture attention quicker despite the pointing cue. It was ultimately revealed that pointing gestures capture attention and motion alters its effects.

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Appendix A

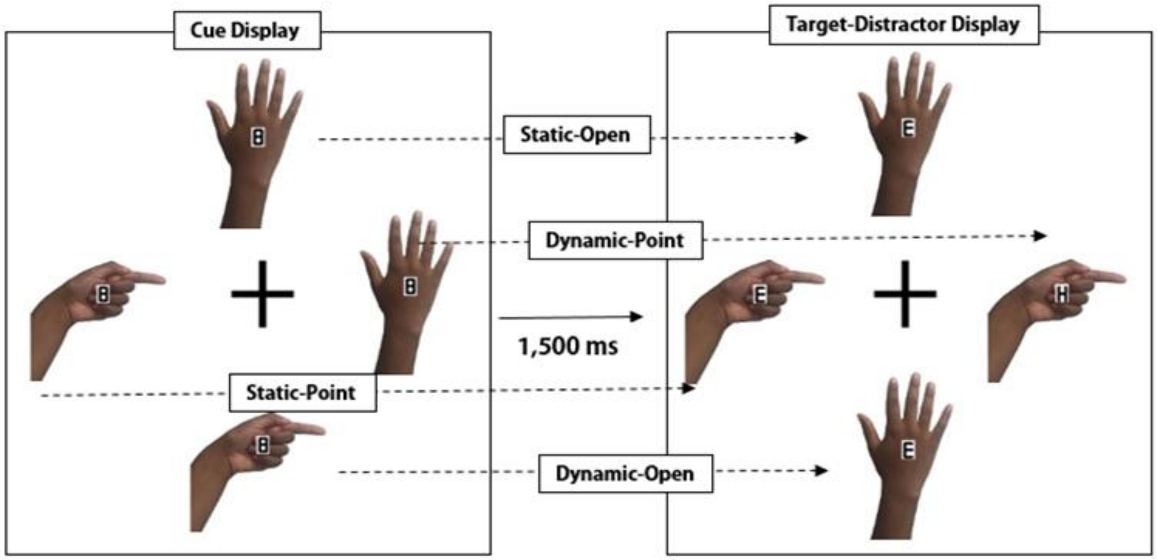

Figure 1. Example trial display sequence. One trial consisted of two displays: cue display and target-distractor display. The cue display shows four hand images, each with the number “8” overlaid on it, surrounding a central fixated cross. Two of the hands have a pointing gesture and two of the hands have an open gesture. After 1,500 ms, the cue display transitioned to the target-distractor display. One of the hands changed from pointing to open gesture (dynamic-open condition), and one changed from open to pointing gesture (dynamic-point condition). The other two hands did not change in gesture (static-open and static-point conditions). Concurrently, an “8” placeholder was replaced by a target letter (“H” or “S”), while the other three placeholders were replaced with the same distractor letter (“E” or “U”).

Appendix B

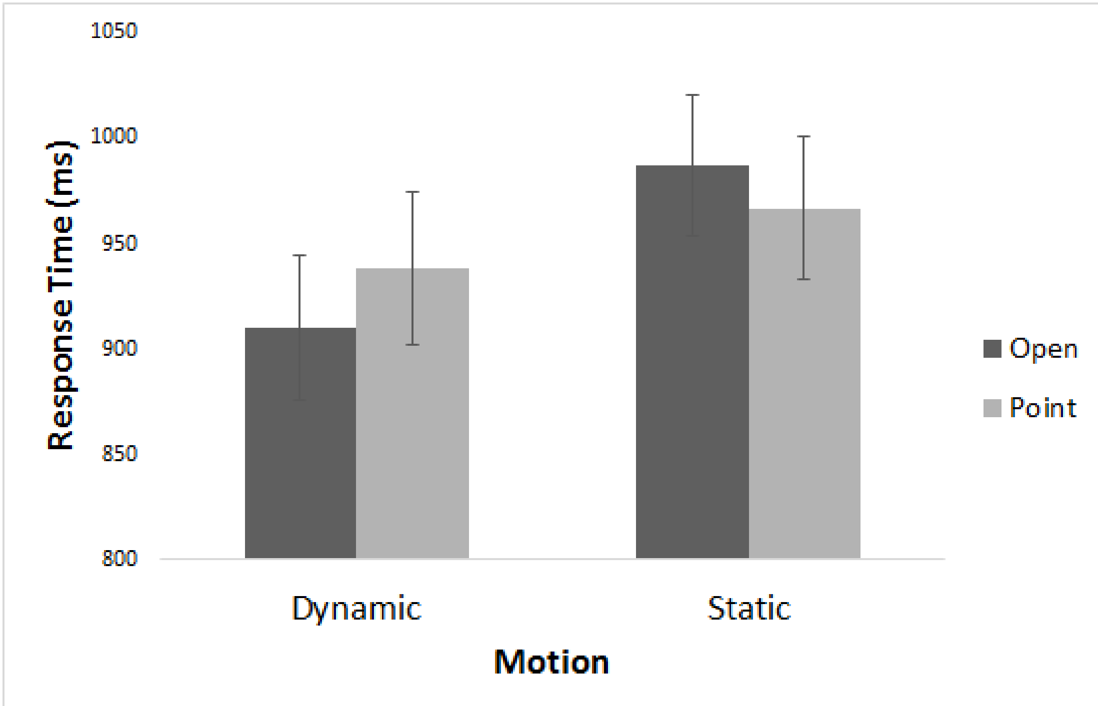

Figure 2. Response Times across conditions. Error bars represent the standard errors of the means.