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Perception-Action System Calibration in the Presence of Stable and Unstable Perceptual Perturbations

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PERCEPTION-ACTION SYSTEM CALIBRATION IN THE PRESENCE OF STABLE AND UNSTABLE PERCEPTUAL PERTURBATIONS

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ABSTRACT

Actors are able to calibrate to various changes to both their own abilities and their surrounding environments. Most calibration studies have examined recalibration to stable perturbations (i.e., a single, constant change). However, numerous real-world experiences involve perturbations that do not remain constant. The present studies investigated the effect of varying perturbations on postural sway and prospective control. It was hypothesized that short-timescale variations of a perturbation would affect participants' ability to recalibrate. Specifically, the different patterns of perturbation would result in a change to postural sway that would mediate the relationship between the condition and the ability to calibrate. It was found that accuracy was dependent on the type of environmental conditions of the perturbation change (i.e., the rate of change or the pattern of change). However, in general, calibration effects were found for all conditions. The different perturbations also affected the amount of postural sway. The proposed mediated relationship was not supported by this series of experiments. However, this is most likely due to the task not creating enough variability within the variables of interest. The results of these experiments provide further evidence for perception-action system calibration mechanism through task-relevant feedback.

Author Keywords
Perception-action, calibration, virtual reality, unstable environments

DEDICATION

"Sometimes you can only find Heaven by slowly backing away from Hell."
-Carrie Fisher

This is dedicated to everyone who supported me as I backed away from my hell to find my heaven. Thank you to my family and friends for giving me their unconditional love, support and protection while I demolished my old life to make a new one that I love. Mom, Dad, and Skye: thank you for being the most incredible, supportive, and loving family through everything and I would not be here without you. Lastly, to my advisor and friend, Dr. Chris Pagano, thank you for taking a chance on me and allowing me the freedom to explore and find my voice.

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CHAPTER I.

PERCEPTION-ACTION SYSTEM CALIBRATION IN THE PRESENCE OF STABLE AND UNSTABLE PERCEPTUAL PERTURBATIONS

How do humans successfully interact with their environments under changing conditions? The ability to adapt in order to perform both basic and advanced tasks within varying environments and under countless conditions, enables humans and other organisms to survive and thrive. The capacity to perceive and calibrate to these ever changing environments is one that scientists have strived to understand and predict.

The ecological approach to perception and action takes as its primary unit of study the relationship created by an organism (or actor) and its environment. This relational approach has evolved over six decades of empirical research that investigates the perception and motor control required for an organism to successfully interact with its environment. In the actor-environment relationship, both entities are active and changing (Heft, 2003; Gibson, 1966). The present work is directed at understanding how actors calibrate to changes in this actor-environment relationship.

1. **Direct Perception**

The ecological approach to perception and action starts with an analysis of what makes up the environment (i.e., the surfaces and the make up of the objects) as well as how that information is conveyed to the actor through energy arrays (e.g., J.J. Gibson, 1959, 1966, 1979; Lombardo, 1987; Michaels & Carello, 1981; Turvey, Shaw, Reed, & Mace, 1981). These arrays provided by the environment consist of light for vision, chemical energy for smell, acoustic energy for hearing, etc. The arrays convey information about the various surfaces and substances that comprise the environment and their relationship to the perceiver. For instance, the pattern of

light that enters the eye contains meaningful information that enables the actor to perceive without the need for elaboration by a cognitive system (Lombardo, 1987; Turvey & Carello, 1986).

These information rich arrays and their resulting stimulation patterns become more informative as an actor moves within the environment. For example, as an eye moves the pattern of ambient light changes in a lawful manner, generating what is termed *optic flow*. This pattern of change provides information regarding the locomotion of the actor as well as the dimensional structure of the environment (e.g., distance, depth, size of various objects, directionality of movement, etc.; Bingham & Pagano, 1998; Cutting, 1986; Fajen & Warren, 2003; Gibson, 1979; Gomer, Dash, Moore, & Pagano, 2009; Warren, 2006).

This theoretical approach and understanding of perception off-loads cognition (Zhao & Warren, 2015). The meaningful aspects of the environment do not require higher cognitive functions (e.g., interpretation, representation, memory, calculation, decision making, etc.). Instead the surfaces of the environment provide the information in a lawful manner that allows the meaningful aspects within an environment to be perceptible.

The basic question of how organisms are able to move through an environment and successfully interact with elements within it can be answered in our ability to utilize this perceptual information. Specifically, it allows for *prospective control*, the ability to guide and control future-oriented actions (J.J. Gibson, 1979; E.J. Gibson, 1969; Turvey, 1992; Reed, 1996; Adolph, Eppler, Marin, Weise, & Clearfield 2000; Gibson & Pick, 2000; Littman, 2011). Prospective control can be seen in our day-to-day lives with the majority of the motor movements we use to interact with our environments and others (e.g., reaching, walking,

climbing, catching, etc.). In order to achieve prospective control, an actor must be able to perceive and use the energy arrays available within the environment.

2. Development, Attunement, and Calibration of Perceptual-Motor System

The environmental information that is provided to the perceptual systems is in fact sufficient support for perception (Gibson, 1966). Variables with useful information, that are lawfully related to the property being perceived are known as *specifying variables* (Wagman, Shockley, Riley & Turvey, 2001; Withagen & Michaels, 2005). Through training, observers become attuned to the most specifying perceptual information within the stimulus arrays characterizing each of the senses (E.J. Gibson 1963, 1969; J.J. Gibson & E.J. Gibson, 1955). That is, observers are able to converge on the information that is the most correlated to an object's property. This correlated relationship enables accurate predictions for the use of prospective control. In essence, the lawful relationship found in the arrays, allows for actors to interact within their environment without the use of higher cognitive resources.

This perceptual learning, or the ability to differentiate specifying variables from ambiguously-related or non-specifying variables, is what E.J. Gibson referred to as the *education of attention* or *attunement* (E.J. Gibson 1963, 1969; J.J. Gibson & E.J. Gibson, 1955). In essence, it is tuning the body's perceptual capabilities to correctly gather important task-related information. Without this attunement, untrained perceivers may rely on non-specifying variables (i.e., variables which have less of a lawful relationship to the target property).

This gathering of information inevitably leads to some degree of perceptual error in the results of the action taken (Jacobs, Vaz, & Michaels, 2012). Therefore, the act of attunement is not a passive process; it requires active perceptual exploration of the world. Through perceptual

learning, animals are able to fine tune their abilities to extract the useful and relevant information from the stimulus array. Attunement occurs when useful task-related feedback is available. Through feedback training, calibration enables a rescaling of the perception-action system's output to properly match task demands (Bingham & Pagano, 1998; Day, et al., submitted; Fajen, 2007; Iodice, Scuderi, Saggini & Pezzulo, 2015; Warren, 1984; Withagen & Michaels, 2004). Without continuous task-relevant feedback the perception-action system becomes increasingly inaccurate (Bingham & Pagano, 1998; Ebrahimi, et al., 2016; Wickelgren, McConnell. & Bingham, 2000).

A need to recalibrate will occur if there is a disturbance in either the perceptual or action systems (Bingham & Pagano, 1998). Recalibration is necessary for a system to interact within various environments, under certain changes (long or short-term changes, to be discussed) to the perceptual or musculoskeletal system, environment itself, etc. A system can be thought of as being recalibrated when an environment that has been distorted or transformed in some capacity is no longer perceived as being novel (Dolezal, 1982). Essentially, recalibration can be defined as the return to pre-perturbed performance level after a decrease at the onset of the initial disruption (Dolezal, 1982).

Interestingly, attunement and calibration are primarily unconscious processes. Mark (1987) demonstrated participants were able to calibrate to what chair heights were sit-on-able after their physical dimensions were altered by standing on blocks. While participants were not allowed to practice sitting, they were still able to accurately make judgments based off of their new action capabilities in the various conditions. However, the fact that they could not make an accurate estimation of the height of the blocks they were standing on suggests that the recalibration of the

perception-action system occurs without the specific knowledge of the alterations (Mark, 1987; Day, et al., submitted).

3. **Perceiving Affordances**

Affordances are the opportunities for action provided by the surfaces of the environment. For example, a horizontal plane allows for actions such as standing, sitting, tripping over, etc. These action opportunities are presented lawfully through environmental information (Gibson, 1976/1982, 1979; Turvey, 1992). The relations between the environment and the capabilities of the organism make activity such as those requiring prospective control possible (Turvey, 1992; Turvey & Shaw, 1995; Fajen, Riley & Turvey, 2008).

There are two primary categories of affordances: body-scaled and action-based (Fajen, 2007; Fajen, Riley & Turvey, 2008). The majority of the research completed within the ecological field investigates one of these two types of affordances. The first category of affordances is the body-scaled aspect, in which the environment is scaled to the geometric dimensions of an individual's body (Fajen, 2007; Fajen, Riley & Turvey, 2008). For example, the ratio of knee-height to perceiving whether a horizontal surface is sit-on-able (Mark, 1987), ratio of leg length to most comfortable stair height (Warren, 1995), and ratio of doorway width to shoulder width in perceiving pass-ability (Warren & Whang, 1987). Studies such as these have revealed ratios that remain invariant over different body sizes which enable affordances to be quantifiable through it (e.g., leg-length units are the more proper unit for determining the affordance of stair climbing than centimeters or inches; Warren, 1995; Cesari, 2005; Cesari et al., 2003; Konczak et al., 1992).

However, the ratios for optimal performance differ between individuals with different action capabilities, such as able-bodied young adults to able-bodied older adults (Cesari, Formenti, & Olivato, 2003; Konczak et al., 1992; Sakurai et al., 2013, 2014). Thus, an actor's ability to interact with the environment goes beyond their simple geometric dimensions. Therefore, the second component of the affordance theory corresponds to the energy and strength component of affordances, and is known as action-based affordances or action capabilities (Fajen, 2007). This component takes into account factors such as strength and flexibility (Day, Wagman, & Smith, 2015; Fajen et al., 2009; Gibson, 1976/1982). Importantly, these are still perceptually specified in the relationship between the environment and the actor. For instance, when comparing able-bodied older adults with college students, the ratio for optimal performance in a stair climbing task changes. For instance, older participants select shorter riser heights even though their geometric dimensions are similar to that of the college students (Cesari, Formenti, & Olivato, 2003; Konczak et al., 1992; Sakurai et al., 2013, 2014). Day, Wagman, and Smith, (2015) concluded that there is only one overarching type of category which is action-scaled, and that the body-scaled affordances are simply a special subset.

For both components that make up affordances (i.e., geometric dimensions and action capabilities), changes in the environment and/or the actor change what is possible for a given individual acting within an environment. Therefore, in order to obtain "an accurate understanding of perception" one must consider "the perceiver and the environment as a single unit (O'Neill & Russell, 2017, p 54)."

3.1. The Effect of Postural Sway on Affordance Judgements

Postural sway is one mechanism actors utilize in order to explore the global array for affordance based judgements. For example, Mark, Balliett, Craver, Douglas, & Fox (1990) demonstrated that actors recalibrate to extensions of their leg lengths (i.e., leg lengths extended with platform shoes), so long as they can sway or move. However, they also demonstrated that calibration for affordances can be inhibited through the manipulation of postural sway movement. This manipulation was either by restricting the postural sway or artificially increasing it.

Mark et al., (1990) restricted postural sway by having participants stand against a wall rigidly or restricting the postural sway by requiring participants to view the seat (i.e., for judgements of *sit-on-ability*) through a peep-hole. Both of these movements diminished or canceled the natural postural sway of participants. Additionally, they were able to increase the amount of postural sway by having participants stand in an awkward stance (i.e., heels together, toes pointed outward). They found that those who had their postural sway manipulated either by restriction of or with additional variability introduced, recalibration was retarded or halted completely. Essentially, their errors and variability of their motor decisions remained high. Whereas, the individuals that were in groups without a postural sway manipulation, recalibration occurred quickly.

Many studies have further demonstrated the utility of head and torso movements during and prior to making affordance judgements, specifically in terms of the accuracy of the affordance perception (e.g., Bingham & Pagano, 1998; Bingham & Stassen, 1994; Gomer et al., 2009; Stoffregen et al., 2009; Yu et al., 2011; Yu & Stoffregen, 2012). Mantel et al. (2008) demonstrated that participants who were allowed to actively engage in a virtual environment

(i.e., allowed to move their head and torso in order to change viewing angles, etc.) were more accurate and precise than those who were only shown a previous recorded video of exploratory movement. Self-generated exploratory movement enables the generation of useful invariants to be gleaned from the animal-environment system (Bingham & Pagano, 1998; Mantel et al., 2015). Even minimum movement that occurs with ordinary body sway (e.g., slow, ~ 0.2 Hz and small ~2 cm) provides information about the animal within the system (Stoffregen & Mantel, 2015).

These studies suggest that information regarding one's action capabilities is not simply stored in a fixed or quantitative manner. Optic flow from head movements and postural sway reveals information about depth that is not available in static viewing. Such information includes the classic distance cue of motion parallax. Since information from vision alone is necessarily angular, it does not provide information about definite (i.e., absolute) distance that can be used for prospective control. However, somatosensory information available during active exploration provides a metric for the angular information provided optically, and thus vision is in fact multi-modal, with perception and motor control being a unitary process (Bingham & Stassen, 1994; Mantel et al., 2015). Calibration via feedback is used to properly scale the application of this metric to produce accurate performance (Bingham & Pagano, 1998; Pan, Coats & Bingham, 2014). People gather the necessary information through actions such as a change in their postural sway in order to appropriately gauge their capabilities within the specific environment under the specific Condition (Stoffregen, Wang, & Bardy, 2005). Essentially, movement reveals useful information that enables actions to be properly scaled to features of the environment. For instance, if there is an increase in postural instability, then the perception of doorway pass-ability is affected (i.e., more narrow doorways appear less passible; O'Neill & Russell, 2017).

Research has also investigated the effect of disruption of the perceptual system on postural sway, and subsequently affect recalibration. Littman (2009, 2011) used a visual distortion (e.g., prism illusion) within a virtual environment. These types of disturbances caused participants to demonstrate compensatory movements to detect the appropriate new mapping. Littman's findings and others (e.g., Riccio & Stoffregen, 1991; Smart & Smith, 2001) demonstrate that compensatory reactions are due to the initial failure of an appropriate mapping in novel situations that can lead to instability and subsequent motion sickness. Active exploration and the learning of new mappings can reflect a recalibration for the novel stimulus (Littman, 2009).

3.2. Calibration to Changes in Affordances

The perception of affordances is a dynamic process (Fajen, Riley, & Turvey, 2009; Wagman, Higuchi, & Taheny, 2014). This malleability allows for calibration to the body's changing physical dimensions or abilities. For example, if an individual injures their ankle, what once was possible (e.g., jumping, climbing, or walking) is now not as feasible or possible using the same motion. Similarly, the use of a tool makes new actions possible (e.g., Day et al., 2017; Witt, Proffitt, Epstein, 2005). Regardless of their malleability, affordances are continuously perceived as the body moves through the environment.

Changes within an individual or environment can be described as occurring over short- or long-timescales and can affect both body-scaled and action-scaled affordances. It should be noted that the categorization of the timescale (i.e., short or long) is of course relative. For example, fatigue has been considered both long- and short-timescales, depending on the research interest of a study (e.g., Fajen, Riley, & Turvey, 2008).

Short-timescale changes of affordances can be loosely defined as any changes that can revert back to the original or baseline conditions in a relatively short time period. Some common examples of these type of short-timescale changes include: fatigue (e.g., Witt et al. 2009; Bhalla & Proffitt, 1999; Schnall, Zadra, & Proffitt, 2010; Proffitt, Stefanucci, Banton, & Epstein, 2003), changes in body dimensions through the use of equipment (e.g., Day et al., 2017; Petrucci, M. N., Horn, G. P., Rosengren, K. S., & Hsiao-Wecksler, E. T., 2016; Warren, 1984), change to one's action capabilities or geometric dimensions via tools (e.g., Scott & Gray, 2010), prism goggles (Bingham & Romack, 1999), etc. The majority of short-timescale changes occur with a rapid change and then stabilize at a particular point. For instance, when firefighters put on their equipment they are abruptly much larger and heavier than they usually are, which can lead to fatigue. Petrucci et al., (2016) found that firefighters adjusted their affordance judgements accordingly by selecting larger aperture widths or higher beams to pass under.

Long-timescale changes of affordances can result in permanent changes. Some common examples include changes throughout the lifespan (e.g., Comalli, Franchak, Char, & Adolph, 2013; Ishak, Franchak, & Adolph, 2014; Sakurai et al., 2013; Hackeny & Cinelli, 2013). What is most unique about long-timescale changes is the pattern of continued change across the timespan. An example of this is the development that occurs from birth to the maturation phase where strength and body dimensions are at their peak. From this point onward, there is a leveling off of abilities and then a general decline as an individual continues to age. Due to this, the perception of affordances is constantly having to be adjusted based on the particular environment and task. As an illustration, body-scaled affordances that are based on the anthropometric measurements of the body change at a particularly rapid rate from infancy until maturation.

This type of ever changing animal-environment relationship can be observed for short-timescale changes such as injury or fatigue. Both of these examples could be considered long-timescale changes if they occur over extended periods of time, and calibration may occur gradually during that period. A sprained ankle, for example, takes time to heal, but as the ligaments and soft tissues gradually repair, the actor can begin to place more weight on the ankle and begin to move around more easily. They would eventually no longer require a walking aid. While some injuries are instantaneous, others can be categorized as being stress injuries that occur over longer time periods. In some cases, people recover from their injuries but show some permanent change.

Our ability to adjust to short- and long-timescale changes has led researchers to study recalibration. These changes can be considered *perturbations*, a deviation from the normal state of the system. Such perturbations are typically held constant within an experimental Condition. In essence, the change or perturbation introduced in the experiment, either a change in the environment, actor, or the perceptual processes, remains constant. For example, in the well-studied prism goggle perturbation, the visual device shifts the visual image which causes participants to make errors until they are able to recalibrate their perception-action system to the shift (e.g., Harris, 1965; Bingham & Romack, 1999; Cunningham & Welch, 1994; Welch, Choe & Neinrich, 1974). A similar example is Mark's (1987) experiment of adding blocks to the feet, the displacement of the eye height was constant.

A gain is a type of perturbation that rescales the system's output. For example, a visual perturbation within a virtual environment that causes a reaching hand to appear to be moving 20% further than it is actually moving is a gain of 1.2 (Ebrahimi et al., 2015). Gains can be considered constant when they remain the same throughout an experimental session. So while a

gain is different from a displacement, both can be seen as being held constant in past experiments. There is no change to the perturbation that is introduced into the system.

A different class of perturbations are those that are unstable. For such perturbations the amount of gain or the degree of displacement changes from moment to moment. Similarly, changes in one's action capabilities that vary instantaneously result in instability. Such situations result in an *unstable* actor-environment relationship, due to perceptual-motor perturbations that do not remain fixed or constant. While there is a large literature of empirical studies involving stable perturbations, unstable perturbations have received little attention. It is hypothesized that unstable perturbations to the perception-action system will be more difficult, and perhaps impossible, to calibrate to (e.g., Bingham and Romack, 1999).

A common example of this type of relationship can be seen through consumption of alcohol. As an actor consumes alcohol they are constantly changing their level of inebriation. As alcohol is absorbed into the blood stream multiple systems within the body are affected including vestibular, visual, cognitive, and motor abilities. This effect demonstrates a similar pattern found in most long-timescale changes yet occurs within the time-frame of short-timescale changes. The changes in level of inebriation is not necessarily constant in terms of rate of inebriation or time within that inebriated level. As the alcohol is absorbed in the body, an individual's ability to interact with the environment changes. In most cases this change is a diminishing of the coordination of perception-action systems. While this example is not simple or perfect due to the intricacies of the various systems that are affected and their interactions, what should be focused on is the pattern of the blood alcohol content and the resulting behavioral deficits. While the effects of alcohol have been studied individually with the various systems, from an ecological perspective, the question remains as to what specifically is being disrupted in the actor-

environment relationship to cause individuals to be unable to calibrate to the perturbation within the system.

In order to demonstrate the logic behind this unique relationship, the previous example of an injury can be used for comparison. The rate of healing for an injury generally consists of periods of stabilization that allow for actors to recalibrate to the new conditions of the actor-environment system. These periods of stabilization are due to the longer timescale that are generally seen in injury recovery. Thus, this type of relationship can be considered essentially a stabilized one since the changes have these periods of stabilization to allow for actors to recalibrate, whereas the example of alcohol consumption does not.

Essentially, both examples demonstrate various action-perception systems under different conditions of disturbance. While both experience perturbations, the injury example is a much more stabilized actor-environment system allowing for the recalibration of prospective control, whereas the other can be described, at least anecdotally, as having a much more unstable actor-environment system potentially interfering with calibration.

3.3. Virtual Reality as a Tool to Examine Affordance Perceptions

While perturbations enable scientists to examine the process of calibration, it can be difficult to create perturbations in the real environment. Virtual environments (VE) are useful tools for examining conditions and/or tasks that would not otherwise be feasible due to lack of resources, safety, or simply are impossible to create in a structured manner. While some research has shown that people perform differently in VEs than in the real world (e.g., Napieralski et al., 2011; Ebrahimi, Babu, Pagano, & Jorg, 2016), other research has found that VEs can be reliable and representative of real world experimental conditions (Bertram et al., 2015; Ganier, Hoareau, &

Tisseau, 2014; Hyltander et al., 2002; Larrue et al., 2014; Regian, 1997; Rose et al., 2000). In general, VEs have been shown to be useful for examining the mechanics of calibration to perturbations such as perceptual distortions (e.g., Altenhoff et al., 2012; Bingham, Bradley, Bailey & Vinner, 2001; Littman, 2009; 2011).

For instance, a task that humans engage in frequently is determining what is within reach. Being able to determine what is within reach is an important affordance which must remain calibrated in the face of changes in posture, stability, the addition of tools, and changes in accuracy required. Previous research has altered users' reaching abilities by extending their reach with tools (e.g., Bourgeois, Farnè, & Coello, 2014; Day, et al., 2017; Day, et al., submitted; Maravita & Iriki, 2004), or manipulating the perception of where the target is located using virtual reality (e.g., Ebrahimi, Altenhoff, Pagano, & Babu, 2015). This research has investigated what occurs if physical dimensions or the physical perception of the environment is altered and whether individuals can attune to these changes. In all of the studies, calibration can be observed through changes in the participants' behavior after appropriate training or feedback has been given (Bingham & Pagano, 1998; Ebrahimi et al., 2015; Ebrahimi, et al., 2016;).

Bingham and Romack (1999) investigated the introduction and removal of a perturbation (i.e., taking prism goggles on and off). Participants were not only able to calibrate under both conditions but recalibration occurred more rapidly with each successive perturbation shift. One example of how VEs can assist in researching calibration is that the perturbation can be changed in both duration and amount without providing any cues (e.g., changing out goggles). For example, Littman (2011), was able to create a perturbation that contained multiple perceptual distortions simultaneously by the use of yaw and pitch rotations by using VE technology in order to study the effects on calibration.

Both Littman (2011) and Bingham and Romack (1999) used stable levels of perturbation throughout their experiments. While Bingham and Romack (1999) removed and added the perturbation of the googles, the change between these two perceptual environments were the same since the same amount of perturbation was added or removed each time. What if the change in the perturbation was not shifting back and forth but constantly changing?

4. **Purpose and Goals**

While many changes in the actor-environment relationship happen either instantaneously such as an injury, a change in height due to donning high heels, etc., or over very long timescales such as with growth. However, others fall in between. It has been demonstrated that actors are able to calibrate to changes in affordances over very short time scales (e.g., prism goggles, the addition of a tool, etc.) or long-term changes that persist over long time scales (e.g., body growth, aging, physical training, pregnancy, etc.). However, there are some changes to affordances that occur in short-time frames but have the pattern of a long-time scale change. These essentially create unstable actor-environment interactions. In essence, something within the interaction is causing the relationship that is stable under most conditions to have increased variability causing it to be unstable. The purpose of this series of experiments is to examine the effect of unstable environments on calibration: specifically, how changes to the amount of perturbation affects calibration. The goal of this experimentation is to further enhance our understanding of perception-action calibration.

CHAPTER II.

EXPERIMENT ONE

Both experiments used a multiplicative visual gain perturbation to investigate the effect of an unstable environment on performance. The perturbation was a multiplicative function of the rate of visual rotation in the VE which was coupled with the movement of participants' rotational head movements. The gain only occurred on the unitary plane of yaw (i.e., looking left or right). Therefore, instead of a 1-to-1 representation from the head rotation action to its visual effects displayed in the VE, a perturbation increased the rate of rotation in the visual scene. For instance, a gain value of 2 will double the rate of visual rotation (e.g., a head rotation of 15 degrees will result in a visual rotation of the VE scene of 30 degrees while a head rotation of 10 degrees will result in a 20-degree visual rotation). It is not a fixed value across all degrees of head rotation movements thereby creating a change in the optic flow.

This type of visual gain can be seen in video games and other virtual environments in terms of panning across the screen. Essentially, in these examples, the panning movement speed increases the longer you move across a scene. This gain can also be seen in new power steering automation in cars. At faster speeds, a driver is required to turn the wheel more than when driving at slower speeds to create the same type of movement. Thus, the effect of wheel input on car movement depends on the speed of the car.

In this experiment there were three conditions of visual gains: control, constant, and randomized increase. The first, was a *control* condition with the visual gain of one (i.e., one times the amount of head rotation). A visual gain of one is analogous to regular viewing within a VE where head rotation maps 1-to-1 with visual rotation. This condition allowed for the

examination of any fatigue effects that could occur within the task as well as any effects of being in a VE.

The second condition had a stable perturbation level (i.e., the gain remained at the same value during the experimental blocks). This *constant* condition is analogous to that of previous research that had a constant gain during the calibration phase. The amount of gain in this condition was the mean of the total amount of gain in the third experimental condition (i.e., 2.5x gain). Meaning that the visual movement within the VE will be two and a half times the amount of the actual head rotation movement (e.g., a head rotation of 10 degrees will create a visual rotation of 25 degrees). This condition will allow for us to determine if any retardation of recalibration is simply due to the stimulus itself (i.e., rotational gain perturbation) and not the changing of the gain.

The last condition is the experimental condition where the amount of gain in the system changed for each block. The pattern of the change of gain is important as it can result in confounding of the results. There are three patterns of change that could occur: increase, decrease, or a combination of the two. While all three of these patterns can be found in naturalistic settings and are important to investigate, decrease and the combination of both have conflated patterns. In essence, in both of these patterns, there are both increase and decreasing (e.g., in order to decrease, one would have to increase up to a high level of gain) patterns observed. This conflation would make it difficult to isolate the cause of the effect to the rate of gain change as the effect could simply be the result of the mixture of increasing and decreasing. Therefore, the increase pattern was selected for both experiments with the hope that future experiments will examine the effect of decreasing and the combination of both. In order to

determine the effects of varying gain for this first experiment, the gain amount in this condition always changed in the amount of change between blocks.

Figure 1 depicts the randomized gain amounts for the experimental condition and control condition. The three different types of environments created by these different conditions are examples of stabilized environments (i.e., control and constant gain) and an unstable environment (i.e., the gain is consistently increases in a randomized fashion).

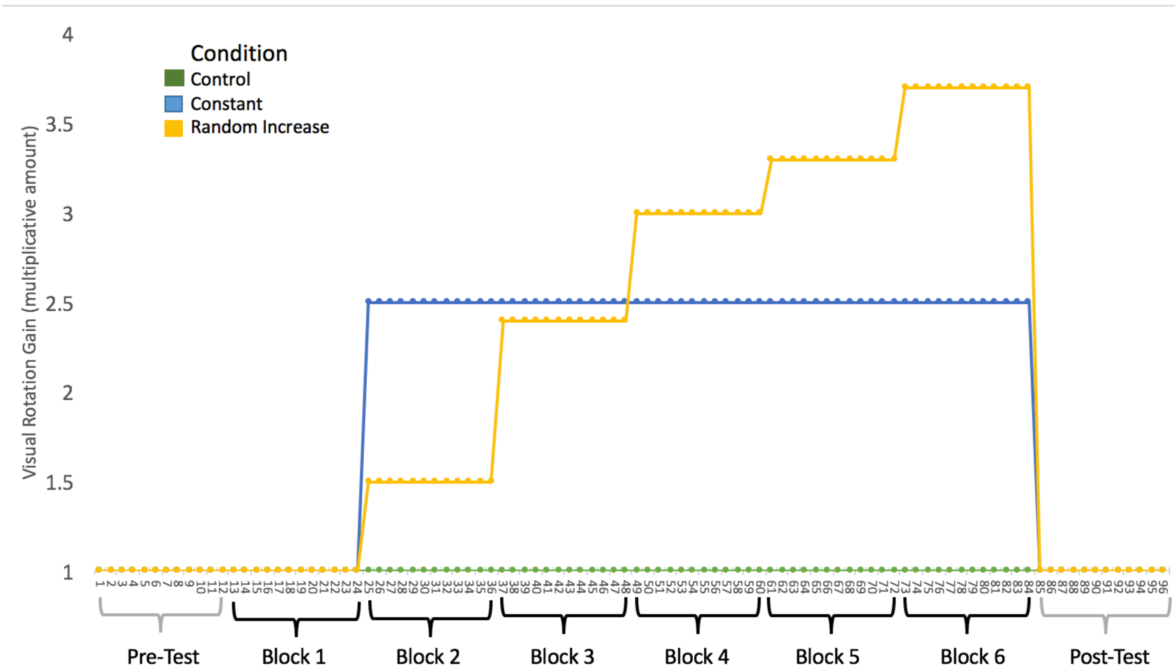


Figure 1. Visual rotational gain profiles for Experiment 1. The pre-test and post-test blocks do not have any visual feedback of estimates or the calibration task.

Recalibration was examined within blocks of trials as well as across the blocks. This allowed the examination of recalibration for a specific block of trials and the overall recalibration effect across the blocks. Recalibration was operationally defined as a decrease in absolute error in the target location estimations and examined within the blocks of trials. Additionally, pre-test and post-test data was compared for any carryover effects.

1. **Hypotheses**

The current study has four primary hypotheses. (1) We expect that the more unstable an environment is, the more difficult it will be to recalibrate (i.e., the longer it will take to recalibrate). The control group will show the most rapid recalibration. The constant group will also show rapid recalibration after the initial onset of the perturbation. The randomized increase group (i.e., the experimental group with the varying amounts of gain changes between blocks) will take the longest to recalibrate. (2) It is hypothesized that the unstable environment will cause greater target estimation errors and (3) have greater postural sway (e.g., higher levels of entropy) than the other two groups. (4) Lastly, it is hypothesized that postural sway (e.g., entropy) will mediate the relationship between the type of perturbation condition (i.e., type of environment) and target estimation errors (see Figure2).

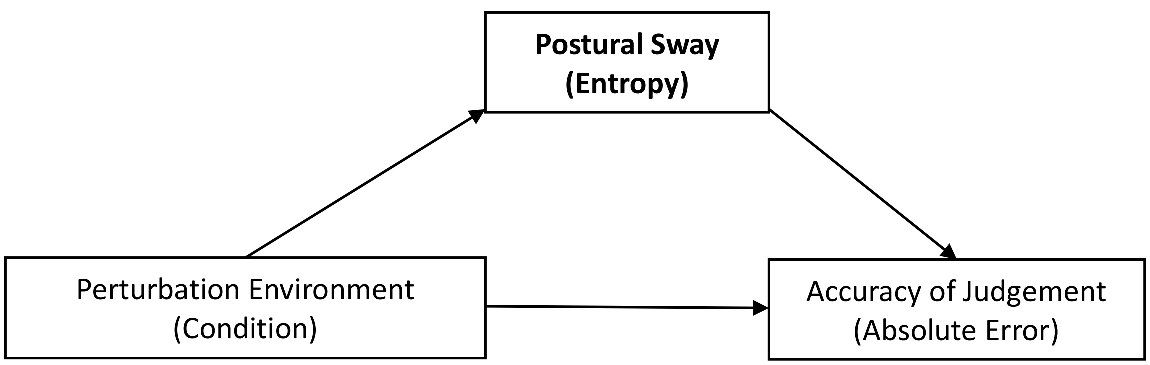


Figure 2. Mediation Model. Postural Sway (a measure of entropy) is hypothesized to mediate the relationship between the perturbation of the environment (i.e., the different conditions) and the accuracy of participant’s judgments measured by error.

2. **Methods**

2.1. *Participants*

Since this study is a repeated measures design which includes a time-series component, multilevel analysis will be used. Estimating power for a multilevel study requires consideration of the Level 2 (L2) units (i.e., the number of participants) comparatively to the size of Level 1 (L1) units (i.e., the number of measurement occasions) and the intraclass correlation (ICC). Due to the nesting of the L1 variables within the Level 2 variables require additional assumptions during power estimations.

Fifty-three university undergraduate students participated in the study (19 males and 36 females; age range 18-23; mean 19.33). These participants were recruited using the Clemson participant pool and given course credit for their participation in the study. Participants were allowed to stop the experiment at any time. Participants' data that did not complete the entire experiment, had equipment or experimenter error, or did not participate in the study correctly (i.e., did not follow instructions) were not included in the analyses. Five participants withdrew from the experiment due to simulator sickness (two in the constant condition and three in the random increase condition), two participants were removed due to equipment failure, three were removed due to failure to follow instructions, and one was removed due to experimenter error. Additional participants were run in order to have the total 42 right-handed participants required for the study with complete data.

2.2. *Materials & Apparatus*

2.2.1. Wii Balance Board (WBB)

Postural sway or the slow low-amplitude movement of the body can be measured through center of mass or center of pressure (COP). The COP is essentially the distribution of the vertical ground reaction force. During an upright stance, the COP can be thought of as being distributed between each foot and generally is about midway (Pellecchia & Shockley, 2005). The change in the location of the COP over time (i.e., the shifting of the distribution of the center point) creates a pathway that allows researchers to examine the factors that influence postural control.

Body sway data were collected using a Nintendo Wii Balance Board (WBB). The WBB was connected to a computer using Bluetooth and data were collected using BrainBLoX software (Cooper, Siegfried, & Ahmed, 2014). Previous research has validated the use of the WBB for scientific collection of body sway data (e.g., Clark et al., 2010; Michalski et al., 2012; Reed-Jones et al., 2012; Stoffregen et al., 2013; Scaglioni-Solano & Aragón-Vargas, 2014; Weaver, Ma, & Laing, 2017). COP data was collected in the anteroposterior (AP) and mediolateral (ML) axes with a sample rate of 50 Hz. Due to the concerns of individuals being affected by simulator sickness and potentially stepping to catch their balance, a platform was constructed of garden stone around the WBB to create a more level surface to prevent any falls (see Figure 3). The garden stones surrounding the WBB did not touch the surface of instrument to prevent any measurement error due to surface contact. To prevent participants' feet from sliding into the crevice between the WBB surface and garden stones, interlocking rubber mats were placed around the surface (not touching the WBB surface).

Figure 3. Wii Balance Board set up with platform.

2.2.2. Motion Tracking

An HTC Vive System (HTC, Taiwan) was used to track participants' movements. Two Vive Base Stations positioned seven feet above the ground at 45-degree angles were used to track HTC Vive Trackers and remote. Two base stations increase measurement precision.

The Vive controller measures 12 cm wide at its widest point (the tip), 26.5 cm long from base to tip, and 3 cm wide at the base of the handle. The other Vive tracker measured hip placement with one tracker mounted to a belt and placed on the hip bone of the participant. Positional data along the X, Y and Z axes were collected for each tracker at a sample rate of 60 Hz. Data from the trackers was collected using a SteamVR program and filtered offline to account for any error (e.g., unexplainable jumps) in the positional data.

The Vive head mounted display (HMD) also contained a tracker that was used to measure participants' head movement and angle at the time of their estimation. The visual display in the HMD is binocular (i.e., each eye receives a slightly different image, rendered from the correct eye position) with a fixed distance to the simulated surface and has a 110° horizontal field of

view. Therefore, the eye accommodates to view an image shown at the fixed depth of the simulated surface. However, since each eye receives a different image, the vergence angle of the eyes change depending on how far away the simulated object is presented within the VE. The simulated targets were kept at a constant distance of 2.91 meters away from the participants in the VE. The HMD's interpupillary distance (IPD) setting was adjusted so that it matched the participant's IPD.

2.2.3. Virtual Environment

The virtual scene used in this experiment was a room with wooden floors and four brick patterned walls (see Figure 4) and was created using Unity. These two patterns were used in the environment to provide texture to increase the information gathered through optic flow. Participant location in the room was held constant across all participants (i.e., even if the WBB were to move in the laboratory, the participant would still have the VE rendered in the same location).

The trial targets were bullseyes that were created by overlapping three virtual circles. The outside white circle had an approximate radius of 12.5 cm, the red middle circle had a radius of 11 cm, and the central circle had a radius of 1.2 cm. These were located on an invisible circular arc around the participant keeping the distance from the target to the participant constant at 2.91 meters. There were four target placements: two on either side of the participant at 90 degrees and 61.3 degrees. Targets were not within the field of view when participant was looking at the "+." The trial targets were not constantly visible and would only appear for the randomly assigned trial (i.e., participants would only be able to see one target at a time).

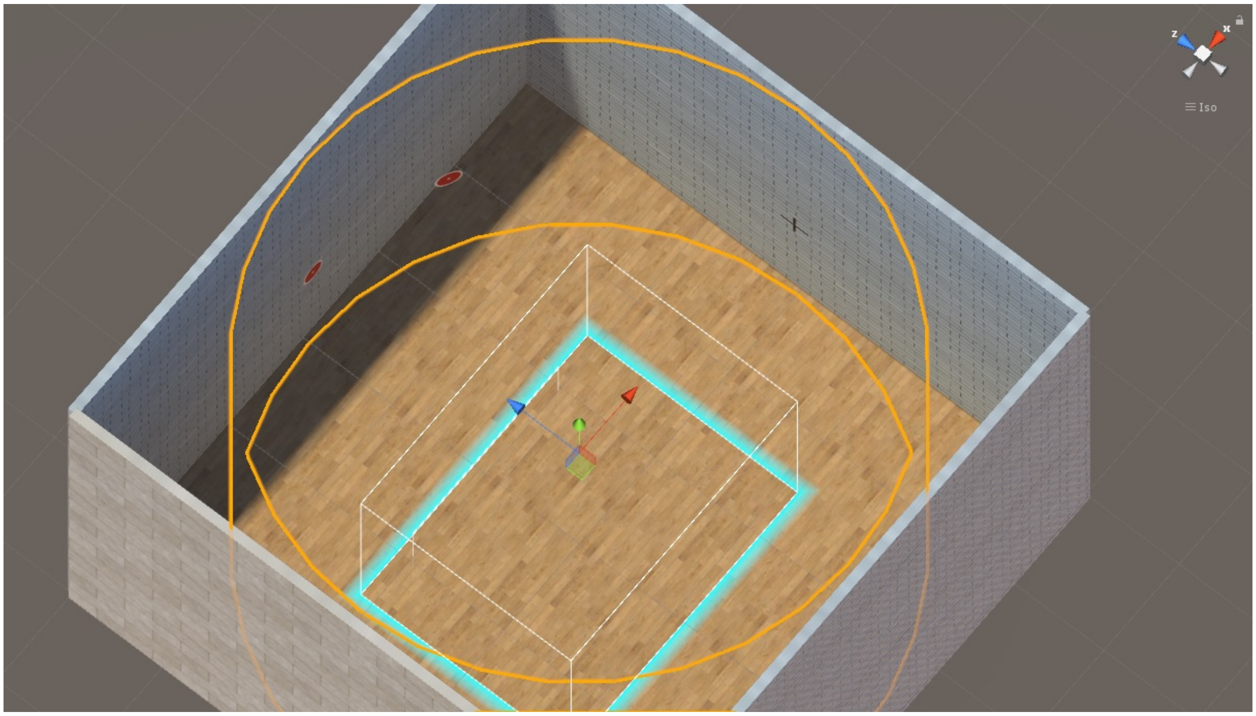


Figure 4. Virtual Environment Layout. Location of participant is the green marker intersected by the two arrows. The “+” can be seen on the far wall and two target locations (targets 1 and 2) are demonstrated on the invisible cylindrical wall. While in the depiction this and the participant location box have highlights on their dimensions, these were invisible to participants in the study.

3. **Procedure**

Participants were given a brief overview of the purpose of the experiment and provided their informed consent. They then responded to an initial questionnaire which consisted of both demographic and motion sickness susceptibility questions (Reason & Brand, 1975, e.g., Kinsella, 2014). The demographic questionnaire included information on participants’ age, gender, and previous experience with virtual environments. After this, participants completed a stereopsis test, their interpupillary distance (IPD) was measured and the Motion Sickness Assessment Questionnaire (MSAQ; Gianaros et al., 2001).

They then were outfitted with the various motion sensors and asked to find a comfortable stance on the WBB. Participants were instructed that they needed to remain in the same stance

on the WBB throughout the experiment. Therefore, during the action of a target estimation, participants only engage their upper body (i.e., twisting at waist and moving the arm upward to make target estimation judgments; see Figure 5b and c). Before the start of the data collection phase, participants were given instructions for the experiment, given two practice trials, and the were asked to explain the task and objective to the experimenter to check for comprehension.

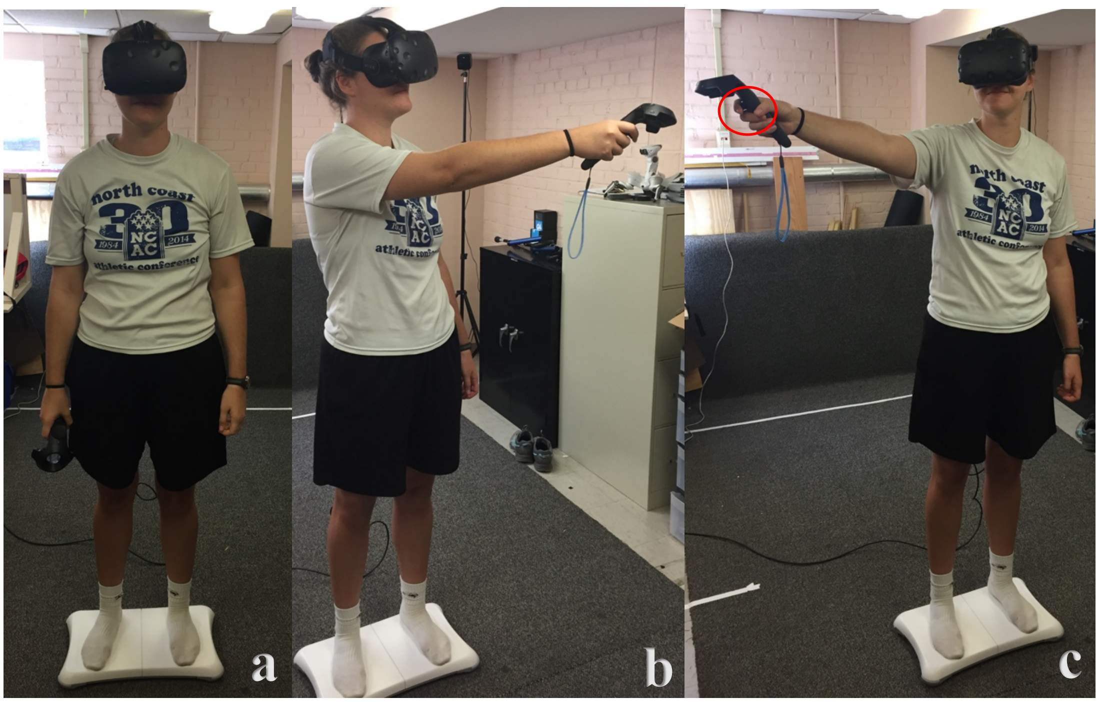


Figure 5. Participant movement during trials. a) relax starting position, b) action required for targets 3 and 4 to the right side of the body, c) action required for targets 1 and 2 to the left side of the body. The red circle in figure c is to highlight the location of the remote controller trigger used to mark participants' estimations.

For each block of trials, participants were forward facing in a relaxed stance—arms resting down to the side of the body with head looking straight ahead (see Figure 5a). They were instructed to have their head and eyes facing the "+" in the center of the wall in front of them in the VE (see Figure 6a). Participants were given a verbal cue to begin the block of trials. For each trial, the participant pointed the remote at the "+" and pulled the trigger. This action resulted in

the initiation of the trial (i.e., the initiation of the Vive tracking system) and a red arrow indicating the location of the trial's target (either to the left or the right of them) to appear (see Figure 6b). The targets were not in the field of view when the participant was looking directly forward.

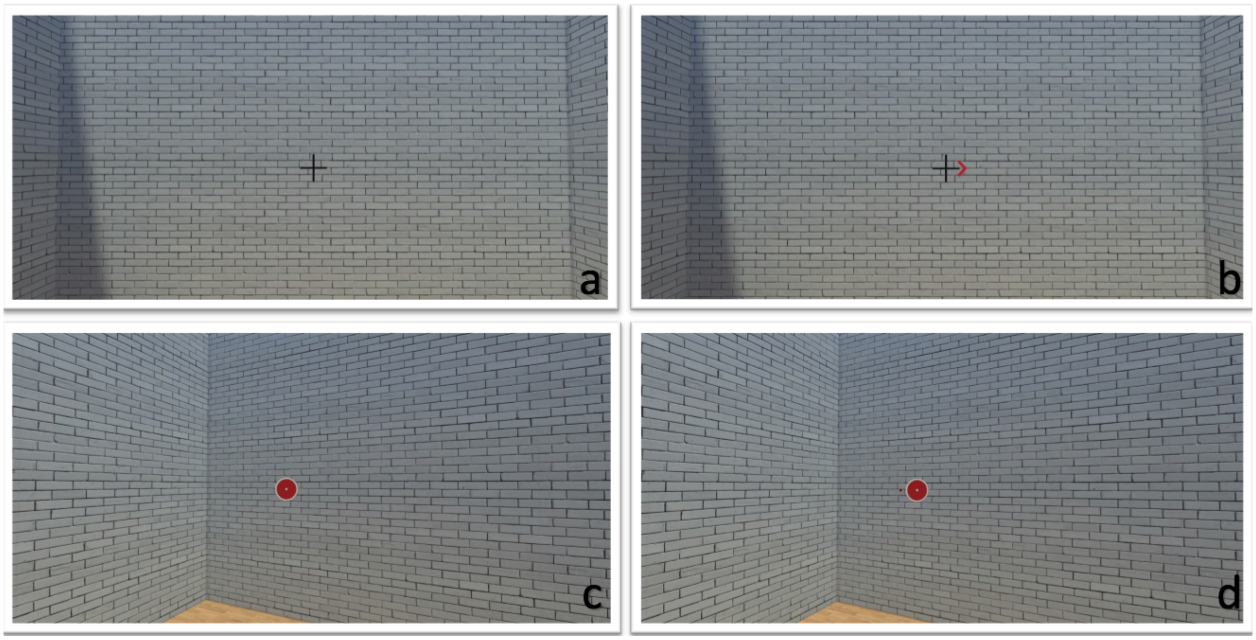


Figure 6. Participants' views of Virtual Environment during different trial tasks. (a) Stimulus of "+" target and (b) the direction of target location indicator after participant initiated trial by pointing and pulling the trigger at the "+" target, (c) participant viewing a target, (d) example of missing a target before participant recalibrates to hitting the target.

Participant's then rotated their head and/or upper torso to locate the bullseye trial target (Figure 6c). After finding the target and fixating on it, participants marked their estimate of the location of the target by raising the arm with the remote controller up and pulling the trigger located at the back (see the red circle for the location of the trigger in Figure 5c). Participants were instructed their goal was to hit center position of the target. When making their estimates they were required to bring their arm up in a straight manner. When making their initial estimate,

participants did not have any visualization of the controller or their arm in the virtual world. This is similar to previous work of "blind" reaches (e.g., Day et al., 2017).

During the pre- and post-tests, after marking their estimate of a target's location, participants did not receive any additional feedback as to their performance other than a laser "zapping" noise that just provided feedback they had made an estimate. At this point, they would rotate back to the "+" in order to start the next trial (i.e., pointing and triggering the remote at the "+").

During the experimental blocks, after the participant made their target estimation a ball appeared displaying the location of their estimation (see Figure 6d). At this point they were instructed to correct the location (if they did not hit it in their initial estimation) of the hand remote until it matched the location of the target (e.g., central point of the target) and to again pull the trigger. If participants missed during their recalibration they were instructed to continue aiming and shooting until they hit the target. They were given an auditory feedback cue when they correctly hit the target of a high pitched "ding" sound. Once this occurred, they were asked to return their hand to the starting position and point and trigger the remote at the "+" in order to start the next trial. Four targets were randomly presented three times in each of the eight blocks of trials. Therefore, there was a total of 96 trials (12 per block).

Blocks of trials were completed automated through the VE programing. Therefore, participants were in control of the timing of trials and the rate in which they completed blocks. Once participants completed all trials within a block, they were told they could relax and remained in the environment while the simulator sickness questionnaire (SSQ) was administered verbally (Kennedy, Lane, Berbaum & Lilienthall, 1993). While simulator sickness is not a variable of interest for this study, it is important to determine if it influenced the data.

3.1. *Pre-Test Phase*

Each condition started with a block of trials that were considered the pre-test phase. These trials were without any perturbation gains (i.e., gain= 1x head rotation) or visual feedback of where they made their target estimates. This block of trials allowed for a comparison of performance to observe calibration effects in the post-test phase.

3.2. *Experimental Phase*

3.2.1. Block 1: Baseline Phase

The experimental phase began after the completion of the pre-test phase. The first block in this phase is considered a baseline for the experimental block. This block of trials remained at a gain of 1 but received visual feedback after their initial estimation. This block of trials allowed for a baseline of measurements to be used to compare the other experimental trials that include varying levels of perturbation.

3.2.1. *Blocks 2-6: Experimental Phase*

During the experimental phase, the constant condition (2x gain) and random increase condition (different changes in level of gain between blocks) had perturbations included. These perturbation of visual gain can be seen in Figure 1 for each block of trials. Participants were not informed of any visual gain changes in any condition.

3.3. *Post-Test Phase*

The post-experimental-baseline phase was simply a repeat of the initial baseline phase after the administration of the experimental phase. Like the pre-test, the participants received no visual feedback about their performance. This block of trials allowed for an examination of returning back to an unperturbed environment.

4. **Data Preprocessing**

4.1. *Postural Sway: Entropy*

Postural sway was recorded and analyzed in order to obtain the degree of entropy and determinism of the system (i.e., amount of postural control demonstrated by the participant). Entropy can be defined as the amount of new information generated by a system. Approximate entropy (ApEn) can be used to characterize the observed postural sway of a participant and examine the factors influencing the dynamical structure (Newell, 1998; Pincus, 1991). Richman and Moorman (2000), later modified ApEn for shorter times series (i.e., 100-20,000 points) termed sample entropy (SampEn).

SampEn quantifies the overall complexity or irregularity of a system. Systems that are generating non-redundant information have large SampEn values. This increase in entropy occurs when a system visits new states (Kantz, 2004). SampEn was used in this experiment to quantify the amount of postural movement that a participant performs. SampEn was created for each block of trials. Unfortunately, the individual trials did not provide enough data points for analysis purposes due to the speed at which they were completed. While this did not allow for the quantification of postural sway within the specific blocks of trials to investigate recalibration within the block (i.e., the trials within each block), it was still possible to examine postural sway

recalibration across the blocks. This information enabled the investigation of how the different conditions affect postural sway as well as how postural sway affects performance (i.e., amount of error in an estimation).

As previously discussed, a WBB and BrainBLoX software was utilized to collect the postural sway data (Cooper, Siegfried, & Ahmed, 2014). This data was divided into two different files one for the sway occurring on the x axis (mediolateral sway) and the second the y-axis (anterior-posterior sway). These were split due to the requirements of the SampEn analysis. Data filtering was then applied to each participant's individual blocks of trials in order to check for any measurement noise in the data. A fourth order zero-phase shift low-pass Butterworth filter was used with a cut-off frequency of 10 Hz commonly used in the studies devoted to the dynamical properties of COP signals (e.g., Salavati et al. 2009; Randami et al., 2009). This data was then filtered through a SampEn analysis and analyzed to select the appropriate tolerance (r) and maximum length (m) to calculate the SampEn values. A tolerance of 0.3 and a maximum length of 3 was selected for the final value utilized in this analysis.

4.2. *Transformation Variables*

4.2.1. Accuracy: Absolute Error

For every trial of this experiment, an initial target estimation was performed by the participant. The difference between the target angle and the estimation angle defines the level of accuracy for the trial. This can be thought of in terms of *error*. Measurement of error can be problematic. In previous research error has been examined in raw form, by its variability, and in absolute values (e.g., Schmidt, 1988). The raw error term can be created by taking the angle of the presented target and the estimated target angle or degrees for each trial (error=estimated

angle-presented target angle). This results in a measure where lower (negative) values indicate greater error due to underestimation, middle values near zero indicate less error, and higher values indicate greater error due to overestimation. Thus, the scale is not a linear representation of error. To address this problem absolute error can be assessed by taking the absolute value of the signed error. Low values near zero reflect less error and higher values reflect greater error. Although absolute error is a linear measure of error, directionality, or error due to under or over rotation, is lost. Measures of absolute error assume error due to under or over rotation are equivalent. However, effects on absolute error may depend on whether the error is due to under or over rotation. Directionality of the error has been shown to moderate the influence of experimental conditions on absolute error (e.g., Day et al., 2017). Therefore, to deconflate absolute error (directionality conflated with size of error) two terms were created: *absolute error* (which takes the absolute value of the signed error and is the amount of error regardless of rotation) and *directionality* (a dichotomous variable to distinguish under- and over-rotation in the estimation)

4.2.2. Target Specifying Variables

The four targets used in this experiment were transformed into two variables to analyze the effects of their location and the action required to aim at them. Both of the variables were dichotomous. *Location* was defined in terms of whether the target was at 90 degrees or 63.1 degrees. Targets 1 and 4 were considered *peripheral* in their location and targets 2 and 3 were considered *frontal* (see Figure 7). The second term created was *action requirement*. This term specified if the aiming action was open- or cross-body. Targets 1 and 2 were considered cross-body while targets 3 and 4 were considered open-body (see Figure 8).

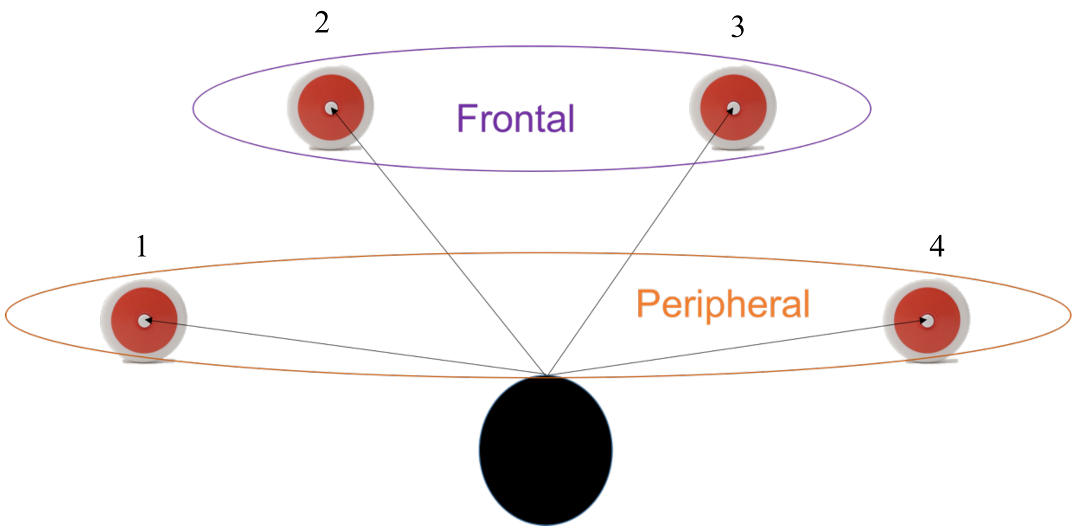


Figure 7. Target dichotomous location assignments. Targets 1 and 4 were coded as peripheral (0) and targets 2 and 3 were coded as Frontal (1).

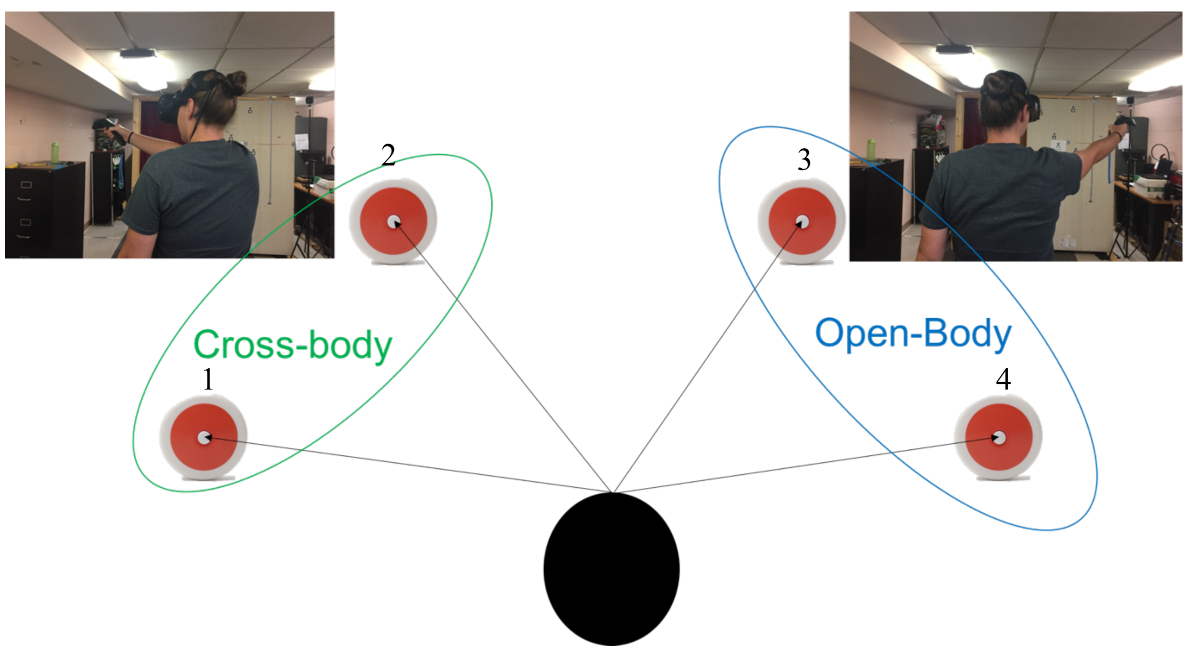


Figure 8. Target dichotomous action requirement assignments. Targets 1 and 2 were coded as cross-body (0) and targets 2 and 4 were coded as open-body (1).

4.2.3. Head Movement Variables

Three head movement variables were created from the tracker in the HMD and the remote controller. The first measured the maximum angle the head/ body rotated in the VE and was termed *max rotation*. The *total rotation* variable was created to measure the amount of rotation of the head/body along the yaw rotation axis. This variable was additive where any amount of rotation in any direction was included. While this variable does provide a metric of total movement within a trial, it does not include the information of directionality change that would have allowed it to be more informative. However, it will be included in the models as a coarse scale of total movement. The last variable was the rotation difference between the central tracker on the HMD and the remote tracker (i.e., the estimation angle). This variable coarsely measures the amount of eye movement within the HMD to the target at the time of estimation.

4.3. *Variable Reference Specification*

4.3.1. Categorical Variables

All categorical variables were dummy coded for analyses and a reference category was specified for each. This reference remains constant throughout all analyses. For the condition variable, the control condition was used as the reference group. Block 1 of the experimental trials were used as reference in the analyses of these trials while the pre-test block was used as the reference for the pre/post-test comparison analyses. The reference group for directionality was over rotation. For the target variables, frontal was the reference for the location variable and open-body was used to for the action requirement variable.

4.3.2. Continuous Variables

Continuous variables such as SampEn, MSAQ, SSQ, head movement variables were grand mean centered. This allows for a meaningful zero for these data and allows for the intercept variance to be estimated correctly across addition of variables. The block trial variable was not mean centered as the meaningful zero point for this condition is the first trial. Therefore, this variable was transformed so that the trial number began at zero instead of one (i.e., subtracting one from the variable).

5. **Results of Experiment 1**

Evidence for the first hypothesis examining recalibration rate can be studied at the block level or within blocks at the trial level. Therefore, any significant findings in the experimental block analysis of absolute error with any interactions containing both block or trials within block and condition can be examined for this hypothesis.

While the first hypothesis examines the rate of recalibration observing the change in absolute error within the experimental blocks, the second hypothesis is used to examine the overall effect of the three environments on calibration in general. This can be observed in the carry-over effects found in the post-test. Therefore, the interaction of interest is block and condition in the pre-/ post-test analysis of absolute error.

The third hypothesis can be found in the postural sway analyses. The interaction of block and condition in the experimental blocks indicate how the different levels of perturbation affect

the mediolateral sway and/ or the posterior-anterior sway. The overall effect of the environments on the postural sway can be observed in the carry-over effects found in the post-test.

Lastly, the mediation model is utilized to integrate the other analyses into a relational model between condition and absolute error with postural sway as a mediator. Block was then included as a moderator to determine recalibration effects in the experimental blocks and carry-over effects in the pre-/ post-test blocks.

In order to address the rich complexity of the data, comprehensive analyses were conducted. While the lower-order main effects and interactions described above can provide evidence for the various hypotheses, these interactions can be dependent on other variables. Therefore, higher-order interactions were included for full factorial models to examine other moderating factors. This is specifically for the primary dependent variable of absolute error. These analyses were conducted in a systematic fashion examining primary variables that are specific to the hypothesis and the principal focus of the current study before secondary variables that could be impacting the results (e.g., simulator sickness, head rotation, etc.). Additionally, while all significant effects are discussed, main effects and lower-order interactions are the average of higher-order interaction variables and should be examined as such. In essence, significant higher-order interactions demonstrate moderating factors of lower order main effects and interactions. Descriptive statistics for collected variables can be found in Appendix A for the experimental blocks and Appendix B for the pre-/post-test blocks for Experiment 1.

5.1. *Outlier Analysis*

For each analysis, full models (i.e., a model with all predictors and interactions that will be analyzed) were conducted to determine any outliers. From these models residuals were obtained,

standardized, and examined for any potential outliers and extreme cases that are outside of the normal distribution (Cohen et. al, 2003). Generally, it has been found that these points are due to malfunctioning in the tracking equipment based or on participant error (e.g., marking an estimation prematurely). All analyses found less than 1% of the trials removed due to outlier analysis.

5.2. *Hierarchical Linear Modeling (HLM)*

Variables have considerable nesting within participants due to the repeated-measures design used in this research. In order to address the nesting of trials within participants, multilevel modeling (*hierarchical linear modeling*, HLM) was used to analyze both accuracy and entropy as dependent variables. HLM allows more flexibility in the modeling of repeated-measures data and has many advantages over traditional repeated-measures analysis of variance (e.g., Cohen et al., 2003). For instance, predictors may be nominal or continuous and vary at the measurement occasions (i.e., they can be *time-varying* and can change between trials). This allows for the variances across measurement occasions and within participants to be kept and analyze instead of being disregarded by other mean based type analyses. The use of HLM also allows for a more flexible approach to modeling the possible error structures and "fit" statistics of the repeated measures.

Predictors that carry variance at the measurement occasion level are Level 1 variables. These variables are anything that can potentially change from trial to trial (e.g., target location, visual gain, phase or block of the trial, trial number, etc.). Predictors that carry variance at the person-level are Level 2 variables. These are any variables that remain constant for participants during the experiment. Interaction terms will also be created which can be either inter-level

interactions (e.g., Level 1 by Level 1 *or* Level 2 by Level 2) or cross-level interactions (e.g., Level 1 by Level 2).

Effect sizes in HLM are often called pseudo-R^2 and are the percent of explained variance. Level 1, Level 2, and Cross level interactions all have their own error variance; Level 1 error variance (residual variance) for Level 1 predictors and Level 2 error variance (intercept variance) for Level 2 predictors, and the percent reduction in the Level 1 slope variance for cross level interactions (L1 by L2). Like other traditional statistical modeling approaches, HLM addresses normally distributed outcomes with the use of general linear models.

Due to the different tasks between the pre- and post phases compared to the experimental calibration phases, the data was split into two different data sets. The first data compared the six experimental blocks of trials. The second data set compared the pre- and post-tests. Both sets of data will have the same data analyses conducted.

5.3. Accuracy: Absolute Error (degrees)

The following models predict absolute error which is considered the accuracy of the trials. Two models were conducted. The first included all primary predictor variables (i.e., block, block trials, condition, target location, and action requirement) required to answer the first and second hypotheses comprehensively. The second included all primary predictor variables and secondary variables (i.e., MSSQ, SSQ and head movement variables) to investigate their effects on the model. The primary analyses included all interactions of the primary variables up through the six-way interaction. The secondary analysis only included interactions determined to be important in the investigation of their effects.

For the dependent variable of accuracy measured by absolute error a main effects model including all Level 1 and 2 predictors was conducted for a more conservative model to estimate effects and coefficients. Level 1 predictors include: block (categorical), block trial (continuous), target location (dichotomous), action requirement (dichotomous), SampEn (continuous), and SSQ. The level 2 predictors will be condition and MSAQ-pre and –post for experimental models. The MSAQ-pre and –post will be grouped into a single variable for the pre-/post analysis creating a level 2 variable.

5.3.1. Experimental Block Analyses for Absolute Error in Experiment 1

5.3.1.1. Absolute Error Primary Analysis in Experimental Blocks for Experiment 1

The F-Test results from the hierarchical linear modeling for accuracy as the outcome can be seen in Table 1. Continuous variables also have the coefficient estimate of the slope and standard error. For a comprehensive table of all predictors' coefficients is located in Appendix C.

Table 1. Fixed Coefficients, Standard Errors and $R^2\Delta$ for Absolute Error for the primary variables in the experimental block of Experiment 1.

Fixed Effects						
				ΔR^2		
Predictor	Coefficient (SE)	F-Test	P-value	L1	L2	Cross-Level Interaction
Intercept	1.73 (0.16)	--	--	--	--	--
Block	--	5.70	<0.001	.0207	--	--
Block Trial (Btrial)	-0.01 (0.01)	2.18	0.15	--	--	--
Location (Loc)	--	1.96	0.16	--	--	--
Action Requirement (AR)	--	2.51	0.12	--	--	--
Directionality (Dir)	--	13.06	0.00	.0135	--	--
Condition (Cond)	--	1.07	0.35	--	--	--
Block*Btrial	--	2.12	0.06	--	--	--
Loc*Block	--	0.19	0.97	--	--	--
AR*Block	--	0.94	0.46	--	--	--
Dir*Block	--	3.19	0.01	.0028	--	--

Loc*Btrial	--	0.65	0.42	--	--	--
AR*Btrial	--	1.64	0.20	--	--	--
Dir*Btrial	--	0.03	0.87	--	--	--
Loc*AR	--	1.54	0.22	--	--	--
AR*Dir	--	0.21	0.65	--	--	--
Loc*Dir	--	8.52	<0.001	.0020	--	--
Cond*Block	--	1.63	0.09	--	--	--
Cond*Btrial	--	1.14	0.33	--	--	--
Cond*Loc	--	0.53	0.59	--	--	--
Cond*AR	--	0.21	0.81	--	--	--
Cond*Dir	--	0.08	0.93	--	--	--
Loc*Block*Btrial	--	1.44	0.21	--	--	--
AR*Block*Btrial	--	1.25	0.28	--	--	--
Dir*Block*Btrial	--	0.54	0.75	--	--	--
Loc*AR*Block	--	0.57	0.73	--	--	--
Loc*Dir*Block	--	1.72	0.13	--	--	--
AR*Dir*Block	--	0.95	0.45	--	--	--
Loc*Dir*Btrial	--	0.90	0.34	--	--	--
AR*Dir*Btrial	--	17.30	<0.001	.0043	--	--
Loc*AR*Dir	--	2.82	0.09	--	--	--
Loc*AR*Btrial	--	0.78	0.38	--	--	--
Cond*Block*Btrial	--	1.31	0.22	--	--	--
Cond*Loc*Block	--	1.33	0.21	--	--	--
Cond*AR*Block	--	0.99	0.45	--	--	--
Cond*Dir*Block	--	0.79	0.64	--	--	--
Cond*Loc*Btrial	--	0.16	0.86	--	--	--
Cond*AR*Btrial	--	0.54	0.59	--	--	--
Cond*Dir*Btrial	--	1.56	0.20	--	--	--
Cond*Loc*AR	--	0.85	0.43	--	--	--
Cond*Loc*Dir	--	0.68	0.51	--	--	--
Cond*AR*Dir	--	1.91	0.15	--	--	--
Loc*AR*Dir*Block	--	0.57	0.72	--	--	--
Loc*AR*Dir*Btrial	--	0.02	0.89	--	--	--
Loc*AR*Block*Btrial	--	1.11	0.35	--	--	--
Loc*Dir*Block*Btrial	--	1.90	0.09	--	--	--
AR*Dir*Block*Btrial	--	0.69	0.63	--	--	--
Cond*Loc*Block*Btrial	--	0.93	0.51	--	--	--
Cond*AR*Block*Btrial	--	1.85	0.048	--	--	.0030
Cond*Dir*Block*Btrial	--	0.55	0.86	--	--	--
Cond*Loc*AR*Block	--	1.93	0.04	--	--	.0031
Cond*Loc*Dir*Block	--	0.62	0.80	--	--	--
Cond*AR*Dir*Block	--	0.80	0.63	--	--	--
Cond*Loc*AR*Btrial	--	0.80	0.45	--	--	--
Cond*Loc*Dir*Btrial	--	0.04	0.97	--	--	--
Cond*AR*Dir*Btrial	--	0.64	0.53	--	--	--
Cond*Loc*AR*Dir	--	0.64	0.53	--	--	--
Loc*AR*Dir*Block*Btrial	--	0.94	0.45	--	--	--
Cond*Loc*AR*Dir*Block	--	0.56	0.85	--	--	--
Cond*Loc*AR*Dir*Btrial	--	0.22	0.80	--	--	--
Cond*Loc*AR*Block*Btrial	--	0.59	0.83	--	--	--
Cond*Loc*Dir*Block*Btrial	--	1.21	2.85	--	--	--
Cond*AR*Dir*Block*Btrial	--	1.42	0.17	--	--	--
Cond*Loc*AR*Dir*Block*Btrial	--	0.93	0.50	--	--	--
			Total ΔR^2	.0433	--	.0061

There were two significant main effects: block and directionality. The means and standard deviations for block can be found in Table 2 and the LSD post hoc tests comparing the other means are in Appendix D. As visually shown in Figure 9, absolute error decreased in general as the participants went through the experimental blocks. All blocks were significant different from block 1. The effect accounted for a total of 2.07% of explained variance. As the participants when through the experimental phase, their error decreases indicating recalibration regardless of condition.

Table 2. Means and standard deviations for the main effect of block for the experimental blocks of experiment 1.

Experimental Block	Mean	SD
1	2.152	1.81
2	1.97	1.83
3	1.87**	1.59
4	1.91**	1.67
5	1.69***	1.42
6	1.78***	1.46

*p<0.05, **p<0.01, ***p<0.001

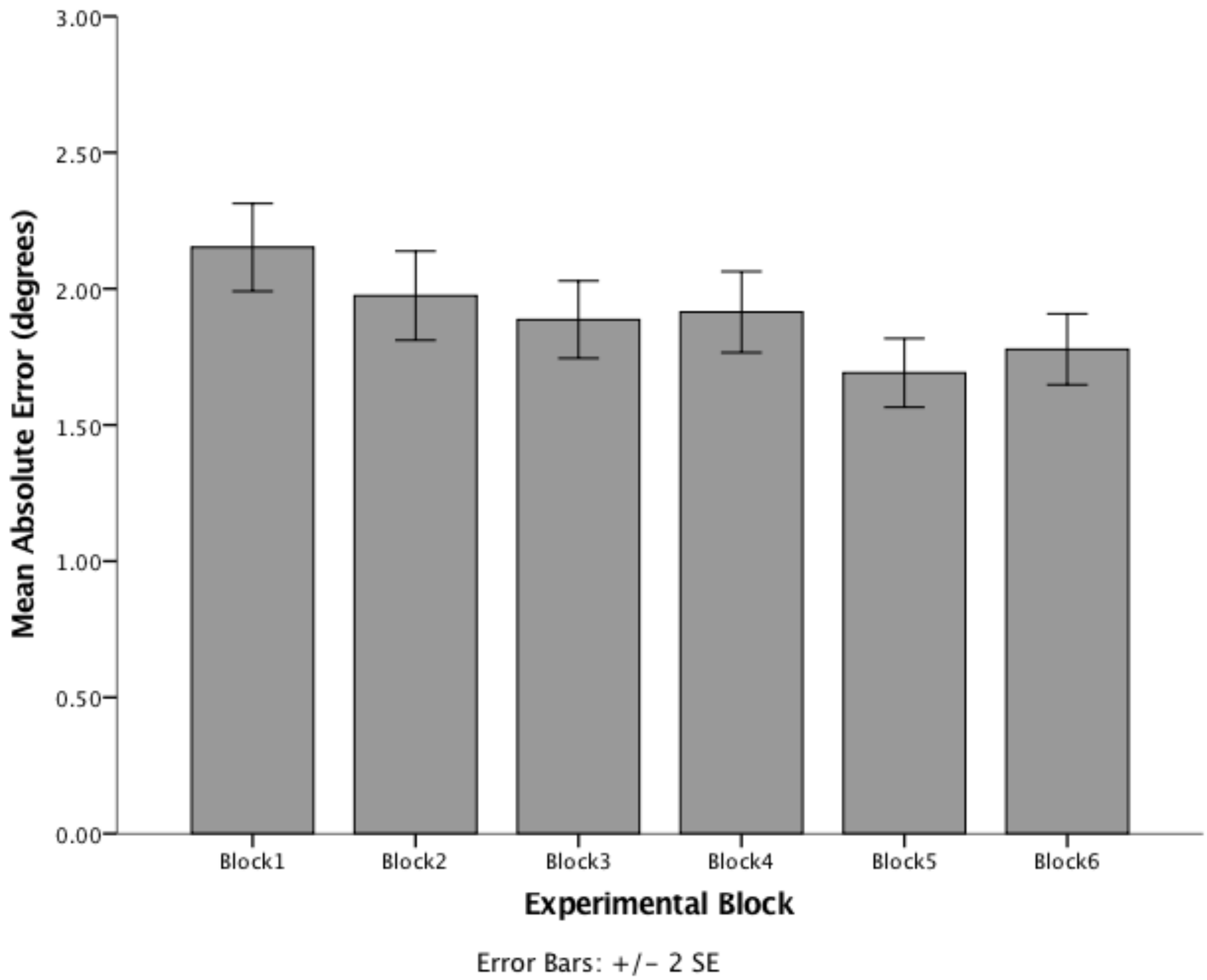


Figure 9. The main effect of block on absolute error (degrees) in experimental blocks for experiment 1. Block 1 was used as the reference group with blocks 3-6 being significantly different. As the participants when through the experimental phase, their error decreases indicating recalibration regardless of condition.

The directionality main effect showed that the amount of error depended on the direction of the estimation. Estimations that were under rotated had more error (M = 2.07 degrees, SD = 1.74) than over-rotation estimations (M = 1.53 degrees, SD = 1.74; see Figure 10). The effect account for a total of 1.35 % of explained variance.

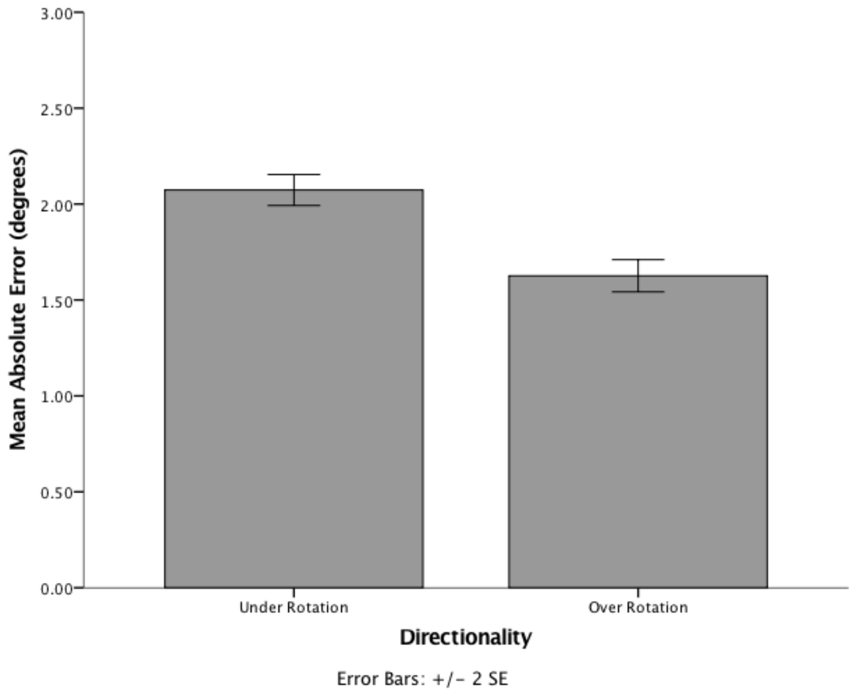


Figure 10. Graph of main effect of directionality on absolute error (degrees) in the experimental blocks of experiment 1. Amount of error depends on the direction of the rotation.

There were two Level 1 moderating Level 1 interactions that were significant: directionality moderating the effect of block on absolute error and directionality moderating the effect of target location on absolute error. To tease apart the interactions, the data file was split by file to determine the simple effects of block and location. For the interaction of directionality and block, only under-rotation estimations were significantly different in absolute error across the blocks (see Figure 11 and Table 3). In general, a pattern of decrease in absolute error can be seen across the blocks except for an influx of block 4. Blocks 3, 5, and 6 were significantly different from block 1. This effect demonstrates that across the blocks, the amount of error during over estimations did not significantly change whereas there was a significant reduction in error when participants under-rotated in blocks 3, 5, and 6 compared to block 1. The effect account for a total of 0.28 % of explained variance.

Table 3. Absolute Error means and standard deviations for block by directionality interaction for the experimental blocks of experiment 1. Only under-rotation means were significantly different.

Directionality	Experimental Block	Mean	SD
Under Rotation***	Block1	2.42	2.01
	Block2	2.18	1.95
	Block3**	2.05	1.70
	Block4	2.23	1.83
	Block5***	1.75	1.44
	Block6***	1.82	1.33
Over Rotation	Block1	1.75	1.36
	Block2	1.65	1.57
	Block3	1.62	1.36
	Block4*	1.44	1.26
	Block5	1.59	1.39
	Block6	1.71	1.66

*p<0.05, **p<0.01, ***p<0.001

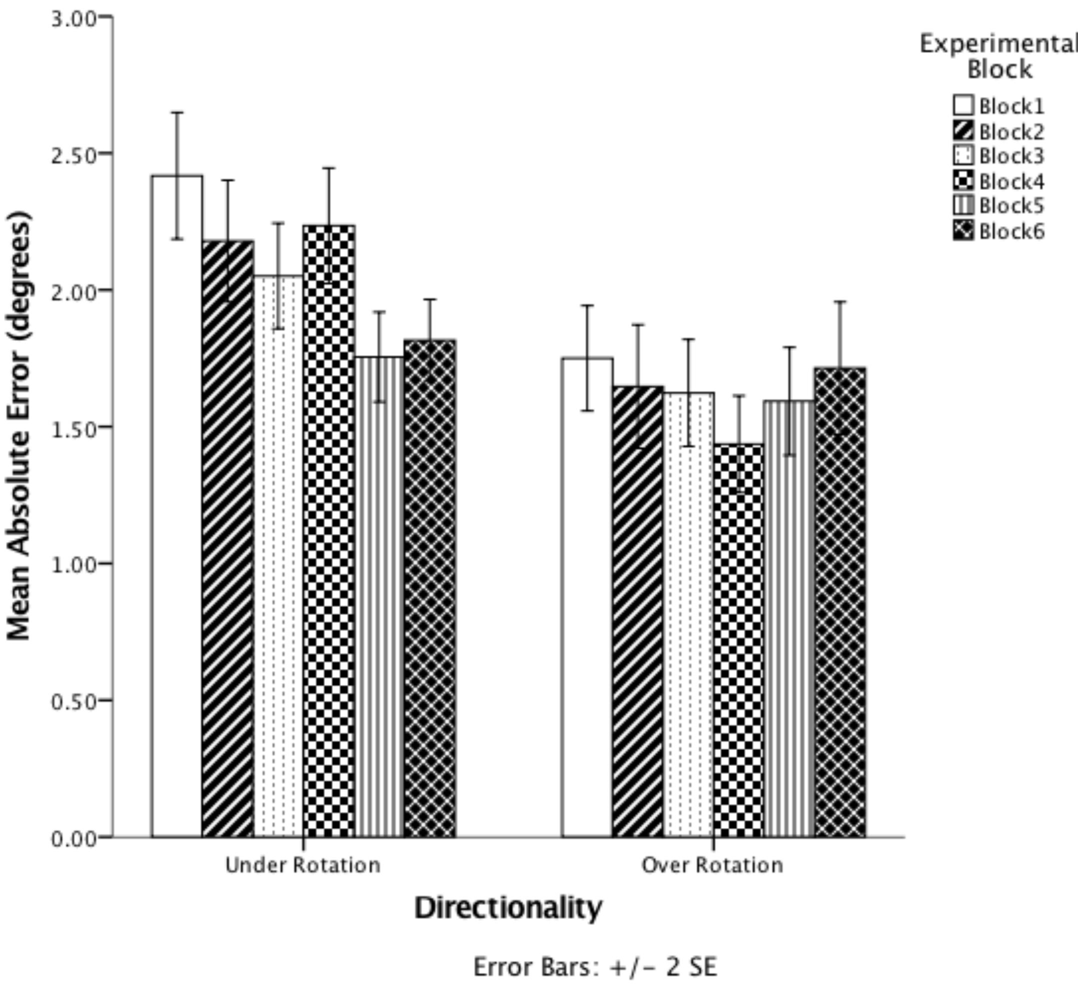


Figure 11. Interaction of block by directionality estimating absolute error (degrees) experimental blocks of experiment 1. The simple effect of block estimating absolute error is only significant when participants are under-rotating.

For the interaction of location, only over-rotation was significantly different in absolute error between frontal and peripheral location. The means and standard deviations of the interaction can be found in Table 4 with a visualization in Figure 12. For the peripheral targets (targets 1 and 4) participants had larger amounts of error (i.e., they over-rotated more than when they estimated peripheral targets. The effect account for a total of 0.20 % of explained variance.

Table 4. Absolute Error means and standard deviations for location by directionality interaction for the experimental blocks of experiment 1. Only over-rotation means were significantly different.

Directionality	Location			
	Frontal		Peripheral	
	Mean	SD	Mean	SD
Under Rotation	2.08	1.72	2.07	1.76
Over Rotation***	1.48	1.27	1.76	1.56

*p<0.05, **p<0.01, ***p<0.001

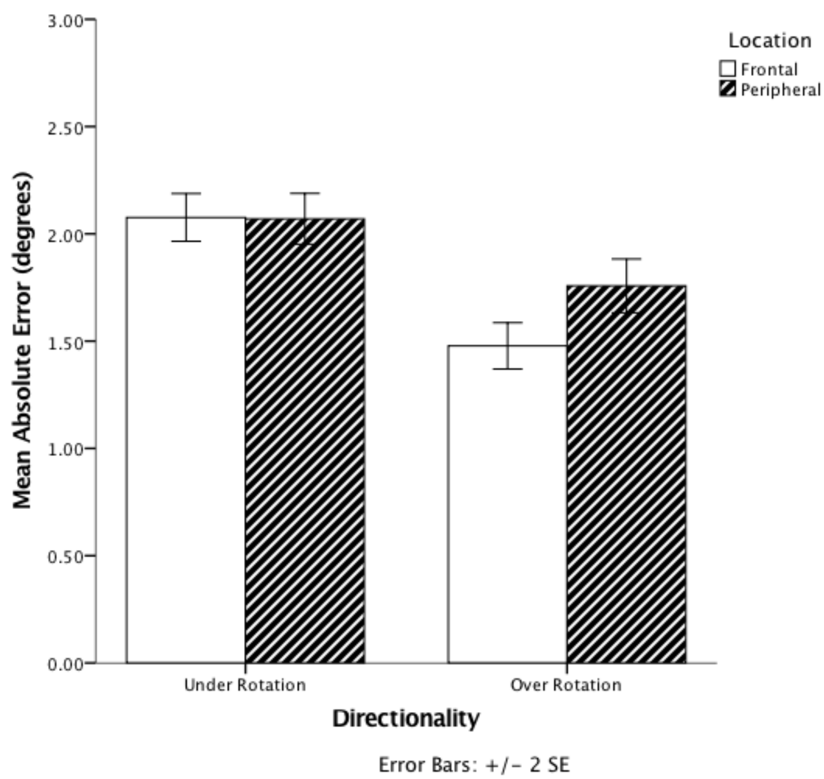


Figure 12. Effect of the directionality of the estimate on the absolute error mediated by the location of the target in experimental blocks in Experiment 1. Only over rotation is significantly different between the locations.

There was one significant three-way L1 interaction between action requirement, target location, and the trials within blocks accounting for 0.43 % of the variance. To investigate the

location of the difference, the data file was first split by directionality and the two-way interaction between action requirement and block trials was analyzed. Both under- and over-rotation had significant interactions in the model. The file was further split by action requirement to investigate the simple effect of block trial. In over-rotation, only cross-body had a significant effect for block trial while in under-rotation only open-body was significant. The figures for this three-way interaction can be seen in Figure 13. In the under-rotation graph, it can be seen that the amount of absolute error decreases in the open body condition while, the cross-body targets increased the amount of absolute error slightly but this slope was not significant. In the over-rotation graph, open-body has a very shallow non-significant slope while absolute error decreased for cross-body targets as the trials continued. The negative slopes for under-rotation by open-body targets and over rotation by cross-body targets indicates calibration effects in these interactions as the trials within the block increased.

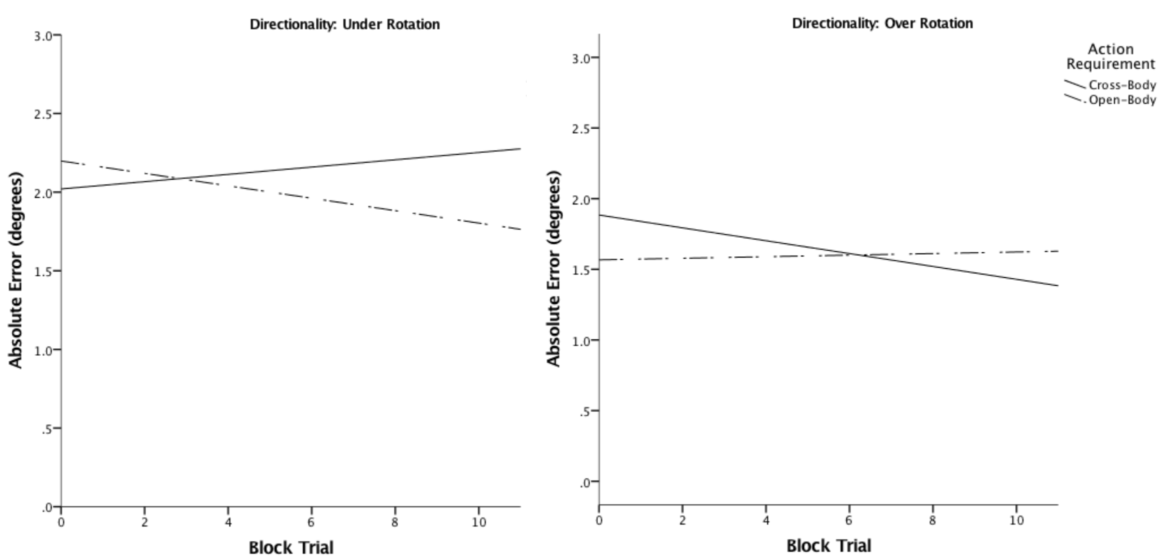


Figure 13. Three-way interaction of directionality, action requirement, and block trial predicting absolute error in the experimental blocks of Experiment 1. In under-rotation only open-body has a significant block trial simple slope. In over-rotation, only cross-body has a significant block trial simple slope. Note that the first trial in a block is considered trial 0 in the analysis and graph.

Lastly, there were two significant cross-level four-way interactions. This first was an interaction between condition, action requirement, block, and block trial which explained 0.31% of the total explained variance This interaction was further explored by splitting the file to find the simple effects of the lower-order interactions and simple slopes. The first comparison was the three-way interaction of condition, block, and block trial by action requirement. In this analysis only the interaction in the cross-body targets were significant. The two-way interaction of condition and block trial were then investigation by splitting by action requirement and block. The examination of the cross-body by block interactions of condition and block trial was only significant for blocks 2 and 6. The last decomposition of the interaction was to split the file by action requirement, block, and condition and investing the simple slopes of block trial within cross-body targets in blocks 2 (the first block of gain in both the constant and random increase conditions) and 6 (the last block of the experimental blocks). In block 2, both the control and constant conditions had a significant negative slope, while random increase showed a non-significant positive slope (see Figure 14). In block 6, only the random increase condition had a significant negative slope (see Figure 15).

The negative slopes indicate calibration across the trial while non-significant slopes indicate a lack of calibration either due to inability to calibrate or pre-perturbed levels of accuracy. Examining these two blocks together provides evidence for the first hypothesis. There is more variability for the random increase non-significant slope condition in block 2 compared to the control and constant non-significant slopes in block 6. Therefore, the lack of calibration in block 2 for the random increase slope can be attributed to an inability to calibrate while the lack

of variability for the control and constant condition in block 6 which can be attributed to calibration occurring in earlier blocks and being at pre-perturbed levels.

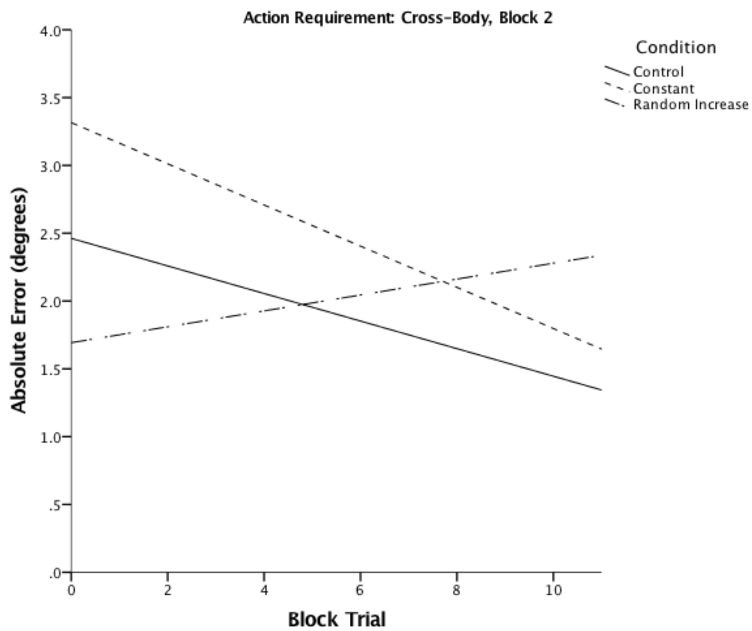


Figure 14. Block 2 of the four-way interaction of action requirement, block, condition, and block trial predicting absolute error in the experimental blocks of Experiment 1. This is the significant interaction for cross-body targets in Block 2. Both the control and constant conditions have significant simple slopes of block trials. Note that the first trial in a block is considered trial 0 in the analysis and graph.

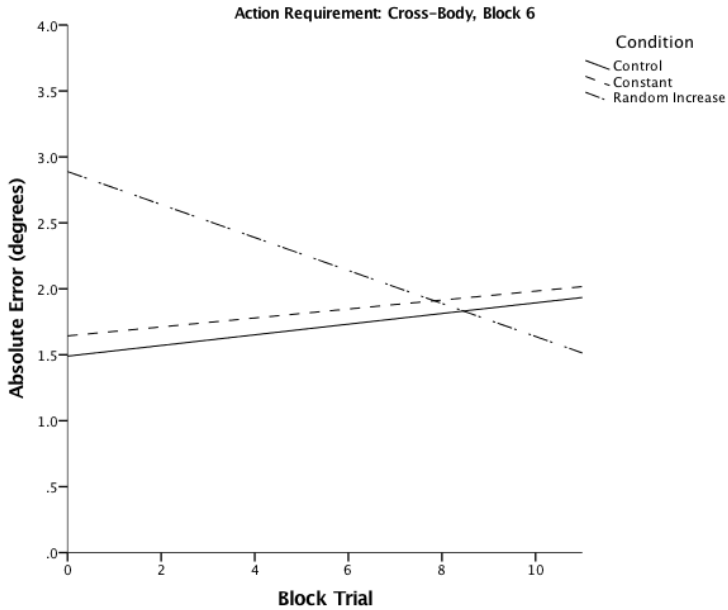


Figure 15. Block 6 of the four-way interaction of action requirement, block, condition, and block trial predicting absolute error in the experimental blocks of Experiment 1. This is the significant interaction for cross-body targets in Block 6. Only the random increase condition had a significant slope. Note that the first trial in a block is considered trial 0 in the analysis and graph.

The second four-way interaction is between condition, block, target location, and action requirement. To investigate the three-way interaction of condition, target location, and action requirement were analyzed by block. The only block that was significant was the first block. Next the two-way interaction of target location and action requirement were analyzed within the first block by condition. Only the constant condition was significant. Finally, the simple effect of action requirement was analyzed in the constant condition's first block by location. Action requirement was only significant within the peripheral targets (see Figure 16). In Figure 16, it can be seen that the constant condition has more absolute error for cross-body peripheral targets (i.e., target 1; M= 2.76, SD= 1.89) than for open-body peripheral targets (i.e., target 4; M=1.52, SD= 1.56). This interaction explained 0.30% of the variance.

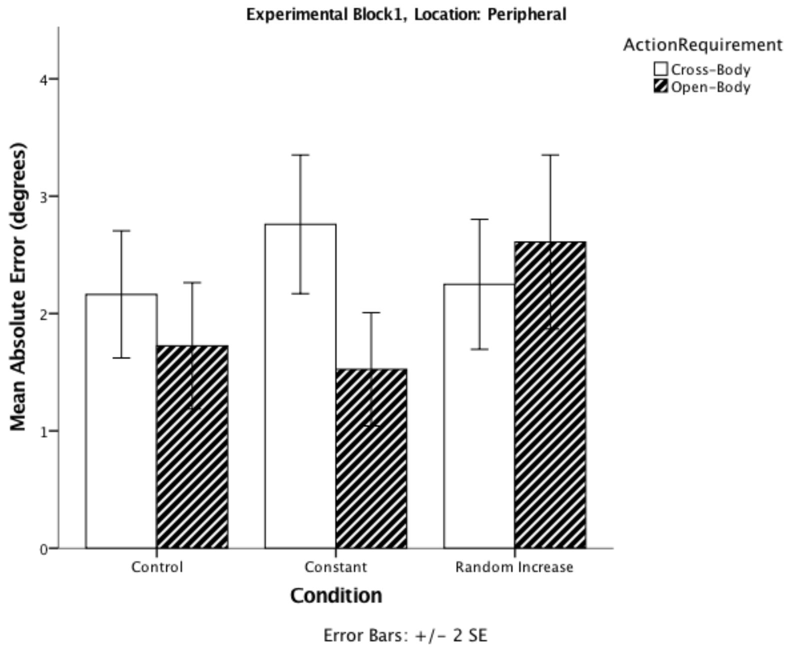


Figure 16. Significant four-way interaction of block, condition, location, and action requirement predicting absolute error in the experimental blocks of Experiment 1. The decomposition of the interaction found the significant was in the first experimental block, in the constant condition, for the peripheral targets.

5.3.1.2. Absolute Error Secondary Analysis in Experimental Blocks of Experiment 1.

In this model, secondary variables and specific interactions were included in the model in order to determine their effects on absolute error while controlling for the primary variables. Level 1 secondary variables include: total head rotation, max head rotation, rotational difference (difference between head rotation and arm rotation), SSQ. Level 2 secondary variables are the MSAQ-Pre and the MSAQ-Post. Due to the high correlation between max head rotation and total head rotation, these two variables were analyzed in their perspective models without the inclusion of the other. This was to guard against any suppression that may occur with both variables in the model simultaneously. Since primary models and interactions have been discussed previous, only the significant new effects will be discussed. The F-Test results from

the hierarchical linear modeling for accuracy as the outcome including secondary variables can be seen in Table 5. Only main effect and significant interactions have coefficients included in the table. For a full table of all coefficients please refer to Appendix E.

Table 5. Fixed Coefficients, Standard Errors and $R^2\Delta$ for Absolute Error for the secondary variables in the experimental blocks of experiment 1.

Fixed Effects						
				ΔR^2		
Predictor	Coefficient (SE)	F-Test	P-value	L1	L2	Cross-Level Interaction
Intercept	1.66 (0.19)	--	--	--	--	--
Block		3.98	<0.001	.0043	--	--
Block trial	-0.02 (0.01)	2.26	0.14	--	--	--
Location		0.87	0.35	--	--	--
Action Requirement		3.17	0.08	--	--	--
Directionality		12.64	0.00	.0115	--	--
Total Rotation	0.003 (0.002)	2.60	0.11	--	--	--
Max Rotation	-0.01 (0.01)	0.88	0.35	--	--	--
Rotational Difference	0.003 (0.01)	0.11	0.74	--	--	--
SampEn-X	-4.41 (1.84)	5.71	0.02	.0018	--	--
SampEn-Y	0.06 (2.84)	0.00	0.99	--	--	--
SSQ	0.002 (0.02	0.02	0.90	--	--	--
MSAQ Pre		2.79	0.10	--	--	--
MSAQ Post		0.78	0.38	--	--	--
Condition		1.33	0.28	--	--	--
Block * SSQ		3.02	0.01	.0036	--	--
Block * Total Rotation		0.66	0.65	--	--	--
Block * Max Rotation		0.49	0.79	--	--	--
Block * Rotational Difference		4.56	<0.001	.0060	--	--
Condition * SSQ		0.14	0.87	--	--	--
Condition * Total Rotation		0.28	0.76	--	--	--
Condition * Max Rotation		0.32	0.72	--	--	--
Condition * Rotational Difference		0.59	0.55	--	--	--
Block * Condition		1.64	0.09	--	--	--
Block * Condition * SSQ		0.63	0.79	--	--	--
Block * Condition * Total Rotation		0.99	0.45	--	--	--
Block * Condition * Max Rotation		1.28	0.24	--	--	--
Block*Condition * Rotational Difference		1.02	0.36	--	--	--
			TotalΔR^2	.0272	--	--

The only significant secondary variable main effect is SampEn-X. This effect is the measurement of mediolateral sway and accounts for 0.18% of the total explained variance. As depicted in Figure 17, in general (i.e., averaged across blocks and conditions), as SampEn-X increases by 0.1 (i.e., as postural sway increases), absolute error decreases by 0.44 degrees. This

is an interesting result as the opposite effect was expected. Specifically, it was expected that the more postural sway the less accurate the estimates would become.

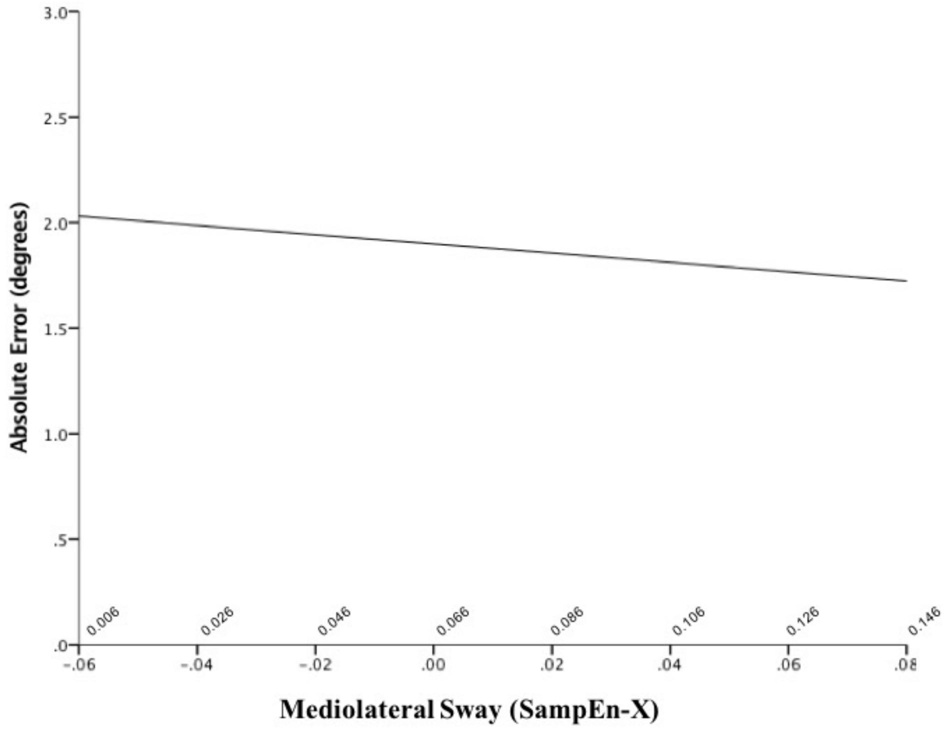


Figure 17. Main effect of mediolateral sway (SampEn-X) predicting absolute error in the experimental blocks of experiment 1. The x-axis scale is the grand mean center version of the SampEn-X variable with the translated actual values located above.

There were two Level 1 moderating Level 1 interactions that were significant: block moderating SSQ scores and block moderating rotational difference between head rotation and estimation rotation. As shown in Figure 18, the slope of SSQ estimating absolute error depends on the block. In blocks 2, 3, and 6, had positive slopes indicating that higher SSQ scores created greater absolute error. Blocks 1,4, and 5 had negative slopes. None of the simple slopes were significant. This accounted for 0.36% of the explained variance.

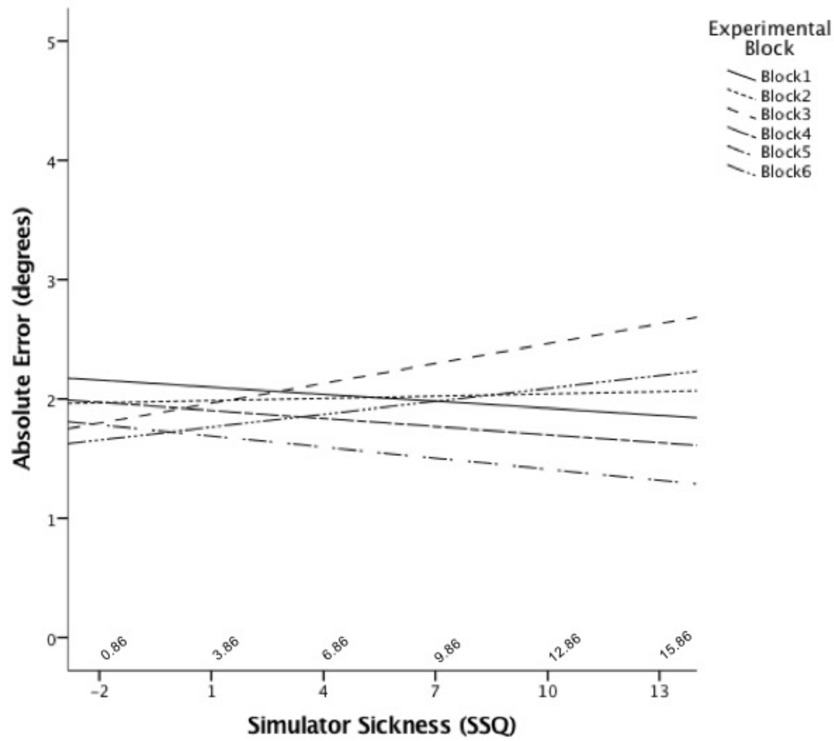


Figure 18. Interaction of block and simulator sickness (SSQ) predicting absolute error (degrees) in the experimental blocks of experiment 1. The x-axis is the grand mean center SSQ variable, with the translated actual values located above. Note that SSQ scores were whole numbers and the translated values in the figure are based on the mean of the variable and values depicted.

The second significant two-way interaction was block moderating the effect of rotational difference on absolute error. This effect accounted for 0.6 % of the variance. Figure 19 shows that the effect of rotational differences depended on the block. Block 1 has the greatest influence on the relationship between rotational difference and absolute error. In this block, as rotational difference increases absolute error decrease. Essentially, after the initial block with visual feedback, rotational differences did not have as much of an effect on accuracy. The simple slopes for rotational difference by block were not significantly different from zero.

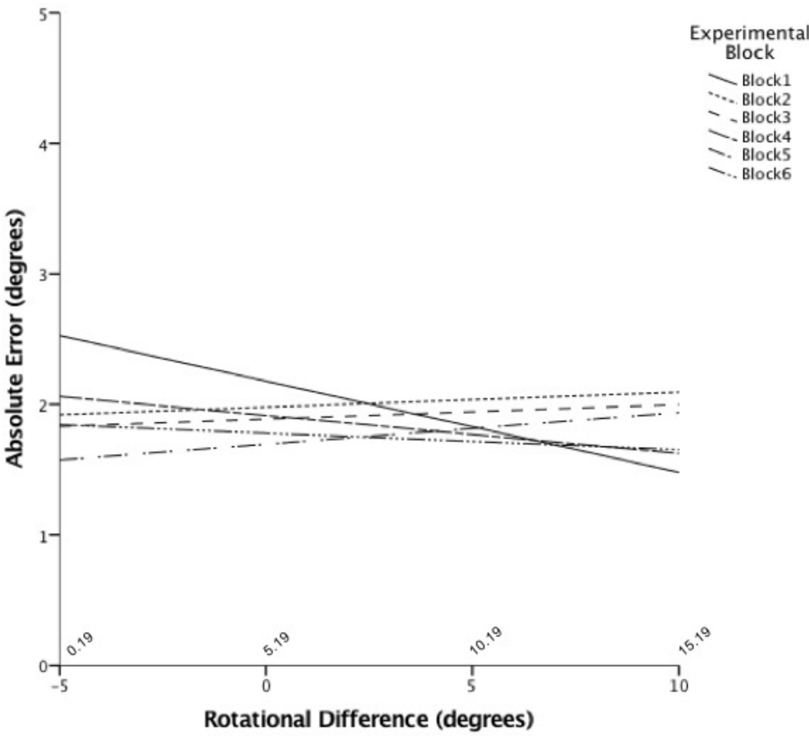


Figure 19. Interaction of block and rotational difference (degrees) predicting absolute error (degrees) in the experimental blocks of experiment 1. The x-axis is the grand mean center variable of rotational difference, with the translated actual values located above.

5.3.2. Pre-/ Post-test Analyses for Absolute Error in Experiment 1

The only change from the experimental block analysis is that in the secondary analysis MSAQ-pre and –post is grouped into a single variable for the pre-/post analysis creating a level 2 variable.

5.3.2.1. Absolute Error Primary Analysis in Pre-/ Post-test blocks of Experiment1

The F-Test results from the hierarchical linear modeling for accuracy as the outcome can be seen in Table 6. Due to the size of the complete coefficient table, only the main effects' and

significant interactions' coefficients and standard errors are included in the table. Please see Appendix F for the comprehensive coefficient table.

Table 6. Fixed Coefficients, Standard Errors and $R^2\Delta$ for Absolute Error in the Pre-/ Post Blocks of Experiment 1.

Fixed Effects						
				ΔR^2		
Predictor	Coefficient (SE)	F-Test	P-value	L1	L2	Cross-Level Interaction
Intercept	1.90 (0.34)	--	--	--	--	--
Block	--	15.08	<0.001	.0136	--	--
Block Trial (Btrial)	0.11 (0.03)	17.97	<0.001	.0238	--	--
Location (Loc)	--	4.50	0.034	.0466	--	--
Action Requirement (AR)	--	3.68	0.062	--	--	--
Directionality (Dir)	--	0.92	0.344	--	--	--
Condition (Cond)	--	1.22	0.305	--	--	--
Block * Btrial	--	0.04	0.834	--	--	--
Block * Loc	--	0.06	0.806	--	--	--
Block * AR	--	0.14	0.707	--	--	--
Block * Dir	--	8.71	0.003	.0033	--	--
Loc * Btrial	--	0.40	0.525	--	--	--
AR * Btrial	--	3.02	0.083	--	--	--
Dir * Btrial	--	1.16	0.283	--	--	--
Loc * AR	--	0.94	0.332	--	--	--
Dir * AR	--	5.33	0.021	.0079	--	--
Loc * Dir	--	3.46	0.063	--	--	--
Block * Cond	--	6.88	<0.001	--	--	.0080
Cond * Btrial	--	0.09	0.913	--	--	--
Cond * Loc	--	0.45	0.640	--	--	--
Cond * AR	--	1.39	0.262	--	--	--
Cond * Dir	--	0.50	0.611	--	--	--
Block * Loc * Btrial	--	4.68	0.031	.0028	--	--
Block * AR * Btrial	--	4.71	0.030	.0017	--	--
Block * Dir * Btrial	--	0.86	0.354	--	--	--
Block * Loc * AR	--	1.44	0.231	--	--	--
Block * Loc * Dir	--	2.65	0.104	--	--	--
Block * Dir * AR	--	1.00	0.317	--	--	--
Loc * AR * Btrial	--	<0.001	0.998	--	--	--
Loc * Dir * Btrial	--	1.94	0.164	--	--	--
Dir * AR * Btrial	--	18.86	<0.001	.0133	--	--
Loc * Dir * AR	--	1.26	0.263	--	--	--
Loc * AR * Btrial	--	0.14	0.873	--	--	--
Block * Cond * Btrial	--	2.43	0.089	--	--	--
Block * Cond * Loc	--	0.49	0.611	--	--	--
Block * Cond * AR	--	3.13	0.044	--	--	.0018
Block * Cond * Dir	--	1.19	0.306	--	--	--
Cond * Loc * Btrial	--	1.11	0.329	--	--	--

Cond * AR * Btrial	--	0.94	0.390	--	--	--
Cond * Dir * Btrial	--	0.41	0.747	--	--	--
Cond * Loc * AR	--	0.43	0.650	--	--	--
Cond * Loc * Dir	--	0.02	0.982	--	--	--
Cond * Dir * AR	--	0.43	0.650	--	--	--
Block * Loc * Dir * AR	--	0.81	0.370	--	--	--
Loc * Dir * AR * Btrial	--	0.47	0.493	--	--	--
Block * Loc * AR * Btrial	--	1.19	0.276	--	--	--
Block * Loc * Dir * Btrial	--	<0.001	0.990	--	--	--
Block * Cond * Loc * Btrial	--	0.82	0.441	--	--	--
Block * Cond * AR * Btrial	--	0.20	0.820	--	--	--
Block * Cond * Dir * Btrial	--	1.94	0.144	--	--	--
Block * Cond * Loc * AR	--	1.90	0.151	--	--	--
Block * Cond * Loc * Dir	--	0.14	0.866	--	--	--
Block * Cond * Dir * AR	--	3.83	0.022	--	--	.0046
Cond * Loc * AR * Btrial	--	0.41	0.667	--	--	--
Cond * Loc * Dir * Btrial	--	0.41	0.665	--	--	--
Cond * Dir * AR * Btrial	--	0.84	0.431	--	--	--
Cond * Loc * Dir * AR	--	0.68	0.506	--	--	--
Block * Loc * Dir * AR * Btrial	--	0.19	0.666	--	--	--
Block * Cond * Loc * Dir * AR	--	0.06	0.940	--	--	--
Cond * Loc * Dir * AR * Btrial	--	2.96	0.052	--	--	--
Block * Cond * Loc * AR * Btrial	--	0.33	0.719	--	--	--
Block * Cond * Loc * Dir * Btrial	--	0.71	0.490	--	--	--
Block * Cond * Dir * AR * Btrial	--	1.69	0.186	--	--	--
Block * Cond * Loc * Dir * AR * Btrial	--	0.84	0.431	--	--	--
			TotalΔR^2	.1130		.0144

There were three significant main effects: block, block trial, and target Loc. For the main effect of block, the pre-test block had more absolute error (M = 3.24, SD = 2.68) than the post-test block (M = 2.78, SD = 2.25). This effect account for a total of 1.36% of explained variance. The block trials main effect can be seen in Figure 20. As participants go through the trials within the pre- and post-test block on average they are increasing their absolute error amount by 0.11 degrees per block. This indicates that without visual feedback, calibration is not occurring within these blocks on average. This effect account for a total of 2.38% of explained variance. Lastly, target location had a significant main effect with a total of 4.66%. There were greater amounts of absolute error in the peripheral target (i.e., targets 1 and 4) estimates (M = 3.17, SD= 2.63) than the frontal target (i.e. targets 2 and 3) estimates (M=2.85, SD = 2.32).

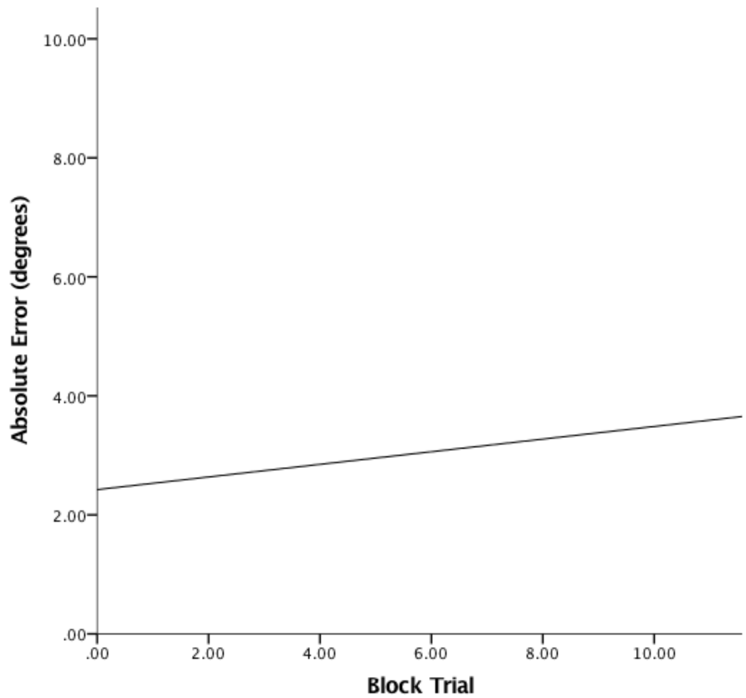


Figure 20. Main effect of block trial on absolute error (degrees) for the pre-/ post-test blocks in Experiment 1. Note that the first trial in a block is considered trial 0 in the analysis and graph.

There were two Level 1 moderating Level 1 interactions that were significant: directionality moderating the effect of block on absolute error and directionality moderating the effect of action requirement on absolute error. To tease apart the interactions, the data file was split by file to determine the simple effects of block and action requirement. When split by directionality only the simple effects of block predicting absolute error in the over rotation were significant. Participants, on average, had less absolute error in the post-test (M= 2.25, SD = 1.98) than in the pre-test (M= 3.22, SD = 2.77) if they over-rotated their estimate. This effect accounts for 0.33 % of the variance. The simple effect of action requirement was only significant in the under rotation estimates. Participants had higher levels of absolute error for cross-body targets (i.e., targets 1 and 2; M= 3.57, SD= 2.69) than for open-body targets (targets 3 and 4; M= 2.61, SD=1.99) if their estimate was under rotated. This effect explained 0.79 % of the variance.

The only cross-level two-way interaction was block by condition which accounted for 0.8% of the variance. When split by condition only the control and random increasing conditions were significant. Both of these conditions significantly improved with the control condition improving the most and constant improving the least (see Figure 21 a). This interaction can also be viewed changing the x-axis to block to see the pattern of the conditions between the blocks (see Figure 21 b). What is most interesting in the post-phase is the increasing amounts of error as the complexity of the condition increased. This supports hypothesis 2.

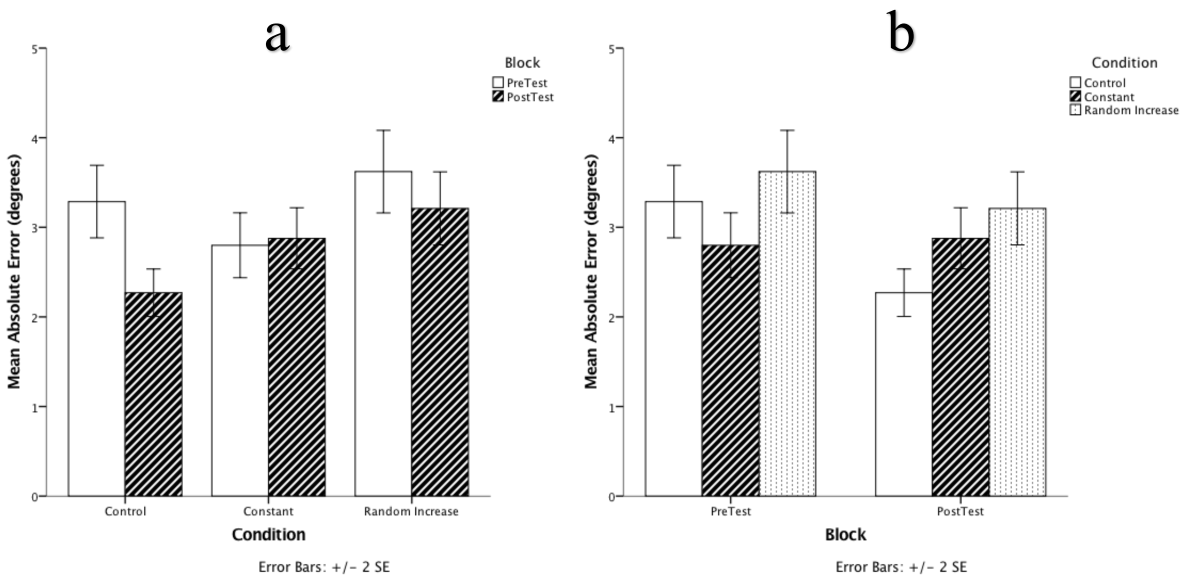


Figure 21. Interaction between condition and block for Pre-/ Post-test in Experiment 1. A) relationship with block moderating condition and b) relationship with condition moderating block.

There were three three-way significant level 1 interactions. The first was block by block trial by target location and accounted for 0.28% in explained variance. To investigate this interaction further, the two-way interaction of block and block trial by location which revealed that there was only a significant interact for frontal targets (i.e., targets 2 and 3). This was further decomposed by looking at the simple slope effects of block trial by block for only the frontal targets. There was only a significant effect in the pre-test meaning that the simple slope was

significantly different than zero. This three-way interact can be seen in Figure 22. As block trials increased in the pre-test for the frontal targets, the amount of error increases by 0.15 per trial.

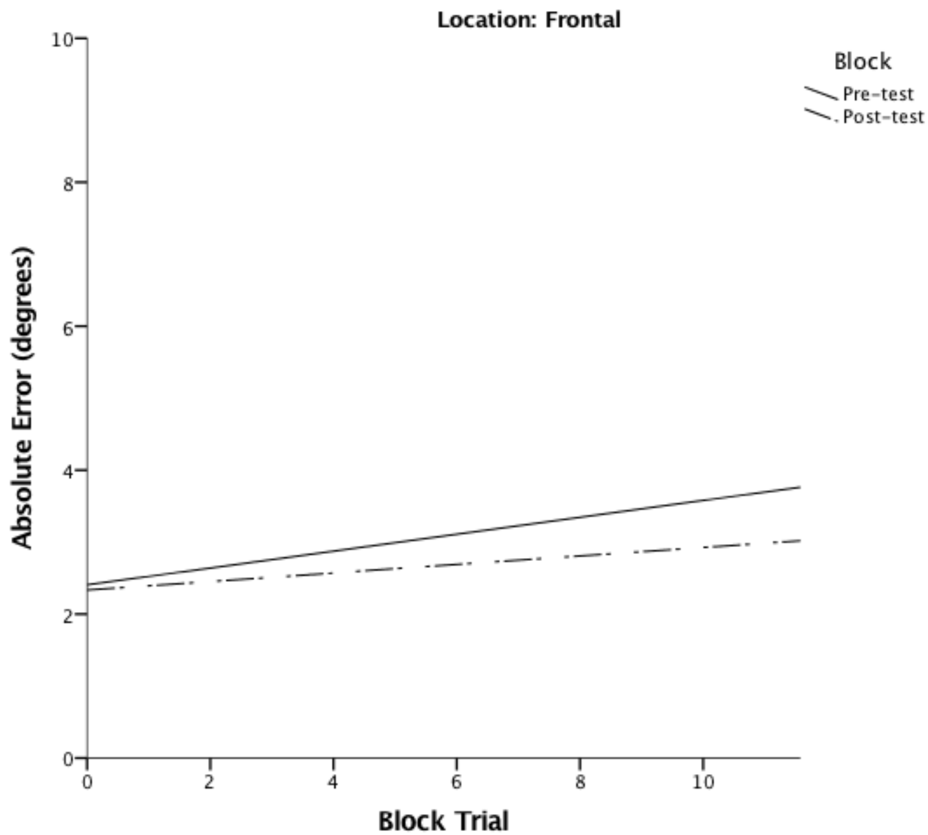


Figure 22. Three-way interaction of block trial by block by target location in pre-/ post-test analyses in Experiment 1. Upon investigating the simple effects of the interaction, it was determined that the pre-test had a significant block trial slope for frontal targets. Note that the first trial in a block is considered trial 0 in the analysis and graph.

The second significant L1 three-way interaction was block by block trial by action requirement and account for 0.17% of the explained variance. Following the same method as described above, the interaction was slowly teased apart. When split by block only post was significant. Split by action requirement and inspecting the effect of block trial on absolute error determined that only cross-body targets had a block trial significant effect in the post-test block. This interaction can be seen in Figure 23. For cross-body targets, in the post-test phase, absolute

error increased by 0.17 (i.e. the simple slope) amount per increase in trial. In essence, as the participant when through the blocks, the estimation errors for cross-body targets also increased.

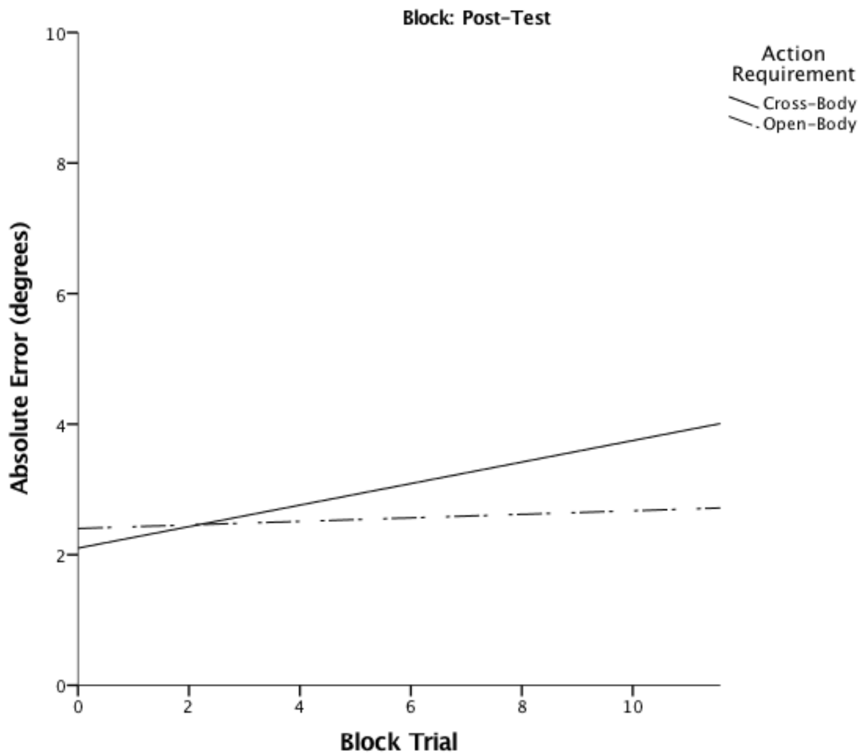


Figure 23. Three-way interaction of block trial by block by action requirements in pre-/ post-test analyses in Experiment 1. Upon investigating the simple effects of the interaction, it was determined that the post-test had a significant block trial slope for cross body targets. Note that the first trial in a block is considered trial 0 in the analysis and graph.

The last level 1 significant three-way interaction was block trial by action requirement by direction. This interaction was investigated by examining the two-way interaction of action requirement and block trial by direction. Both over- and under- rotation had significant two-way interactions. This was then split again by action requirement to determine if the simple slopes were significant. Cross-body targets had a significant slope of block trial for estimations that were under-rotated while open-body targets had a significant slope of over rotation across block trials. These effects can be seen in Figure 24. In essence, for cross body targets, as the participant

went through the trials within the blocks, the amount of error increased (i.e., they under rotated more) as the trials within a block continued. However, for open-body targets. participants began over-rotating their estimates more as the trials continued. This account for 1.3% of the explained variance.

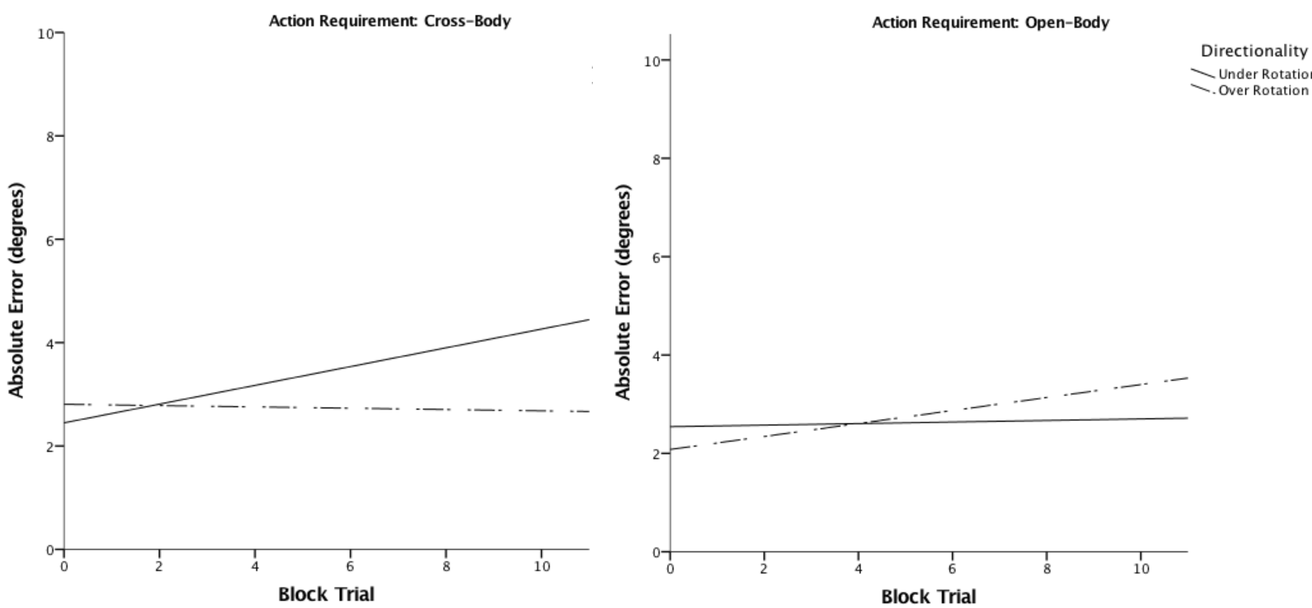


Figure 24. Three-way interaction of block trial by action requirement by directionality in pre-/ post-test analyses in Experiment 1. Upon investigating the simple effects of the interaction, it was determined targets requiring a cross-body movement increased in absolute error for under-rotated estimates as participants continued through the blocks. For open-body movement, absolute error increased for over-rotated estimates as the trials continued. Note that the first trial in a block is considered trial 0 in the analysis and graph.

There was one significant three-way cross-level interaction between condition, block, and action requirement. To investigate the cause of this interaction, simple effects were examined. First the two-way interaction of block by condition was analyzed by action requirement. Only cross-body actions requirement in a significant two-way interaction. Next, the simple effects of

the block were analyzed by condition for cross-body targets. There were two significant simple effects of block in the control condition (pre: M = 3.53, SD = 2.51; post M = 2.36, SD =1.78) and the random increase condition (pre: M = 4.40, SD = 2.57; post M = 2.58, SD =2.81; see Figure 25). Both of these conditions significantly decreased the absolute error for cross body targets in the post-test. This effect accounts for 0.18% of the explained variance.

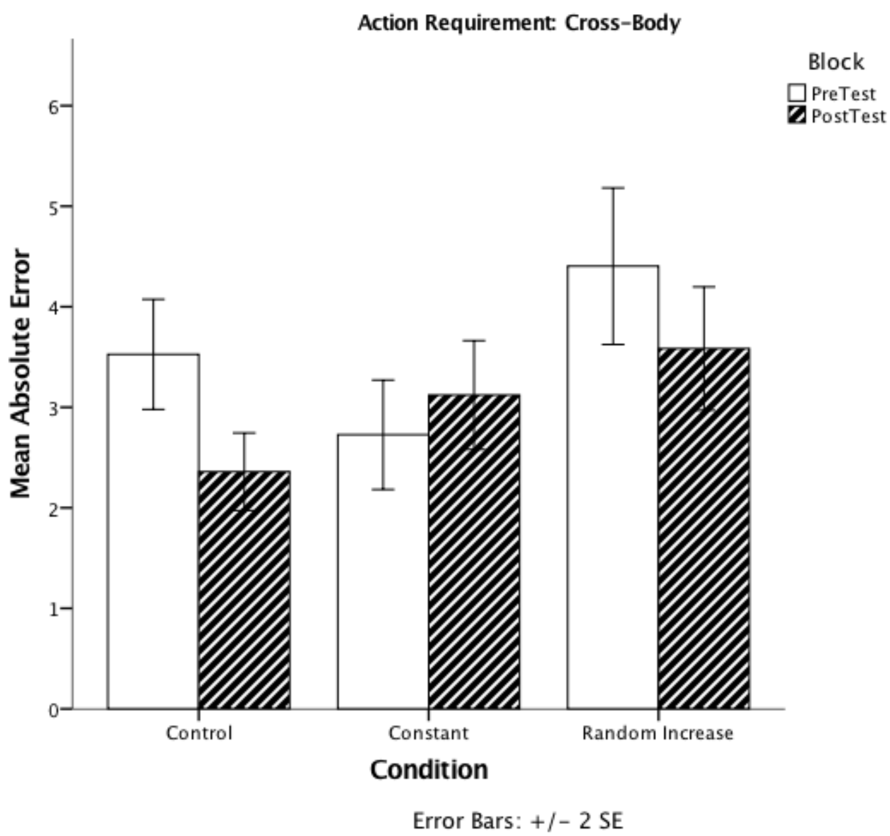


Figure 25. Three-way interaction of block by action requirement by condition in pre-/ post-test analyses in Experiment 1. The pre- and post- absolute error means for the control and random increase condition were significantly different for cross-body targets. Both decreased significantly in the post-test. Constant condition was not significant.

Lastly, there was one significant four-way cross-level interaction between condition, block, action requirement and directionality accounting for 0.46% of the explained variance in the model. After decomposing this interaction as previously discussed it was determined that the simple effect of condition was located in the post-test for open-body targets with under-rotated estimation (see Figure 26). The random increase condition had a significantly greater amount of error when they under-rotated their estimate for open-body targets (M= 3.41, SD= 2.59) than the control group (M=1.83, SD= 1.26) and constant (M=2.87, SD= 1.91).

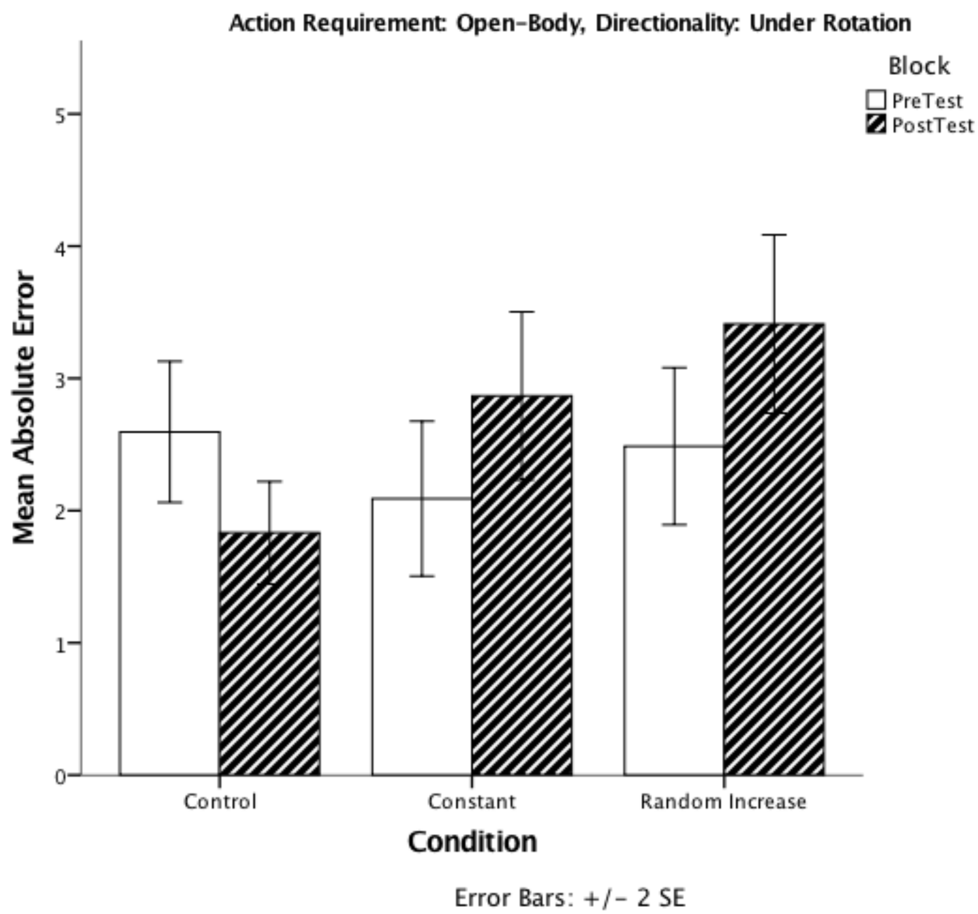


Figure 26. Three-way interaction of block by action requirement by directionality by condition in pre-/ post-test analyses in Experiment 1.

This finding supports that calibration did occur for the control condition, however both the constant and random increase conditions had larger amounts of error when under-rotating their open-body estimates. This effect can be explained due to the interactions in the experimental block where both these conditions did not have to rotate as far as the control conditions causing their estimates to have greater error in the carryover effect of the post-test block. Additionally, as hypothesized, the random increase condition showed the most error and variability in these estimates. The control and random increase conditions had a significant difference between pre- and post-tests. The control condition significantly decreased the absolute error from pre- (M = 2.59, SD = 1.69) to post-test (M = 1.83, SD = 2.59) for open-body targets when they under-rotated (i.e., if they made an under rotated estimate, the total error was less during the post-phase). The random increase condition significantly increased the absolute error from pre (M = 2.49, SD = 1.83), to post-test (M = 3.41, SD = 2.59) for open-body targets when they under-rotated. This finding is evidence supporting hypothesis 2.

5.3.2.2. Absolute Error Secondary Analysis in Pre-/ Post-test blocks of Experiment 1

This is the same analyses as used for the experimental blocks. However, MSAQ was turned into a Level 1 variables as it varies between these two blocks. Again, due to the high correlation between max head rotation and total head rotation, these two variables were analyzed in their perspective models without the inclusion of the other. This was to guard against any suppression that may occur with both variables in the model simultaneously. Since primary models and interactions have been discussed previous, only the significant new effects will be discussed. The F-Test results from the hierarchical linear modeling for accuracy as the outcome including secondary variables can be seen in Table 7. Only continuous variables will have

coefficients and standard errors included in the model. For a full table of all coefficients please refer to Appendix G.

Table 7: Fixed Coefficients, Standard Errors and $R^2\Delta$ for Absolute Error for the Secondary Variables in pre-/ post-test analyses in Experiment 1.

Fixed Effects						
				ΔR^2		
Predictor	Coefficient (SE)	F-Test	P-value	L1	L2	Cross-Level Interaction
Intercept	2.25 (0.38)	--	--	--	--	--
Block		12.08	0.001	.0095	--	--
	0.09 (0.03)				--	--
Block trial (btrial)		13.16	0.001	.0169		
Location		2.33	0.127	--	--	--
Action Requirement		7.86	0.008	.0169	--	--
Directionality		10.05	0.002	.0213	--	--
Total Rotation	-0.01 (0.01)	1.75	0.186	--	--	--
Max Rotation	0.04 (0.02)	3.64	0.057	--	--	--
Rotation Difference	0.13 (0.02)	38.66	<0.001	.0393	--	--
SampEn-X	-6.24 (5.26)	1.41	0.236	--	--	--
SampEn-Y	-3.73 (6.21)	0.36	0.548	--	--	--
MSAQ		0.22	0.639	--	--	--
Condition		1.18	0.319	--	--	--
Block * Total Rotation		0.05	0.826	--	--	--
Block * Max Rotation		0.86	0.355	--	--	--
Block * Rotation Difference		17.57	<0.001	.0131	--	--
Condition * MSAQ		1.14	0.32	--	--	--
Condition * Total Rotation		0.45	0.636	--	--	--
Condition * Max Rotation		1.00	0.367	--	--	--
Condition * Rotation Difference		2.91	0.055	--	--	--
Block * Condition		6.04	0.002	--	--	.0073
Condition * Btrial		0.15	0.861	--	--	--
Block * Condition * Total Rotation		0.33	0.721	--	--	--
Block * Condition * Max Rotation		0.54	0.584	--	--	--
Block * Condition * Rotation Difference		4.45	0.012	--	--	.0047
			TotalΔR^2	.1170	--	.0120

The only significant secondary variable main effect was the rotational difference between the head rotation and the target estimation. This effect accounts for 3.93% of the total explained variance. As depicted in Figure 27, as the difference between the head rotation and estimation rotation increases by 1 degree, absolute error increases by 0.13 degrees. Meaning that more accurate estimations occur when there are smaller disparities between the angle of the head and the the angle of the estimating arm.

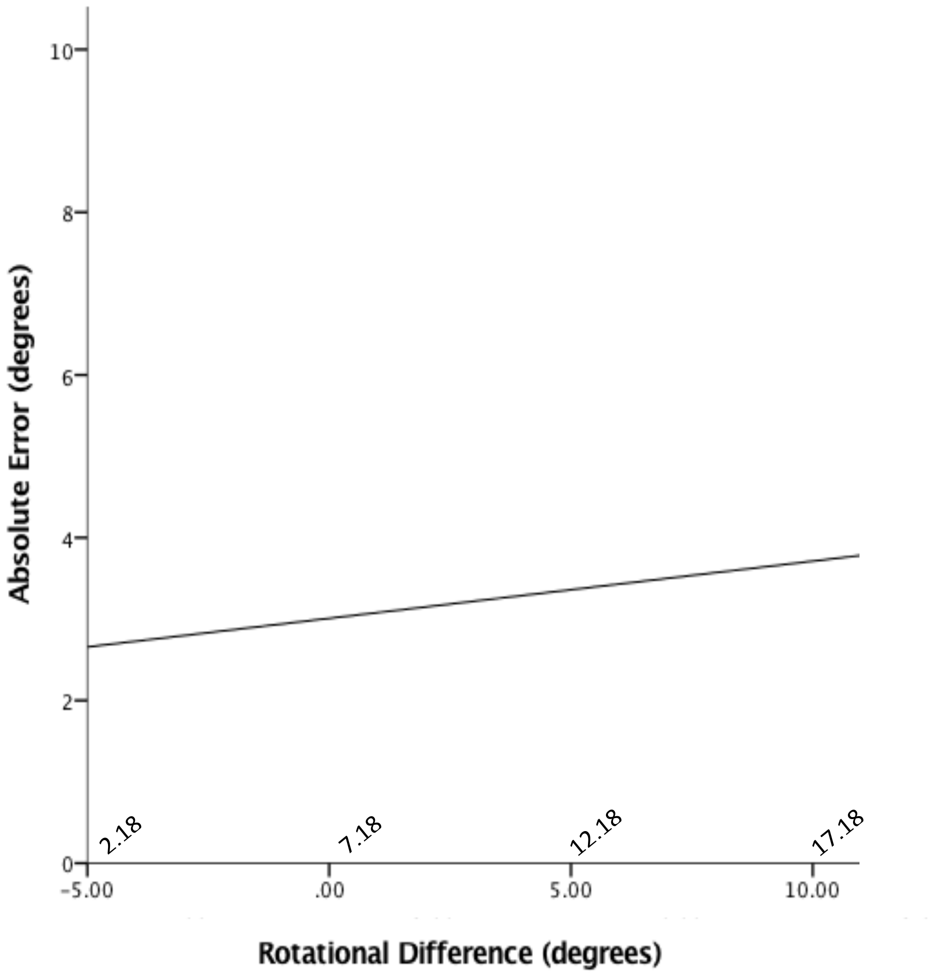


Figure 27. The main effect of rotational difference (degrees) between head rotation and estimating arm rotation on absolute error for pre-/ post-test analysis in Experiment 1. The x-axis scale is the grand mean center rotational difference variable with the translated actual values located above.

There was a significant two-way interaction between rotational differences and block. This interaction accounted for 1.31% in explained variance. Simple slopes were conducted to determine how the slopes vary between blocks. Only the pre-test block had a significant simple slope (see Figure 28). In this figure you can see that in the pre-test as the degree of rotational difference between the head angle and the estimation angle increases, the absolute error also increases by about 0.2 degrees. Essentially, in the pre- test, the difference between head degree

and estimation of the pointing arm greatly influenced the accuracy of the estimate. What is also noteworthy is this effect is not seen in the post-test block.

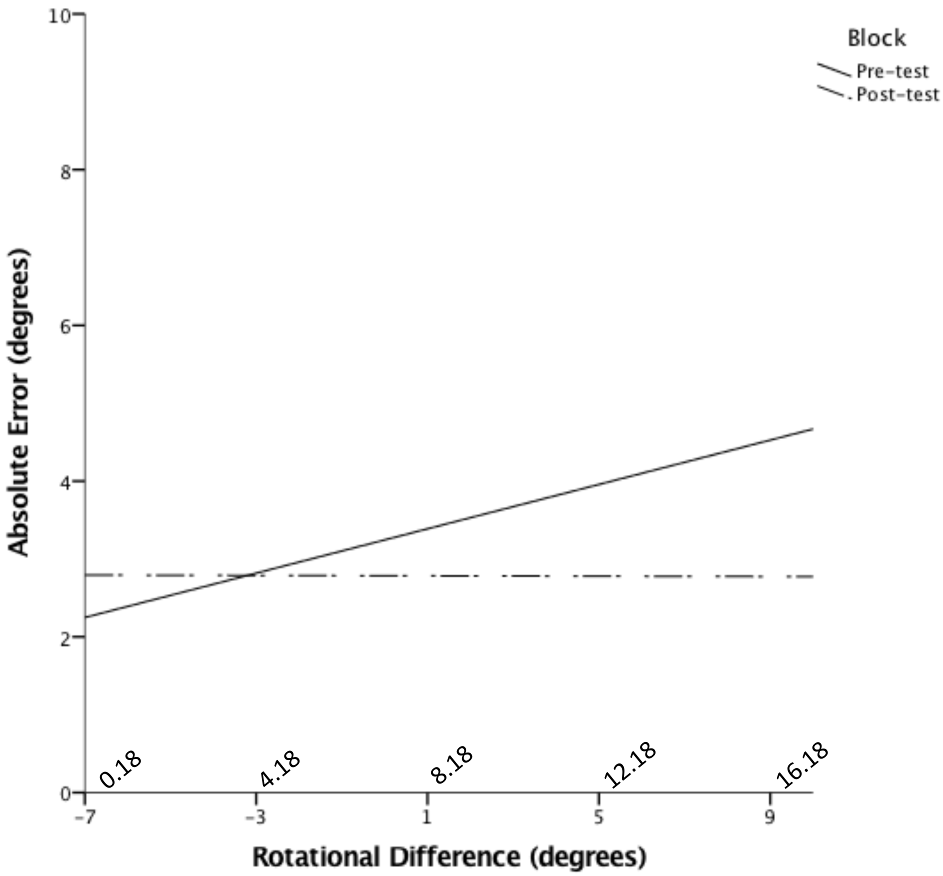


Figure 28. The interaction effect of block and the rotational difference between head rotation and estimating arm rotation on absolute error for pre-/ post-test analysis in Experiment 1. Only the pre-test slope was significant. The x-axis scale is the grand mean center rotational difference variable with the translated actual values located above.

Lastly, there was one significant three-way between block, condition, and rotational difference which accounted for 0.47% in explained variance. Investigating this interaction found the effect of rotational difference on absolute error is in the post-test phase in the control and random increase condition (see Figure 29). As the rotational difference increased, individuals in the control condition increased their estimation error by about 0.14 degrees for every rotational

difference increased. Those in the random increase condition decreased their absolute error by about 0.15 for every rotational difference increase.

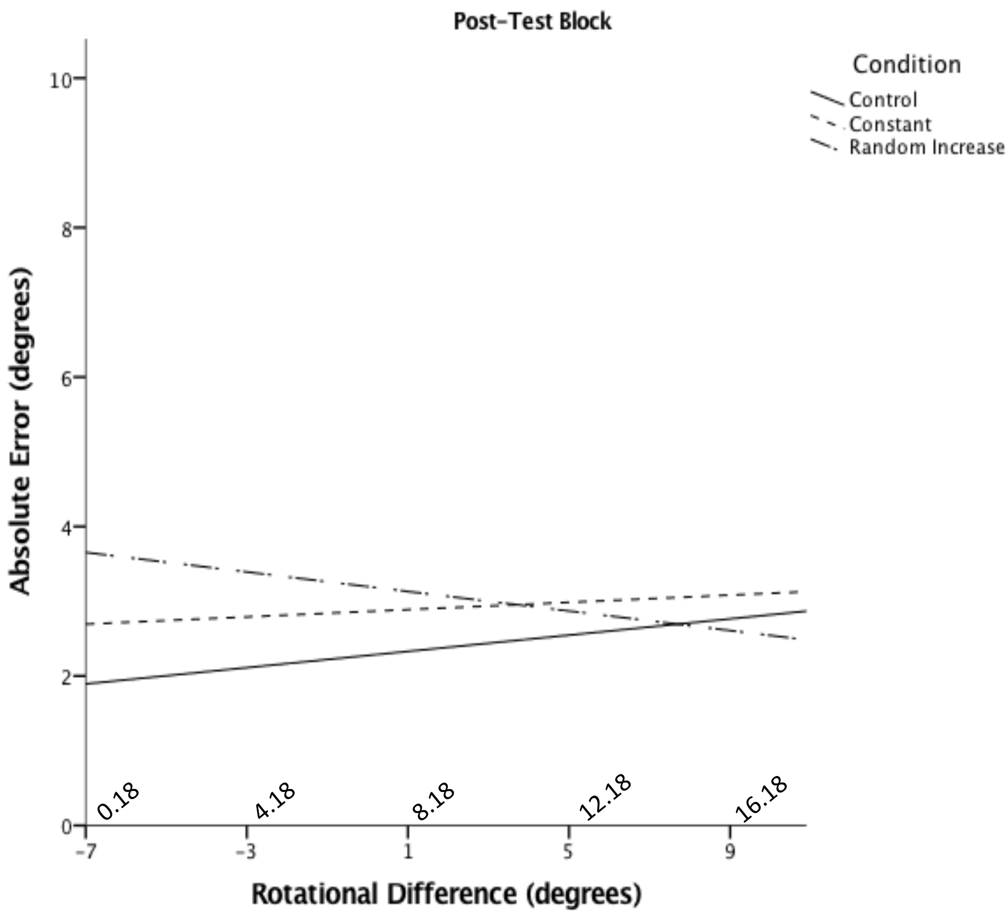


Figure 29. The interaction effect of block, condition and the rotational difference between head rotation and estimating arm rotation on absolute error for pre-/ post-test analysis in Experiment 1. Only the control and random-increase conditions had significant simple slopes in the post-test block. The x-axis scale is the grand mean center rotational difference variable with the translated actual values located above.

5.4. Postural Sway: Entropy

The predictors for the dependent variable of postural sway are block, condition and the two-way interaction. There are two measures of the entropy, the mediolateral sway (SampEn-X) and the posterior-anterior sway (SampEn-Y). Both of these variables are measured at the block level and therefore, trials within blocks cannot be used as a variable. The postural sway indexed by the SampEn-X variable is the shifting of the COP by shifting weight to either side of the body (i.e., left to right). While the SampEn-Y variable is the shifting of the COP by shifting weight forward and backward (i.e., between the toes and heels of the foot).

5.4.1. Postural Sway Analysis in Experimental Block for Experiment 1

The F-Test results from the hierarchical linear modeling for SampEn-X and SampEn-Y as the outcome can be seen in Table 8.

Table 8. F-tests for SampEn-X and –Y for the experimental blocks in experiment 1.

				ΔR^2		
Outcome Variable	Model	F-Test	P-value	L1	L2	Cross-Level Interaction
SampEn-X	Block	42.03	<0.001	.0633	--	--
	Condition	0.13	0.88	--	--	--
	Block*Condition	10.117	<0.001	--	--	.0272
SampEn-Y	Block	11.063	<0.001	.0166	--	--
	Condition	0.302	0.741	--	--	--
	Block*Condition	41.346	<0.001	--	--	.1173

Both outcome variables had significant main effects of block. The means for block can be found in Table 9 and visualized in Figure 30. For both SampEn-X and –Y, all blocks were significantly different from block 1, LSD post hoc analyses can be found in Appendix H for SampEn-X and Appendix I for SampEn-Y. In general entropy increases across blocks for

SampEn-X. However, for SampEn-Y, the first three blocks decreased while the last three blocks increased. This effect accounted for 6.33% of explained variance in the SampEn-X variable and 1.66% in the SampEn-Y variable.

Table 9. Mean and standard deviations of the main effect of block on SampEn-X and SampEn-Y in the experimental blocks of Experiment 1.

	Mean (SD)	
Block	SampEn-X	SampEn-Y
1	0.0618 (0.02)	0.0592 (0.02)
2	0.0654 (0.02)	0.0565 (0.02)
3	0.0636 (0.02)	0.0554 (0.02)
4	0.0627 (0.02)	0.0562 (0.02)
5	0.0695 (0.02)	0.0566 (0.01)
6	0.0723 (0.02)	0.0576 (0.02)

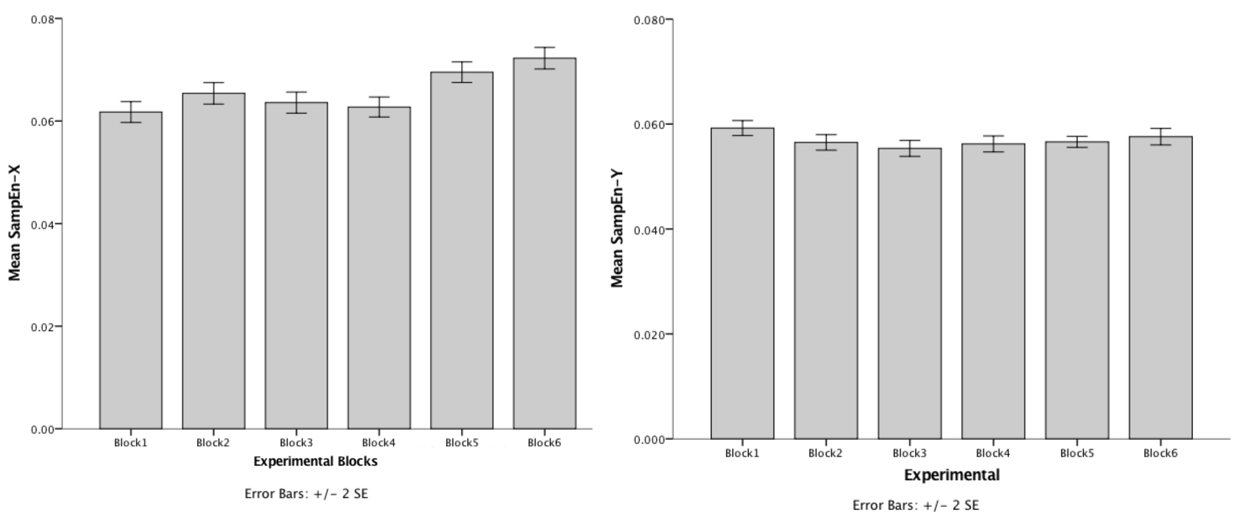


Figure 30. Means and standard errors of the main effect of block on SampEn-X and SampEn-Y for the experimental blocks in Experiment 1.

Additionally, the two-way interaction between block and condition was significant for both entropy outcome variables. For SampEn-X, the interaction accounted for 2.72% in

explained variance while it accounted for 11.73% for SampEn-Y. The means for the interaction can be found in Table 10 and visualized in Figure 31. When the interaction was analyzed for the simple effects, there were significant simple effect of block in all conditions for both SampEn-X and –Y. In general, there was more mediolateral sway than posterior-anterior sway. There was also more variability in the conditions as the complexity of the environment increased for both indices. In essence, the control condition shows the least amount of variability and the random increase shows the most variability. The random increase condition also shows a gradual increase pattern in the SampEn-X outcome variable.

Table 10. Mean and standard deviations of the interaction effect of block and condition on SampEn-X and SampEn-Y for the experimental blocks of Experiment 1.

	SampEn-X			*SampEn-Y*		
Experimental Block	Control	Constant	Random Increase	Control	Constant	Random Increase
1	0.0579 (0.02)	0.0647 (0.03)	0.0627 (0.02)	0.0517 (0.01)	0.0641 (0.01)	0.0620 (0.02)
2	0.0664 (0.02)	0.0684 (0.02)	0.0614 (0.03)	0.0507 (0.01)	0.0557 (0.01)	0.0630 (0.02)
3	0.0650 (0.02)	0.0600 (0.02)	0.0659 (0.02)	0.0546 (0.01)	0.0570 (0.02)	0.0544 (0.02)
4	0.0610 (0.02)	0.0607 (0.02)	0.0665 (0.03)	0.0598 (0.01)	0.0566 (0.01)	0.0522 (0.02)
5	0.0638 (0.02)	0.0708 (0.02)	0.0740 (0.02)	0.0548 (0.01)	0.0609 (0.01)	0.0541 (0.02)
6	0.0695 (0.02)	0.0734 (0.02)	0.0738 (0.03)	0.0573 (0.01)	0.0589 (0.01)	0.0567 (0.03)

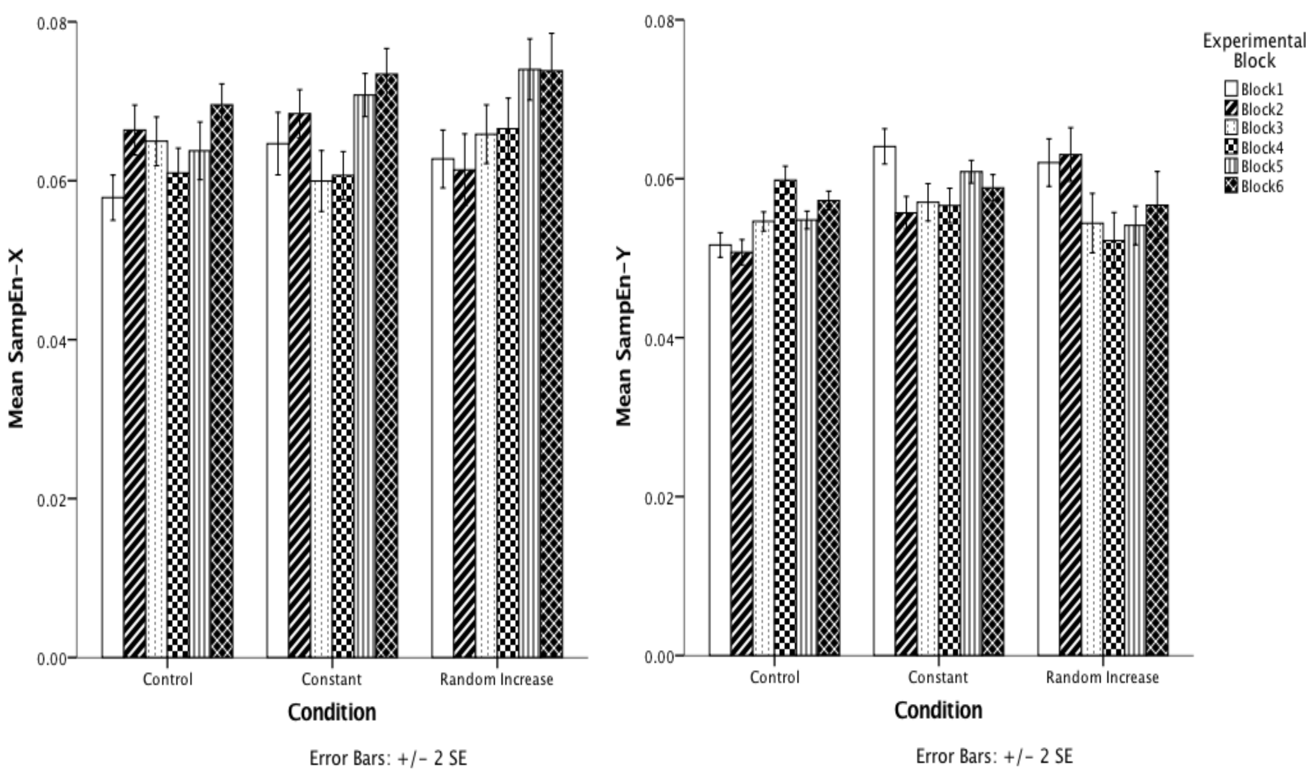


Figure 31. Means and standard errors of the interaction of block and condition on SampEn-X and SampEn-Y for the experimental blocks in Experiment 1.

5.4.2. Postural Sway Analysis for Pre-/ Post-test Block in Experiment 1

The F-Test results from the hierarchical linear modeling for SampEn-X and SampEn-Y as the outcome can be seen in Table 11.

Table 11. F-tests for SampEn-X and –Y for the pre- and post-test blocks in experiment 1.

				ΔR^2		
Outcome Variable	Model	F-Test	P-value	L1	L2	Cross-Level Interaction
SampEn-X	Block	39.64	0	.0342	--	--
	Condition	0.46	0.636	--	--	--
	Block*Condition	1.257	0.285	--	--	--
SampEn-Y	Block	<0.001	0.99	--	--	--
	Condition	0.61	0.55	--	--	--
	Block*Condition	58.446	<0.001	--	--	.1065

SampEn-X had a significant main effect of block. SampEn-X reduced from the pre-test (M = 0.068, SD = 0.02) to the post-test (M = 0.063, SD = 0.02). This indicates that there was less mediolateral sway in the post-test and accounted for 3.42% explained variance. SampEn-Y did not have a significant main effect of block, having the same mean and standard deviation for both pre- and post-test (M = 0.063, SD =0.02).

The two-way interaction was only significant for SampEn-Y outcome variable and accounted for 10.65% in explained variance. There was a significant simple effects of block in only the control and random increase conditions. The means and standard deviations can be found in Table 12. The control condition significantly increased from pre- to post-test, while the random increase condition significantly decreased from pre- to post-test (see Figure 32). In essence, the posterior-anterior sway increased from pre- to post-test for the control condition and decreased for the random increase condition. This finding is noteworthy, as the opposite effect was hypothesized.

Table 12. Mean and standard deviations of the interaction effect of block and condition on SampEn-X and SampEn-Y for pre- and post-test blocks in Experiment 1.

	Mean (SD)		
Block	Control	Constant	Random Increase
Pre-Test	0.0563 (0.01)	0.0658 (0.01)	0.0674 (0.02)
Post-Test	0.0634 (0.01)	0.0664 (0.01)	0.0597 (0.02)

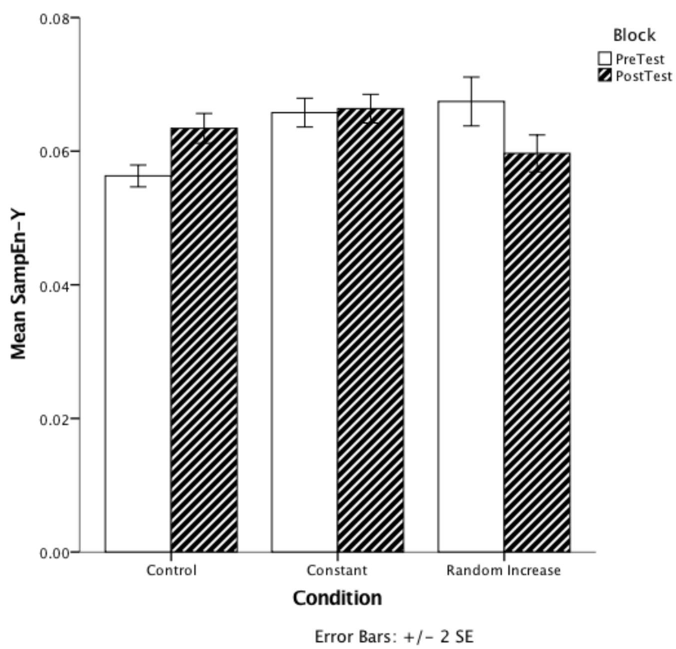


Figure 32. Means and standard errors of the interaction of block and condition on SampEn-Y for the pre- and post-test in Experiment 1.

5.5. *Mediation Modeling for Experiment 1*

To determine if condition impacted participants' accuracy (i.e., absolute error) and if this influence was mediated by the amount of postural sway (i.e., SampEn) in the blocks, a statistical test of the proposed mediating effect was conducted. Since there were two SampEn

measurements, one measuring the mediolateral sway (SampEn-X) and one measuring the posterior-anterior sway (SampEn-Y), this mediation model has two mediators (see Figure 33). Both the constant condition and the random increase condition were compared individually with the control condition. The mediated effect was then modeled with block as a moderating effect. Both the full model and moderated mediations by block for experimental blocks results can be seen in Table 13 and for pre-/post-test blocks can be seen in Table 14 (refer to Figure 33 for pathway locations).

The pathways within the mediation model are regressions with the point of the arrow indicating the prediction direction. Therefore, these simple effects of block were already analyzed in the MLM analyses above. This model is to determine if there are significant indirect effects with SampEn mediating the effects of condition on absolute error.

The first initial model was all the data regardless of block. This mediation model was a 2-1-1 (i.e., condition-L2, SampEn-X/Y-L1, and absolute error-L1). Then to determine if block moderated this mediation, the model was split by block and reanalyzed as a 2-2-1 model (condition and SampEn-X/ -Y are level 2 variables while absolute error remains at a measurement level 1).

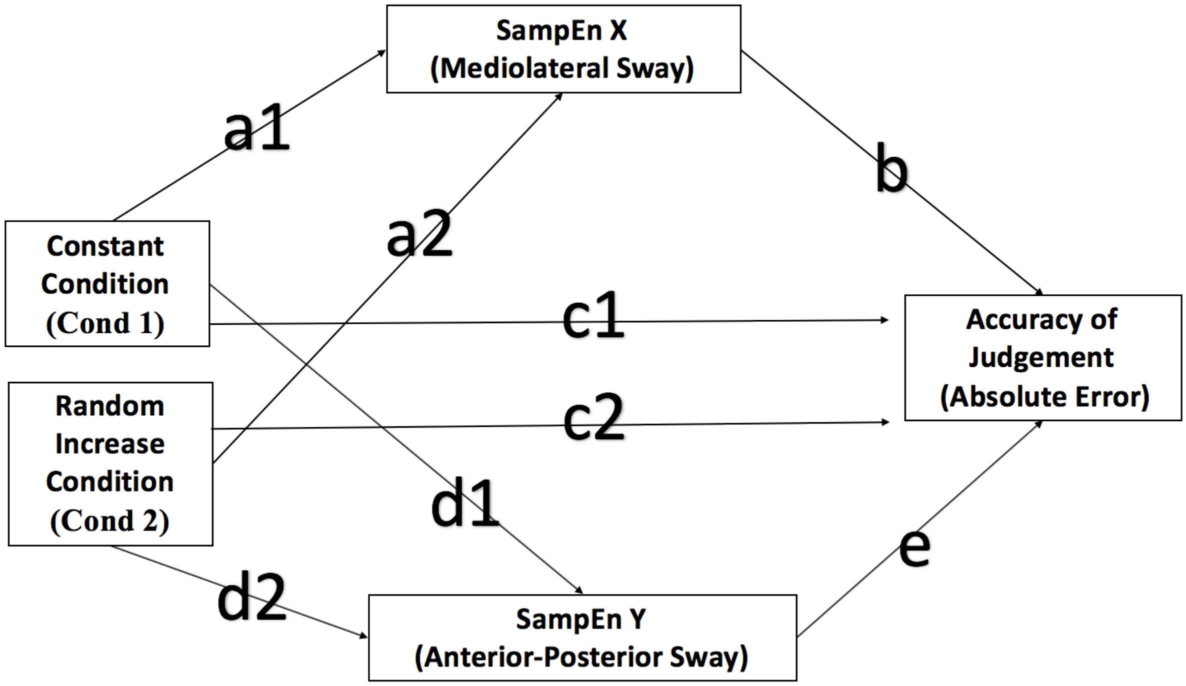


Figure 33. Pathway map of mediation for experiment 1.

5.5.1. Mediation Modeling for Experimental Blocks in Experiment 1

The path coefficients and standard errors of the full model can be seen in the model in Table 13. Please refer to Figure 33 for reference of pathways. The only significant path was SampEn-X predicting absolute error. There were no significant direct or indirect effects.

Table 13. Coefficient estimates and standard errors for the different experimental models for the various paths, indirect effects and direct effects for the experimental blocks in experiment 1.

		Estimate (SE)													
		Pathways								Indirect Effects				Direct Effects	
										SampEn-X		SampEn-Y			
		a1	a2	b	c1	c2	d1	d2	e	Cond 1[a] (a1*b)	Cond 2[b] (a2*b)	Cond 1[a] (d1*e)	Cond 2[b] (d1*e)	Cond 1[a] (c1)	Cond 2[b] (c2)
Full Model		0.002 (0.01)	0.003 (0.01)	<0.001 (0.002)**	0.24 (0.21)	0.25 (0.14)	0.004 (0.003)	0.002 (0.01)	<0.001 (0.001)	-0.02 (0.05)	-0.03 (0.05)	0.003 (0.01)	0.002 (0.01)	0.24 (0.21)	0.25 (0.14)
Block	1	0.01 (0.01)	0.01 (0.01)	-7.32 (6.12)	0.31 (0.3)	0.45 (0.35)	1.24 (0.47)	1.04 (0.58)	0.02 (0.09)	-0.05 (0.07)	-0.04 (0.07)	0.03 (0.10)	0.03 (0.09)	0.31 (0.3)	0.45 (0.35)
	2	0.002 (0.01)	-0.005 (0.01)	-0.83 (7.07)	0.46 (0.32)	0.14 (0.26)	0.50 (0.45)	1.23 (0.64)	-0.06 (0.07)	-0.002 (0.01)	0.004 (0.04)	-0.03 (0.04)	-0.07 (0.08)	0.46 (0.32)	0.14 (0.26)
	3	-0.005 (0.01)	0.001 (0.01)	3.05 (7.56)	0.32 (0.30)	0.34 (0.19)	0.24 (0.46)	-0.02 (0.68)	0.03 (0.06)	-0.02 (0.04)	0.003 (0.03)	0.01 (0.02)	-0.001 (0.02)	0.32 (0.30)	0.34 (0.19)
	4	<0.001 (0.01)	0.01 (0.01)	-10.50 (4.36)*	0.15 (0.25)	0.49 (0.21)*	-0.32 (0.48)	-0.76 (0.68)	0.11 (0.06)	0.003 (0.08)	-0.06 (0.09)	-0.03 (0.05)	-0.08 (0.09)	0.15 (0.25)	0.49 (0.21)*
	5	0.002 (0.01)	-0.01 (0.01)	-0.83 (7.07)	0.46 (0.32)	0.14 (0.26)	0.50 (0.45)	1.23 (0.64)	-0.06 (0.07)	-0.002 (0.01)	0.004 (0.04)	-0.03 (0.04)	-0.07 (0.08)	0.46 (0.32)	0.14 (0.26)
	6	0.004 (0.01)	0.004 (0.01)	-1.78 (4.67)	0.30 (0.24)	0.51 (0.20)*	0.16 (0.35)	-0.06 (0.76)	0.03 (0.06)	-0.01 (0.02)	-0.01 (0.02)	0.01 (0.01)	-0.002 (0.03)	0.30 (0.24)	0.51 (0.20)*

*p<0.05, **p<0.01, ***p<0.001, a= Comparison of control and constant conditions, b= comparison of random increase and control group.

For the moderated mediation model, pathway coefficients, standard errors, and p-values for the different pathways can be found in Table 13 by block. In block 4 there was a significant direct effect which was the c2 path indicating that there was a significant difference between the control and random increasing condition when estimating absolute error. This model also had a significant pathway of SampEn estimating absolute error. Block 6 also had a significant direct effect which was the c2 path. This indicates a significant difference between the random increasing condition and the control. There were no significant indirect pathways in any blocks.

5.5.2. Mediation Modeling for Pre-/ Post-test Blocks in Experiment 1

The path coefficients and standard errors of the full model can be seen in the model in Table 14. Please refer to Figure 33 for reference of pathways. There were no significant pathways, direct or indirect effects in the full model.

Table 14. Coefficient estimates and standard errors for the different experimental models for the various paths, indirect effects and direct effects for the pre- and post-test blocks of Experiment 1.

		Estimate (SE)													
		Pathways								Indirect Effects				Direct Effects	
										SampEn-X		SampEn-Y			
		a1	a2	b	c1	c2	d1	d2	e	Cond 1[a] (a1*b)	Cond 2[b] (a2*b)	Cond 1[a] (d1*e)	Cond 2[b] (d1*e)	Cond 1[a] (c1)	Cond 2[b] (c2)
Full Model		-0.01 (0.01)	-0.01 0.01)	-3.48 (12.73)	0.04 (0.34)	0.62 (0.48)	0.01 (0.004)	0.003 (0.01)	-3.80 (14.10)	0.02 (0.07)	0.02 (0.08)	-0.01 (0.05)	-0.02 (0.08)	0.04 (0.34)	0.62 (0.47)
Block	Pre-Test	0.01 (0.01)*	0.01 (0.01)	-11.75 (6.01)	-0.02 (0.22)	-0.02 (0.25)	0.01 (0.01)*	0.01 (0.01)	3.744 (4.65)	0.01 (0.07)	0.02 (0.08)	0.04 (0.05)	0.04 (0.05)	-0.02 (0.22)	-0.02 (0.25)
	Post-Test	-0.003 (0.01)	-0.006 (0.01)	14.86 (12.74)	-0.16 (0.53)	0.75 (0.61)	0.01 (0.01)*	0.01 (0.01)	-29.161 (15.15)	-0.16 (0.53)	-0.05 (0.13)	-0.28 (0.19)	-0.33 (0.24)	-0.16 (0.53)	0.75 (0.61)

*p<0.05, **p<0.01, ***p<0.001, a= Comparison of control and constant conditions, b= comparison of random increase and control group.

For the moderated mediation model, pathway coefficients, standard errors, and p-values for the different pathways can be found in Table 14 by block. In the pre-test block there were two significant pathways of condition 1 predicting both postural sway indices (SampEn-X and SampEn-Y). Condition 1 is the comparison of the control and constant conditions. This indicates that there were differences between the control and constant conditions predicting both SampEn-X and –Y. In the post-test block, there was only a significant path of condition 1 on SampEn-Y. indicating a difference between control and constant conditions. There were not significant indirect or direct pathways.

6. **Discussion**

In general participants calibrated target estimations across the blocks of experimental trials and from the pre- to the post-test. This indicates that regardless of condition, there was a level of calibration that occurred. This finding supports previous research that task-relevant feedback can overcome systemic distortions or perturbations. On average, participants tended to have higher under-rotation estimations than over-rotation estimation indicating that their errors were greater

if they did not rotate far enough to the target. These under-rotation estimations reduced across the experimental blocks and trials within blocks indicating a high level of calibration effect from them. Target location and action requirement also affected the estimates. Across block trials, under-rotation estimates decreased as participants calibrated to open body targets while over-rotation calibrated more for cross-body targets.

The current study had four primary hypotheses: (1) more unstable environments will take longer to calibrate, (2) that the random increase condition will have the highest amount of target estimation error and (3) the highest postural sway, and (4) that postural sway will mediate the relationship between the conditions and estimation error. While all of these hypotheses can be analyzed with the primary variables of interest, there were concerns of the effect of secondary variables such as simulator sickness and head movement during trials. These variables were analyzed in secondary models while keeping the primary variables in the models as constants.

The first hypothesis of this study was that more unstable environments will take longer to calibrate. This hypothesis can be found in the experimental blocks with any interaction in which block and condition interact. The four-way interaction between condition, block, block trial, and action requirement demonstrated this hypothesized effect. There were two significant blocks within the four-way interaction in which there was a significant simple slope effects for block trial for cross-body targets in which different effects can be seen in the conditions. The first block was Block 2 (see Figure 14). This block is the first block in which the constant condition and random increase condition have the first level of perturbation added into the virtual environment. In this block, both the control and the constant condition have negative slopes, indicating calibration within the block. The constant condition has the steepest slope indicating a faster rate of calibration than the constant condition. The random increase condition has a non-

significant positive slope. A non-significant slope indicates a lack of calibration. This could either be caused due to an inability to calibrate or already being at a pre-perturbed level. The amount of variability seen in the random increase block, indicates an inability to calibrate.

The other block that was significant was block 6 where the constant and control conditions had non-significant slopes and the random increase group had a significant negative slope indicating calibration occurring within the block (see Figure 15). Block 6 is the last experimental block and is the highest amount of rotational gain for the random increase condition. What is most interesting about this block is the relationship to that of block 2. In block 2, both the control and constant conditions demonstrate calibration while in the 6^{th} block they do not. This pattern suggests that both of these conditions experienced calibration during the first block and maintained calibration effects in later blocks. However, because the random increase block was still experiencing changes in the 6^{th} experimental block this required that they continue to recalibrate. This provides support that the control condition rapidly calibrated while the constant condition calibrated at a similar level if not slightly retarded than the control (see Figure 13). The random increase condition was still calibrating in the last experimental block indicating a need to recalibrate even in later blocks.

The second hypotheses can be found in the absolute error analyses with the variable of condition. While this variable was not significant as a main effect in any of the analyses, the effect of the condition can be seen in the carryover effects in the post-test block. As shown in Figure 21b, the amount of absolute error increases as the complexity of the condition increases. The control group has the least amount, the random increase the most error, and the constant between the two groups.

This effect could also be seen in them more comprehensive analysis of the four-way cross-level interaction between condition, block, action requirement and directionality in the pre-/ post-test analysis (see Figure 26). The random increase condition had a significantly greater amount of error when they under-rotated their estimate for open-body targets (M= 3.41, SD= 2.59) than the control group (M=1.83, SD= 1.26) and constant (M=2.87, SD= 1.91). This finding supports that calibration occurred for the control condition, similar to previous research. However, both the constant and random increase conditions had larger amounts of error when under-rotating their open-body estimates. This effect can be explained due to the interactions in the experimental block where both these conditions did not have to rotate as far as the control conditions causing their estimates to have greater error in the carryover effect of the post-test block. The decrease pattern shown in the control condition is a typical pattern seen in calibration studies (i.e., a reduction in error) while the increase in the constant condition is typical of the perturbed conditions of past research where participants calibrate to the perturbed state and the random-increase condition shows the most increase in absolute error between the three groups demonstrating the most difficulty to calibrate. This finding is evidence supporting hypothesis 2.

For hypothesis 3, this interest variable were the two indices of postural sway: SampEn-X measuring mediolateral sway and SampEn-Y measuring posterior-anterior sway. It was predicted that there would be a greater postural sway amount in the random increase condition. Calibration effects would be indicated by a decreasing of entropy across blocks. While there was a significant effect of condition and block in the experimental blocks, there was not a clear pattern to make a concrete explanation of the results (see Figure 31). Interestingly, the random increase condition increased similar to their perturbation increases for the SampEn-X measurement. In general, the random increase condition had the most variability between the blocks compared to

the other conditions. The constant condition variability of both postural sway indices diminished across the blocks of trials to similar levels of the control condition indicating calibration of postural sway. However, the random increase condition remained variable throughout the blocks. Lastly, there were larger effect sizes of the interaction between block and condition for SampEn-Y than SampEn-X indicating that this interaction affected the anterior-posterior sway more than the mediolateral sway.

Within the pre-/ post-block analysis, this hypothesis predicted that the random increase would have the highest perturbation levels. The interaction of block and condition was only significant for the SampEn-Y outcome variable (anterior-posterior sway). The opposite of the proposed effect was found (see Figure 32). The control condition increased in their sway path, the constant condition was not significantly different, and the random increase path actually significantly decreased the entropy from pre- to post-test.

Hypothesis 4 was the relationship between the condition and absolute error mediated through postural sway. This analysis was essentially an assimilation of both the absolute error analysis and the postural sway analysis into a singular integrated model to potentially explain a relationship between the three variables. In the full model in both the experimental blocks and the pre-/ post-test block analyses, there was not an indirect effect. To determine if block moderated the mediation model, it was included as a moderator. Again, no indirect effects were found. Therefore, hypothesis 4 does not have sufficient evidence to be supported from this current study.

CHAPTER III.

EXPERIMENT TWO

One of the questions that Experiment 1 and previous research has failed to answer is whether pattern predictability of changes in perturbation magnitude effect the recalibration rate. Most predictability comes from a closed-loop system in which we perform an action or engage within an environment. For example, as an actor is drinking a cup of coffee, the weight of that cup is predictably decreasing. It may not be known how much that cup weighs or the exact change in the weight of the cup due to the coffee being consumed but they can adjust their movement patterns based off the interaction between them and the environment. This perturbation change can be effectively normalized or made into a constant.

In the previous example, we are an active member of the change through the specific manipulation of consuming the coffee and therefore knowing it is steadily decreasing in weight. For another example, as one pedals a bike the changes in optic flow produced from the amount of force placed on the pedals to rotate the wheels of the bike are coupled. As the bike gains speed, we can shift to higher gears that allow for less rotation of pedals to maintain the specific speed.

This type of change is very similar to the visual gain used in Experiment 1. Every time we shift into a different gear, there is a predictability of the feedback. Likewise, in Bingham and Romack (1999), their participants were explicitly aware of a change in perturbation because they physically removed and the re-donned the same pair of prism goggles. This additional cue in both of these examples could be an assistance of preparing the body for recalibration.

All of these examples are of either the actor facilitating the change or being provided a cue that a change is about to occur. However, there are other times where we are simply subject to

the changes occurring in the actor-environment relationship (i.e., we do not have an active role in the change itself). For example, many aspects within the body change without direct cognitive input from the actor themselves. Additionally, technology can have changes that occur variably (e.g., cursor movement of a mouse getting gradually slower and catching up due to technological glitches).

As previous discussed, VE allows for cues that could provide a cognitive preparation to be eliminated. There is no need to take off and put on other prism goggles in order to alert the participant to a change in the actor-environment system. These cues are not always available in everyday examples of rapid changes. For example, those with nervous system or musculoskeletal disorders which can create rapid changes in the action abilities of the body as well as the movement accuracy, there are not necessarily cues as to when these changes will shift and occur. However, they may have certain predictable traits to them such as severity of deficit changes, etc. While these individuals most likely are aware of their illnesses, they are in a sense passive participants to the changes and not active members of the change.

Bingham and Romack (1999) found that participants recalibrated a faster rate when they consecutively interacted with the two levels of perturbation (displacement using the goggles or regular vision). However, was the recalibration rate effect due to the visual cue that provided knowledge of the nature of the perturbation change between the blocks of trials? Would this recalibration rate increase still occur without this other visual cue?

In this experiment, the effect of predictability of the perturbation gain on rate of recalibration will be examined. Predictability in the contexts of this study is defined as the pattern of change to the perturbation gain and not the knowledge that there will be a change. Participants will not be informed of the nature of the changes (similar to Experiment 1). Both groups will experience the

same level of perturbation change (increase of 0.5 gain per block increase). However, the *oscillating* condition will be following a similar pattern of the Bingham and Romack (1999) experiment which will fluctuate between having the 0.5x perturbation change and no perturbation change (see Figure 34). The second group is a hybrid of group 3 in Experiment 1 and the Bingham and Romack (1999) group. In this group the gain will gradually increase by 0.5 each block (see Figure 34).

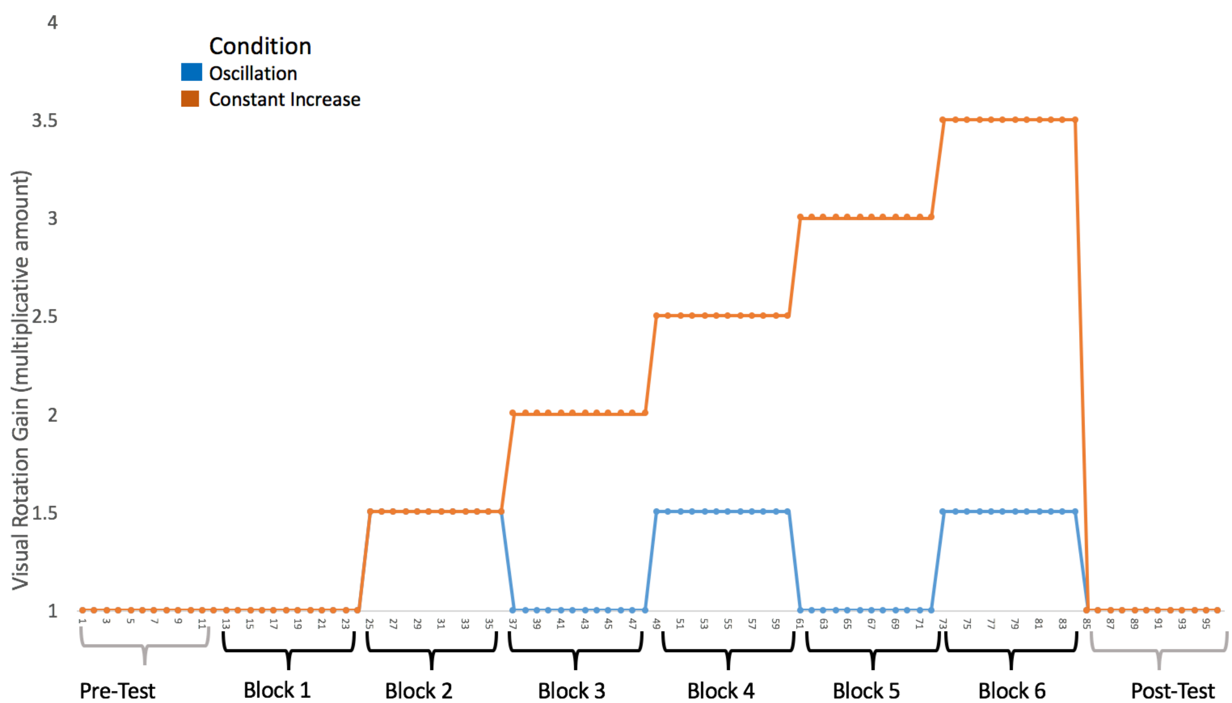


Figure 34. Visual Rotational Gain Profiles for Experiment 2. Both conditions in Experiment 2 have the same amount of perturbation change between blocks of experimental trials. The oscillation condition will be the fluctuate between having an additional gain and not. The constant gain condition will steadily increase perturbation amounts across blocks of trials.

Specifically, this experiment will answer whether the predictability of the pattern of change in the environment can affect the rate of recalibration. While both groups do have an element of predictability, the oscillation group is returning to previously experienced states where as the

constant gain increase group will never be within the same perturbation level. Essentially, will each successive recalibration occur more rapidly, similar to the findings of Bingham and Romack (1999) or will the lack of visual cue creating an expectation of a cue cause similar findings to the other unstable environments (Experiment 1, group 3; Experiment 2 Group 2)?

1. Hypotheses

The current study has three primary hypotheses. (1) It is hypothesized that the rate of recalibration across consecutive trials will be faster in the oscillating condition than in the constant gain increase condition. (2) However, this recalibration rate will be slower than that of the constant condition in experiment 1. (3) Lastly, it is again hypothesized that postural sway (e.g., entropy) will mediate the relationship between the type of perturbation condition (i.e., type of environment) and target estimation errors (see Figure 2).

2. **Methods**

2.1. *Participants*

Thirty-one participants were recruited using the Clemson participant pool and were given course credit for their participation in the study. These were added to the control condition group (study demographics: 22 males and 23 females; age range 18-22 Mean=18.98). Participants were allowed to stop the experiment at any time. Participants' data that did not complete the entire experiment, had equipment or experimenter error, or did not participate in the study correctly (i.e., did not follow instructions) were not included in the analyses. Two participants withdrew from the experiment due to simulator sickness (both in the constant-increase condition), and one was removed due to failure to follow instructions. Additional participants were run in order to

have the total 28 right-handed participants required for the study with complete data. Additionally, the data from the control group of Experiment 1 will be utilized as a reference group in the experiment.

2.2. *Materials & Apparatus*

The materials and apparatus used in this experiment were the same as Experiment 1. The only change in this experiment is to the perturbation gain levels. The gain changes can be seen in Figure 34.

3. **Procedure**

The procedure for this experiment is the same as Experiment 1.

4. **Data Preprocessing**

The data preprocessing for this experiment is the same as Experiment 1.

5. **Results**

To examine the effects of the two analyses in this experiment, the control condition from experiment 1 will be used as a reference condition. (1) It is hypothesized that the rate of recalibration across consecutive trials will be faster in the oscillating condition than in the constant gain increase condition. (2) However, this recalibration rate will be slower than that of the control condition in experiment 1. (3) Lastly, it is again hypothesized that postural sway (e.g., entropy) will mediate the relationship between the type of perturbation condition (i.e., type of environment) and target estimation errors (see Figure 2).

Evidence for the first and second hypothesis examining recalibration rate can be studied at the block level or within blocks at the trial level. Therefore, any significant findings in the experimental block analysis of absolute error with any interactions containing both block or trials within block and condition can be examined for these hypotheses. For both hypotheses, the dependent variables of absolute error and postural sway will be analyzed. Additionally, any carry-over effects in the post-test will allow for discussion of the total effect of the experimental gains in the experimental blocks.

Lastly, similar to the first experiment, the mediation model is utilized to integrate the other analyses into a relational model between condition and absolute error with postural sway as a mediator. Block was then included as a moderator to determine recalibration effects in the experimental blocks and carry-over effects in the pre-/ post-test blocks.

Again, in order to address the rich complexity of the data, comprehensive analyses were conducted. Lower-order main effects and interactions described above to answer the hypotheses can be dependent on other variables. Therefore, higher-order interactions were included for full factorial models to examine other moderating factors. Similar to experiment 1, all significant effects are discussed, however, main effects and lower-order interactions are the average of higher-order interaction variables and should be examined as such. In essence, significant higher-order interactions demonstrate moderating factors of lower order main effects and interactions. Descriptive statistics for collected variables can be found in Appendix J for the experimental blocks and Appendix K for the pre-/post-test blocks for Experiment 2.

5.1. *Outlier Analysis*

For each analysis, full models (i.e., a model with all predictors and interactions that will be analyzed) were conducted to determine any outliers. From these models residuals were obtained, standardized, and examined for any potential outliers and extreme cases that are outside of the normal distribution (Cohen et. al, 2003). Generally, it has been found that these points are due to malfunctioning in the tracking equipment based or on participant error (e.g., marking an estimation prematurely). All analyses found less than 1% of the trials removed due to outlier analysis.

5.2. *Hierarchical Linear Modeling*

Variables have considerable nesting within participants due to the repeated-measures design used in this research. In order to address the nesting of trials within participants, multilevel modeling (*hierarchical linear modeling*, HLM) was used to analyze both accuracy and entropy as dependent variables. For a full discussion on HLM, please see Chapter II section 5.2.

5.3. Accuracy: Absolute Error

The specification for the models are the same as experiment 1 (see Chapter II section 5.3).

5.3.1. Experimental Blocks Analyses for Absolute Error in Experiment 2

5.3.1.1. Absolute Error Primary Analysis for Experimental Block in Experiment 2

The F-Test results from the hierarchical linear modeling for accuracy as the outcome can be seen in Table 15. Continuous variables also have the coefficient estimate of the slope and standard error. For a comprehensive table of all predictors' coefficients is located in Appendix L.

Table 15. Fixed Coefficients, Standard Errors and $R^2\Delta$ for Absolute Error for the primary variables in the experimental block of Experiment 2.

Fixed Effects						
				ΔR^2		
Predictor	Coefficient (SE)	F-Test	P-value	L1	L2	Cross-Level Interaction
Intercept	1.63 (0.13)	--	--	--	--	--
Block	--	3.33	0.005	.0175	--	--
Btrial	-0.02 (0.01)	6.67	0.012	.0037	--	--
Loc	--	1.64	0.201	--	--	--
AR	--	15.62	<0.001	.0138	--	--
Dir	--	13.89	0.001	.0137	--	--
Cond	--	0.11	0.894	--	--	--
Block * Btrial	--	2.35	0.038	.0014	--	--
Block * Loc	--	1.41	0.218	--	--	--
Block * AR	--	1.04	0.393	--	--	--
Block * Dir	--	2.49	0.03	.0022	--	--
Loc * Btrial	--	2.29	0.13	--	--	--
Dir * Btrial	--	0.41	0.523	--	--	--
Loc * AR	--	3.17	0.075	--	--	--
Dir * AR	--	0.02	0.897	--	--	--
Loc * Dir	--	6.01	0.014	.0016	--	--
Block * Cond	--	1.17	0.304	--	--	--
Cond * Btrial	--	0.00	0.996	--	--	--
Cond * Loc	--	0.83	0.438	--	--	--
Cond * AR	--	0.77	0.47	--	--	--
Cond * Dir	--	1.47	0.243	--	--	--
Block * Loc * Btrial	--	0.74	0.592	--	--	--
Block * AR * Btrial	--	2.09	0.064	--	--	--
Block * Dir * Btrial	--	2.29	0.044	.0024	--	--
Block * Loc * AR	--	0.48	0.794	--	--	--
Block * Loc * Dir	--	1.79	0.112	--	--	--
Block * Dir * AR	--	0.50	0.78	--	--	--
Loc * AR * Btrial	--	1.49	0.222	--	--	--
Loc * Dir * Btrial	--	5.72	0.017	.0014	--	--
Dir * AR * Btrial	--	8.24	0.004	.0012	--	--
Loc * Dir * AR	--	0.07	0.797	--	--	--
Loc * AR * Btrial	--	1.55	0.213	--	--	--
Block * Cond * Btrial	--	0.93	0.505	--	--	--
Block * Cond * Loc	--	1.35	0.198	--	--	--
Block * Cond * AR	--	0.98	0.46	--	--	--
Block * Cond * Dir	--	1.07	0.385	--	--	--
Cond * Loc * Btrial	--	0.03	0.969	--	--	--
Cond * AR * Btrial	--	0.71	0.494	--	--	--
Cond * Dir * Btrial	--	2.32	0.073	--	--	--
Cond * Loc * Dir	--	0.50	0.609	--	--	--
Cond * Loc * AR	--	1.05	0.351	--	--	--
Cond * Dir * AR	--	0.02	0.979	--	--	--

Block * Loc * Dir * AR	--	0.62	0.684	--	--	--
Loc * Dir * AR * Btrial	--	0.95	0.33	--	--	--
Block * Loc * AR * Btrial	--	0.68	0.638	--	--	--
Block * Loc * Dir * Btrial	--	0.59	0.706	--	--	--
Block * Dir * AR * Btrial	--	0.40	0.851	--	--	--
Block * Cond * Loc * Btrial	--	1.16	0.315	--	--	--
Block * Cond * AR * Btrial	--	1.69	0.077	--	--	--
Block * Cond * Dir * Btrial	--	1.58	0.107	--	--	--
Block * Cond * Loc * AR	--	0.67	0.751	--	--	--
Block * Cond * Loc * Dir	--	1.78	0.058	--	--	--
Block * Cond * Dir * AR	--	1.34	0.204	--	--	--
Cond * Loc * AR * Btrial	--	0.01	0.995	--	--	--
Cond * Loc * Dir * Btrial	--	0.87	0.419	--	--	--
Cond * Dir * AR * Btrial	--	2.36	0.094	--	--	--
Cond * Loc * Dir * AR	--	3.23	0.04	--	--	.0020
Block * Loc * Dir * AR * Btrial	--	0.72	0.608	--	--	--
Block * Cond * Loc * Dir * AR	--	0.40	0.947	--	--	--
Cond * Loc * Dir * AR * Btrial	--	0.27	0.762	--	--	--
Block * Cond * Loc * AR * Btrial	--	0.22	0.994	--	--	--
Block * Cond * Loc * Dir * Btrial	--	0.98	0.457	--	--	--
Block * Cond * Dir * AR * Btrial	--	1.17	0.307	--	--	--
Block * Cond * Loc * Dir * AR * Btrial	--	0.50	0.889	--	--	--
			TotalΔR^2	.0589	--	.0020

There were four significant main effects: block, block trial, action requirement, and directionality. The means and standard deviations for block can be found in Table 16 and the LSD post hoc tests comparing the other means are in Appendix M. As visually shown in Figure 35, absolute error decreased in general as the participants went through the experimental blocks. Only the last three blocks (4, 5, and 6) were significantly different from block 1. The effect accounted for a total of 1.75 % of explained variance. As the participants went through the experimental phase, their error decreases indicating recalibration regardless of condition.

Table 16. Means and standard deviations for the main effect of block predicting absolute error in the experimental blocks of experiment 2. blocks 4-6 are significantly different from block 1.

Experimental Block	Mean	SD
1	1.87	1.54
2	1.76	1.45
3	1.75	1.48
4	1.62**	1.26
5	1.65**	1.24
6	1.59**	1.31

*p<0.05, **p<0.01, ***p<0.001

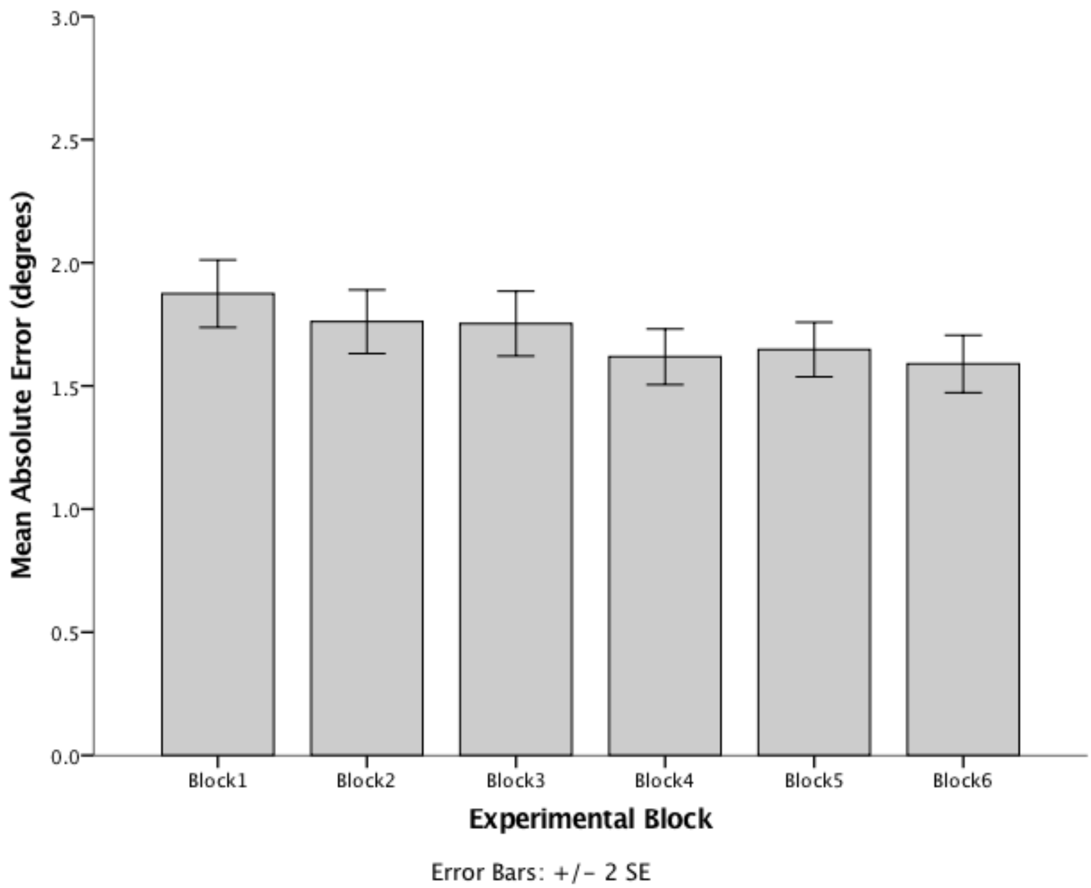


Figure 35. The main effect of block on absolute error (degrees) in the experimental blocks of Experiment 2. Block 1 was used as the reference group with blocks 4-6 being significantly different. As the participants went through the experimental phase, their error decreases indicating recalibration regardless of condition.

Block trial also had a significant effect predicting absolute error and explained 0.37% of explained variance. Figure 36 depicts the relationship between block trial and absolute error. As block trials increased, absolute error decreases by 0.02 on average per trial. This effect provides evidence of calibration occurring within blocks.

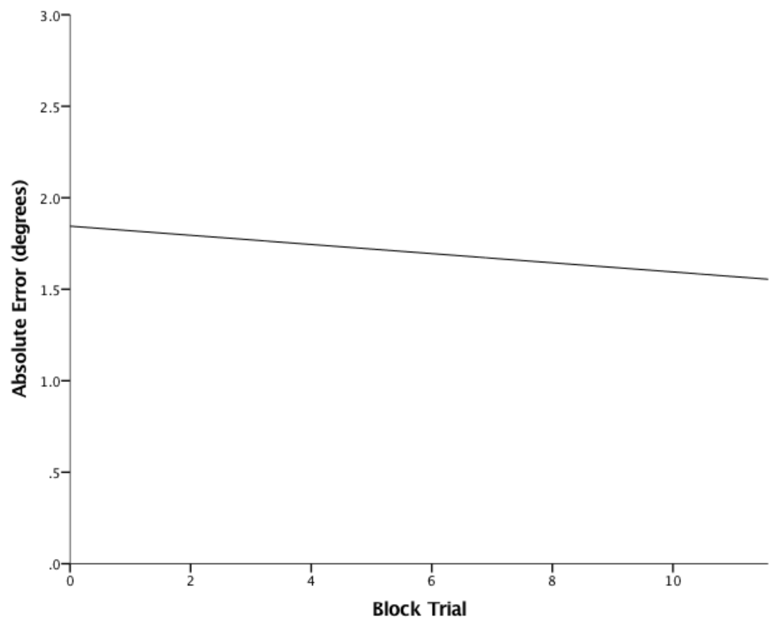


Figure 36. Main effect of block trial on absolute error in the experimental blocks of experiment 2. Note that the first trial in a block is considered trial 0 in the analysis and graph.

Action requirement also significantly predicted absolute error and explained 1.38% of the variance. In general, cross-body actions produced larger error amounts (M = 1.88 degrees, SD = 1.48), than open-body actions (M = 1.54 degrees, SD = 1.26). See Figure 37 for a visualization of this effect.

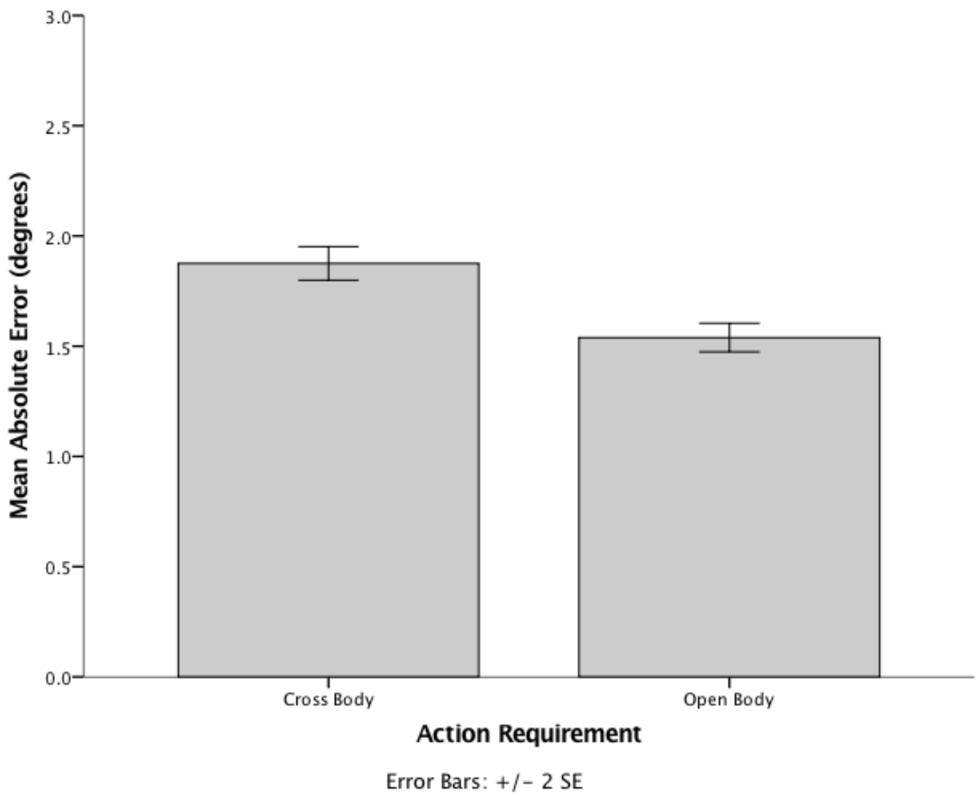


Figure 37. Graph of main effect of action requirement on absolute error (degrees) in the experimental blocks of Experiment 2.

The directionality main effect showed that the amount of error depended on the direction of the estimation. Estimations that were under rotated had more error (M = 1.84, SD = 1.42) than over-rotation estimations (M = 1.50, SD = 1.31; see Figure 38). The effect account for a total of 1.37 % of explained variance.

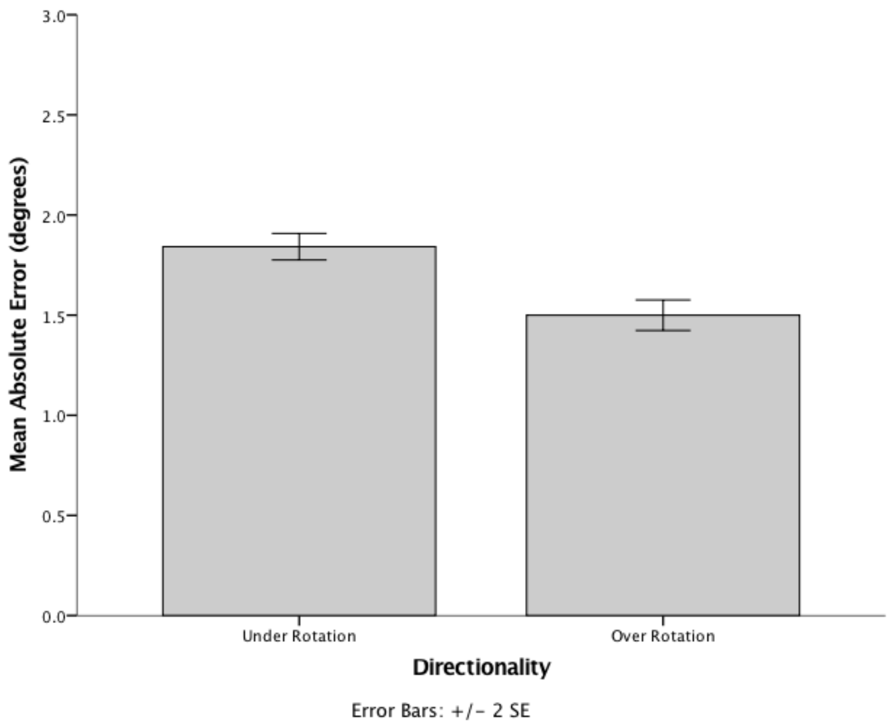


Figure 38. Graph of main effect of directionality on absolute error (degrees) in the experimental block of Experiment 2. Amount of error depends on the direction of the rotation.

There were three Level 1 moderating Level 1 interactions that were significant: block moderating the effect of block trial on absolute error, directionality moderating the effect of block on absolute error, and directionality moderating the effect of target location on absolute error. To tease apart the interactions simple effects were analyzed.

For the interaction of block and block trial, the simple slopes of block trial were examined for each block, only blocks 1 and 2 had significant slopes. Figure 39 depicts the the effect of block trial moderated by block on absolute error. Both block 1 and 2 show significant negative slopes indicating calibration within both of these blocks. Absolute error reduced by 0.07 degrees per trial increase in block 1 and reduced by 0.05 degrees per trial increase in block 2. This is a noteworthy effect as it demonstrates that calibration is occurring within blocks but that it is only significantly occurring during the first two blocks but not the rest of the experimental blocks.

Because there is not a significant interaction between block, block trial, and condition, this effect can be explained as recalibration occurring in the first blocks and the participants not calibrating any further in the later blocks.

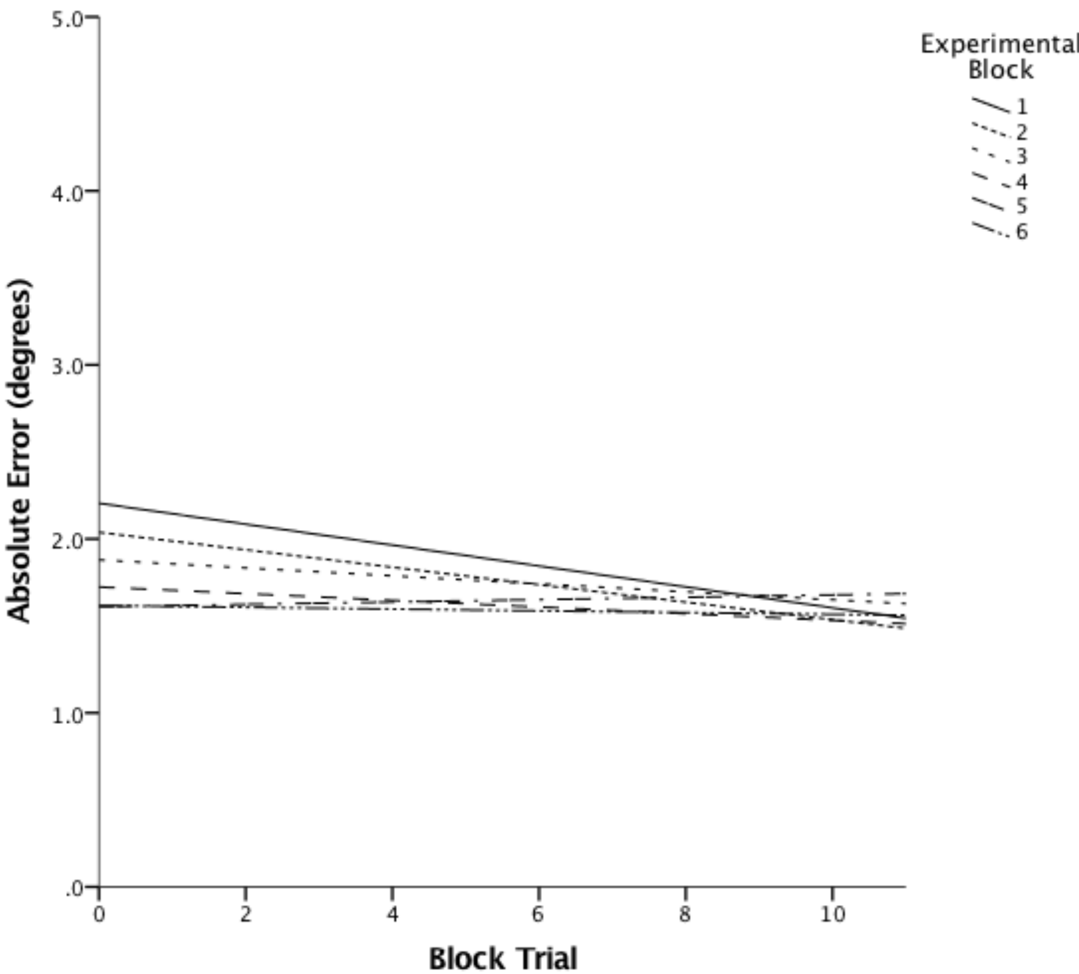


Figure 39. The effect of block trial on absolute error moderated by block in the experimental blocks of Experiment 2. Only block 1 and 2 have significant slopes. Note that the first trial in a block is considered trial 0 in the analysis and graph.

For the interaction of directionality and block, only under-rotation estimations were significantly different in absolute error across the blocks (see Figure 40 and Table 17). In general, a pattern of decrease in absolute error can be seen across the blocks. All blocks were significantly different from block 1. This effect demonstrates that across the blocks, the amount

of error during over estimations did not significantly change whereas there was a significant reduction in error when participants under-rotated in blocks 2-6 compared to block 1. The effect account for a total of 0.22 % of explained variance.

Table 17. Absolute Error means and standard deviations for block by directionality interaction for experimental blocks in experiment 2. Only under-rotation means were significantly different.

Directionality	Experimental Block	Mean	SD
Under Rotation***	Block1	2.16	1.62
	Block2*	1.85	1.41
	Block3*	1.90	1.49
	Block4***	1.77	1.39
	Block5***	1.74	1.20
	Block6**	1.63	1.32
Over Rotation	Block1	1.48	1.32
	Block2	1.62	1.50
	Block3	1.50	1.41
	Block4*	1.38	1.01
	Block5	1.48	1.31
	Block6	1.53	1.30

*p<0.05, **p<0.01, ***p<0.001

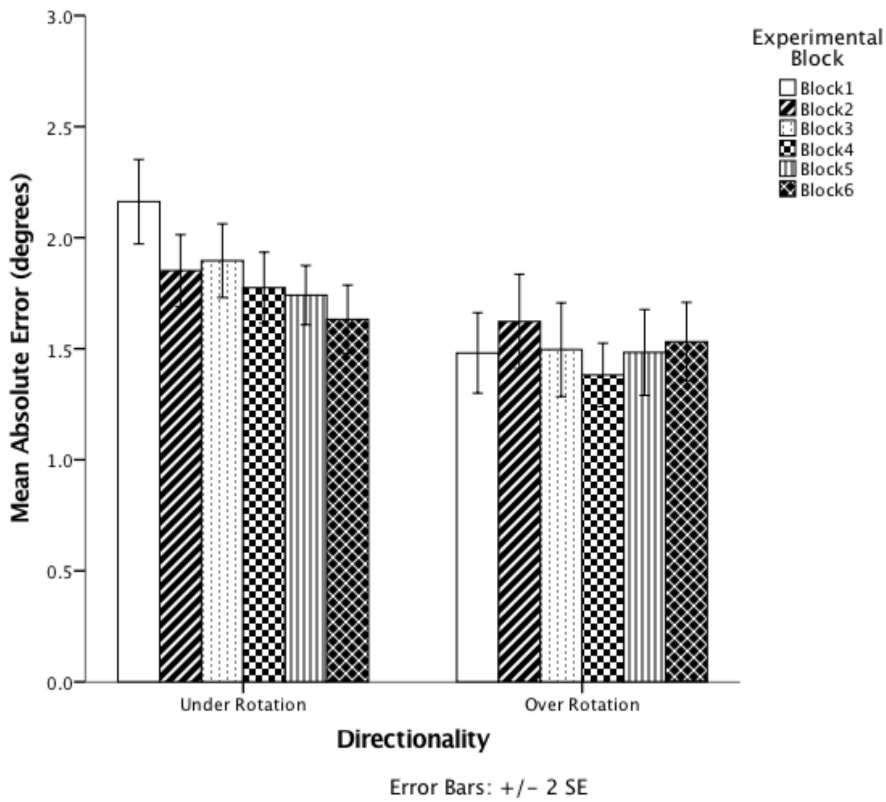


Figure 40. Interaction of block by directionality estimating absolute error in the experimental blocks of experiment 2. The simple effect of block estimating absolute error is only significant when participants are under-rotating.

For the interaction of location and estimate directionality, only over-rotation was significantly different in absolute error between frontal and peripheral location. The means and standard deviations of the interaction can be found in Table 18 with a visualization in Figure 41. For the peripheral targets (targets 1 and 4) participants had larger amounts of error (i.e., they over-rotated more than when they estimated peripheral targets. The effect account for a total of 0.16 % of explained variance.

Table 18. Absolute Error means and standard deviations for location by directionality interaction for the experimental blocks of experiment 2. Only over-rotation means were significantly different.

Directionality	Location			
	Frontal		Peripheral	
	Mean	SD	Mean	SD
Under Rotation	1.85	1.38	1.84	1.45
Over Rotation***	1.39	1.21	1.60	1.40

*p<0.05, **p<0.01, ***p<0.001

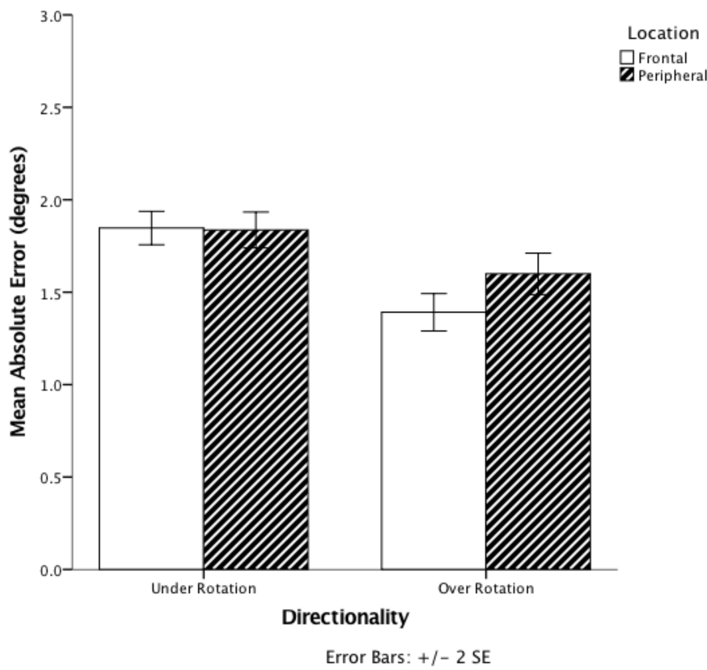


Figure 41. Effect of the directionality of the estimate on the absolute error mediated by the location of the target in experimental blocks in Experiment 2. Only over rotation is significantly different between the locations.

There were three significant three-way L1 interactions: block by block trial by directionality, location by block trial by directionality, and action requirement by block trial by directionality. In essence, these can be thought of as a two-way interaction being moderated by

block, location, and action requirement. All of these need to be decomposed into the simple slopes of block trial.

For the first three-way interaction of block by block trial by directionality, the two-way interaction between block trial and directionality was investigated between blocks. Blocks 1-4 had the significant two-way interactions but not block 5 or 6. When the simple slopes for block trial was examined within the significant blocks, there were only two significant simple slope: block 1 for over estimations, and block 2 for over estimations (see Figure 42). As trial number increased by one the absolute values decreased by 0.11 degrees in block 1 and 0.03 degrees in block 2 for over-rotation estimates. This pattern and the subsequent non-significant slopes across blocks demonstrates calibration occurring in the first two blocks but not calibration occurring in the later blocks. This effect accounted for 0.24% of the explained variance in the model.

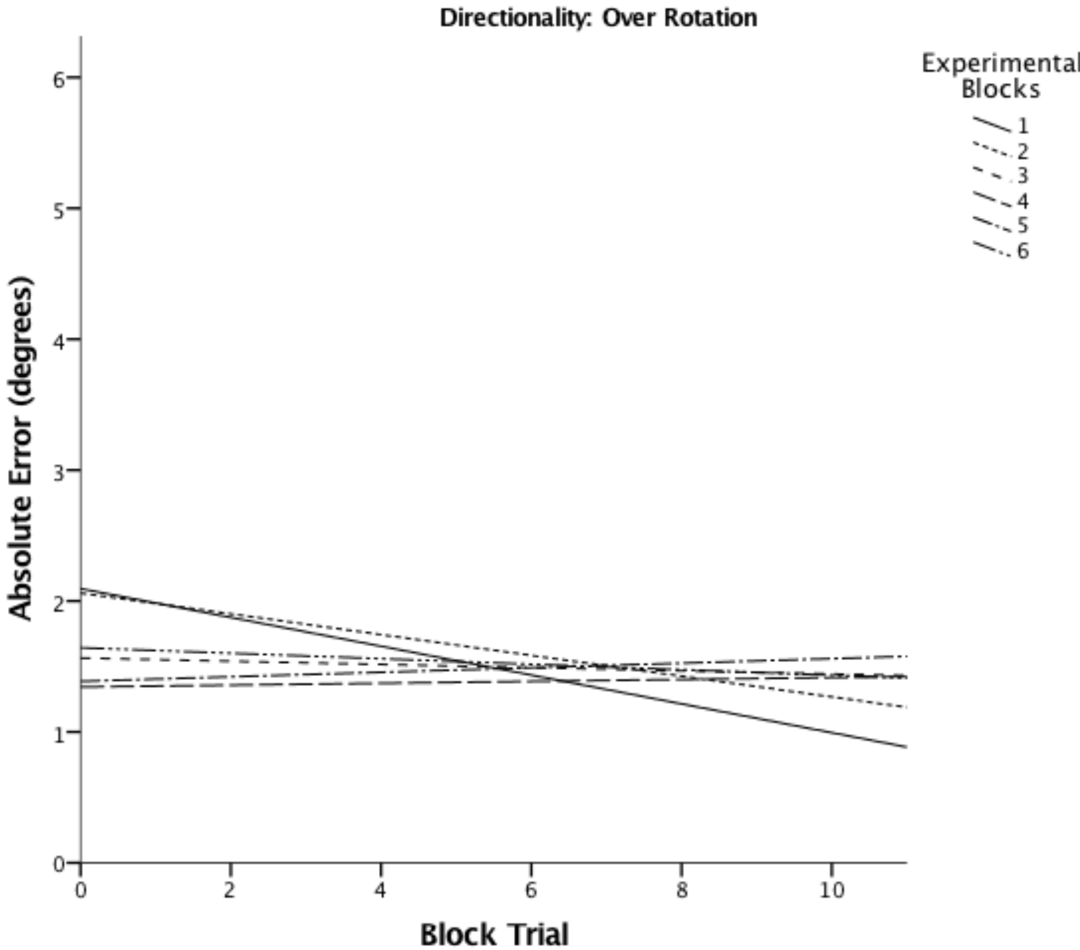


Figure 42. The effect of block trial and directionality on absolute error moderated by block in the experimental blocks of Experiment 2. Only block 1 and 2 have significant slopes for over rotation estimations. Note that the first trial in a block is considered trial 0 in the analysis and graph.

For the second three-way interaction, the simple slopes of block trials were significant for peripheral targets that had over-rotation estimations. In Figure 43, for peripheral targets that had over-rotated estimates decreased by 0.06 degrees in absolute error with each increase of trial within a block. This means that for peripheral targets, participants' over-rotated less as the trials increased within a block. Again, this negative slope indicates calibration occurring in this combination. However, the other simple slopes were not significantly different from zero. Most

likely this effect is due to the gain impact of the peripheral targets compared to frontal targets. Essentially, greater visual gain amounts affect the total head rotation of the peripheral targets more than the frontal targets. This effect account for 0.14% of the explained variance.

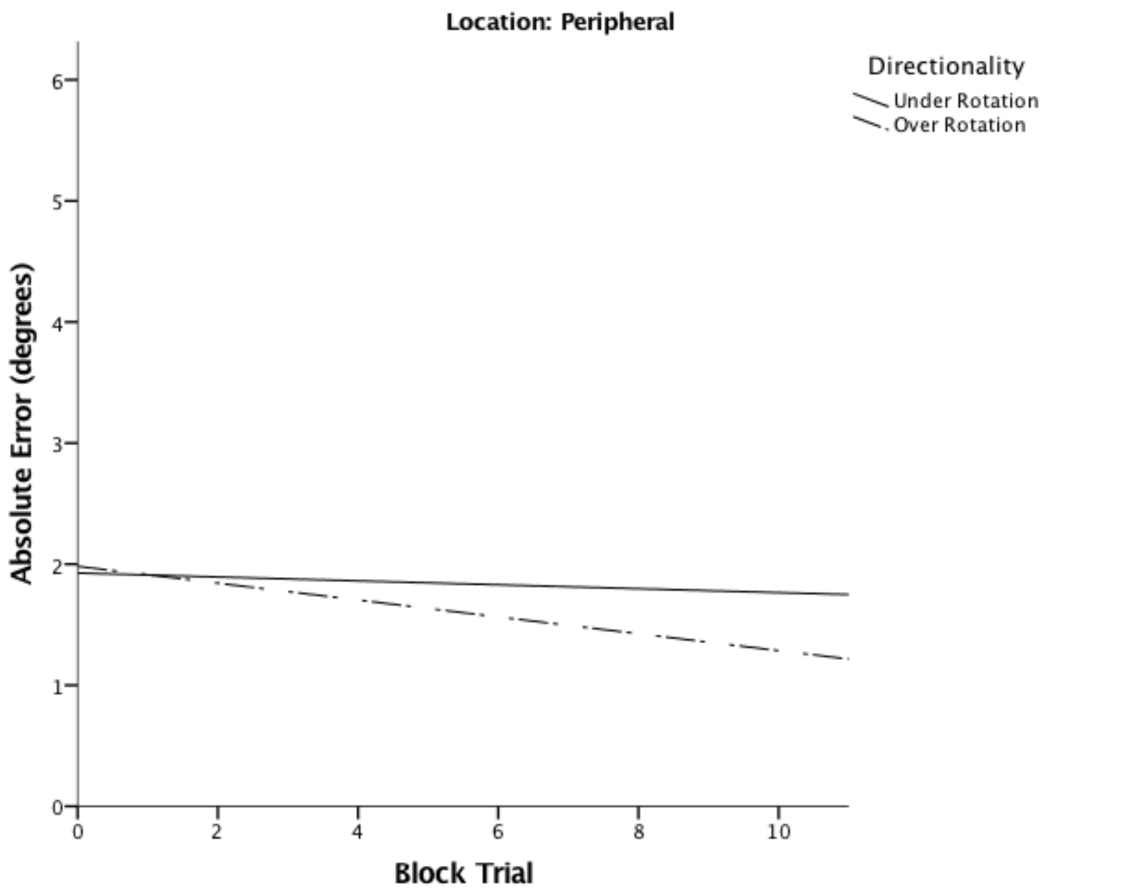


Figure 43. The three-way interaction of location by directionality by block trial in the experimental blocks of experiment 2. The significance of the effect was found for peripheral targets moderated by the directionality of the estimate. Note that the first trial in a block is considered trial 0 in the analysis and graph.

The last significant three-way L1 interaction was between direction, block trial, and action requirement which accounted for 0.12% of the explained variance. The simple effect of this three way was found for open-body targets that had under-rotation estimates. Figure 44

shows that for targets requiring an open-body action, calibration occurred for under-rotations estimations. In essence, the amount of absolute error in under-rotated estimates decreased by 0.05 per trial increase for open-body targets.

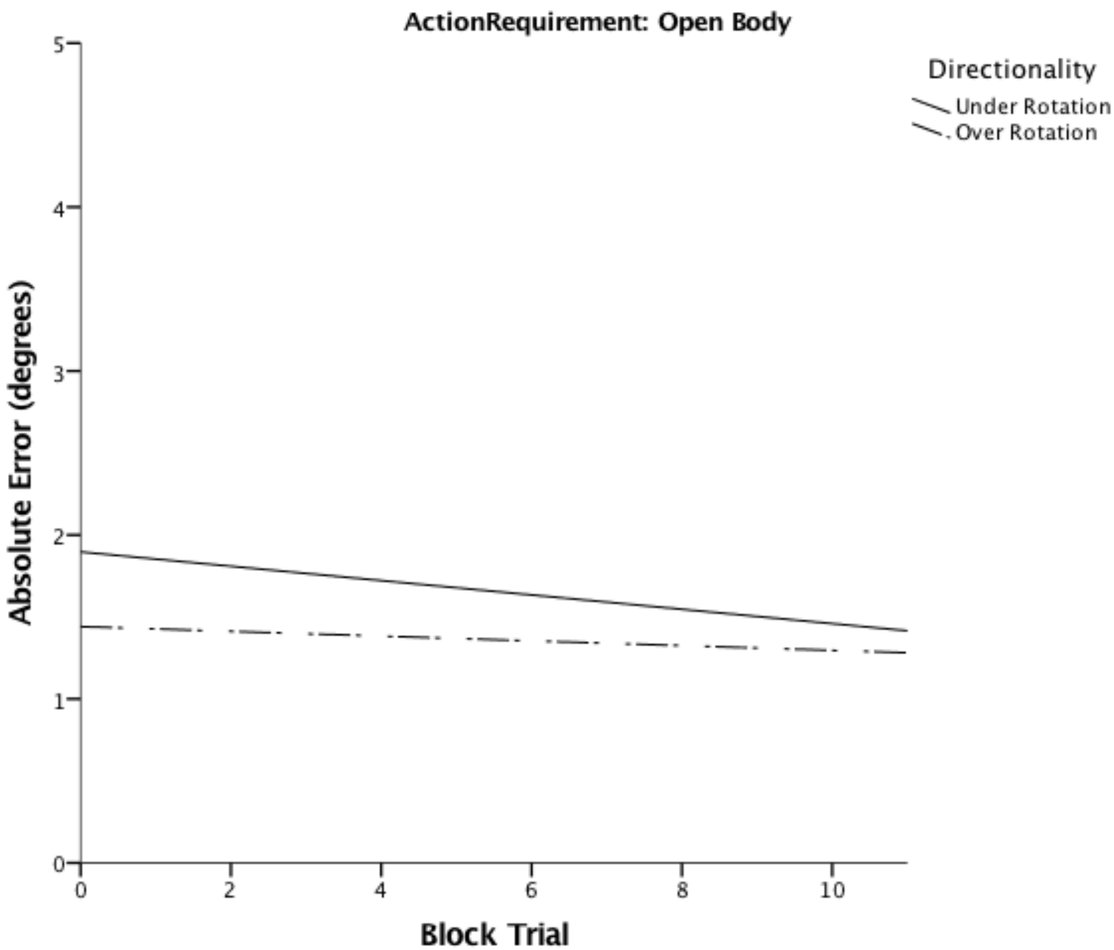


Figure 44. The three-way interaction of action requirements by directionality by block trial in the experimental blocks of experiment 2. The significance of the effect was found for open-body actions (i.e., targets 3 and 4) moderated by the directionality of the estimate. Note that the first trial in a block is considered trial 0 in the analysis and graph.

Lastly, there was one significant cross-level four-way interaction between condition, estimate directionality, target location, and action requirement. To investigate the three-way interaction of condition, estimate directionality, and action requirement were analyzed by

location. Only frontal targets had a significant three-way interaction. Next, the two-way interaction of condition and estimate directionality were analyzed within frontal targets by action requirements. Only the cross-body actions had a significant two-way interaction of condition and direction. Lastly, the main effects of directionality were examined for target 3 (the frontal cross-body target). The only condition that had a significant main effect of directionality was the constant increase condition. This interaction can be seen in Figure 45. Participants in the constant increase condition had larger estimation errors when they under-rotated (M = 2.16, SD = 1.61) for frontal cross-body targets (i.e., target 3) than when they over-rotated their estimates (M = 1.34, SD = 1.20). This interaction explained 0.20 % of the variance. All LSD pairwise comparisons can be found in Appendix N.

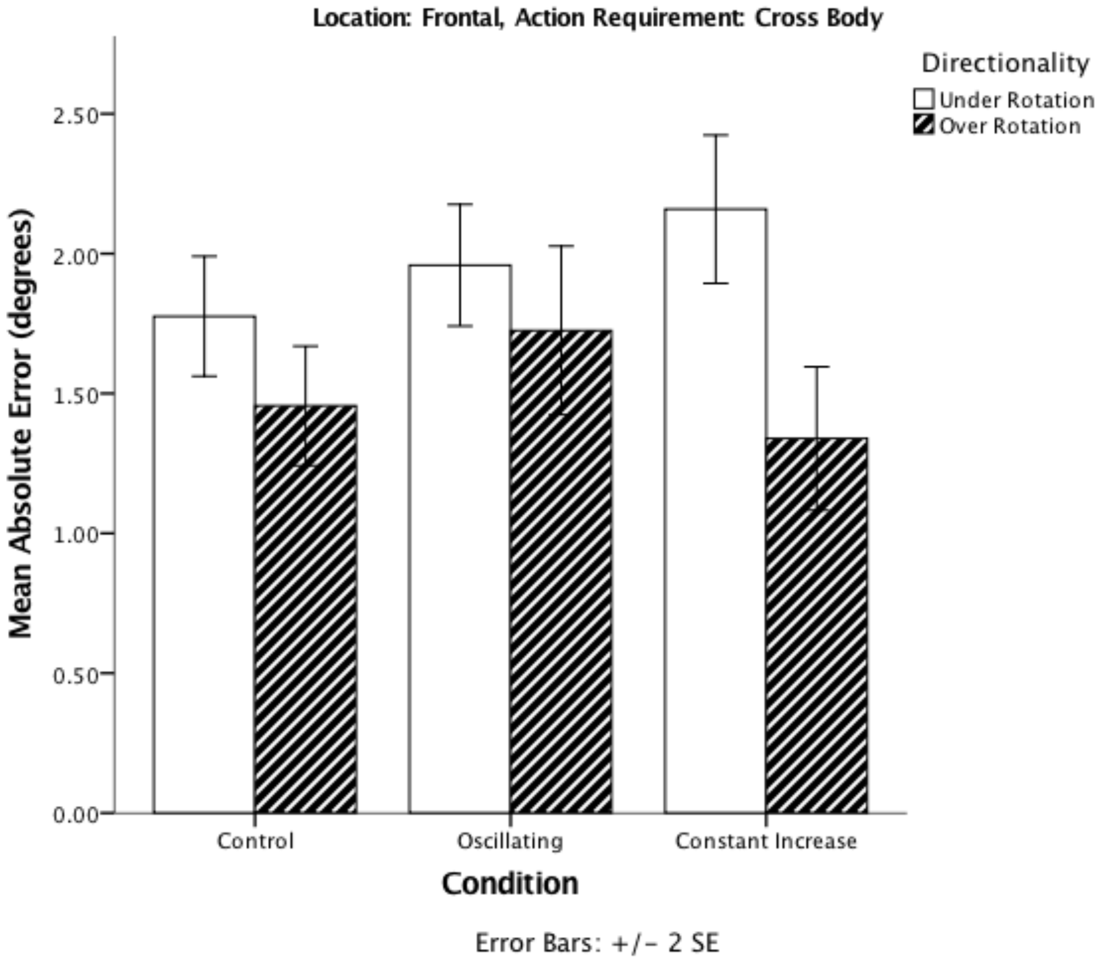


Figure 45. Significant four-way interaction of directionality, condition, location, and action requirement for the experimental blocks in experiment 2. The decomposition of the interaction found the significant was in the first experimental block, in the constant condition, for the peripheral targets.

5.3.1.2. Absolute Error Secondary Analysis for Experimental Block in Experiment 2

In this model, secondary variables and specific interactions were included in the model in order to determine their effects on absolute error while controlling for the primary variables. Level 1 secondary variables include: total head rotation, max head rotation, rotational difference

(difference between head rotation and arm rotation), SSQ. Level 2 secondary variables are the MSAQ-Pre and the MSAQ-Post. Due to the high correlation between max head rotation and total head rotation, these two variables were analyzed in their perspective models without the inclusion of the other. This was to guard against any suppression that may occur with both variables in the model simultaneously. Since primary models and interactions have been discussed previous, only the significant new effects will be discussed. The F-Test results from the hierarchical linear modeling for accuracy as the outcome including secondary variables can be seen in Table 19. Also coefficients and standard errors are only reported for continuous variables in the table. For a full table of the coefficients and standard errors please refer to Appendix O.

Table 19. Fixed Coefficients, Standard Errors and $R^2\Delta$ for Absolute Error for the Secondary Variables for the experimental blocks of experiment 2.

Fixed Effects						
				ΔR^2		
Predictor	Coefficient (SE)	F-Test	P-value	L1	L2	Cross-Level Interaction
Intercept	1.73 (0.16)	--	--	--	--	--
Block		2.02	0.07	--	--	--
Block trial	-0.2 (0.01)	8.39	0.01	.0043	--	--
Location (Loc)		1.56	0.21	--	--	--
Action Requirement		19.04	0.00	.0153	--	--
Shot Directionality		32.34	0.00	0118	--	--
Total Rotation	0.003 (0.002)	0.27	0.76	--	--	--
Max Rotation	-0.006 (0.01)	0.00	0.99	--	--	--
Rotational Difference	0.003 (0.01)	0.94	0.33	--	--	--
SampEn-X	-4.41 (1.84)	1.69	0.19	--	--	--
SampEn-Y	0.06 (2.84)	2.42	0.12	--	--	--
SSQ	0.002 (0.02)	0.00	0.95	--	--	--
MSAQ Pre	-0.03 (0.02)	0.21	0.65	--	--	--
MSAQ Post	0.01 (0.01)	0.21	0.65	--	--	--
Condition		1.54	0.22	--	--	--
Block * SSQ		2.42	0.03	.0025	--	--
Block * Total Rotation		0.96	0.44	--	--	--
Block * Max Rotation		1.34	0.24	--	--	--
Block * Rotational Difference		1.93	0.09	--	--	--
Condition * SSQ		0.75	0.48	--	--	--
Condition * Total Rotation		0.48	0.62	--	--	--
Condition * Max Rotation		1.08	0.34	--	--	--
Condition * Rotational Difference		0.72	0.49	--	--	--
Block * Condition		1.12	0.34	--	--	--
Block * Condition * SSQ		1.82	0.052	--	--	--
Block * Condition * Total Rotation		0.68	0.75	--	--	--
Block * Condition * Max Rotation		0.82	0.61	--	--	--
Block * Condition * Rotational Difference		1.18	0.30	--	--	--
			TotalΔR^2	.0339	--	--

There were no significant main effects of the secondary variables. There was one significant level 1 interaction between block and SSQ scores. As shown in Figure 46, the slope of SSQ estimating absolute error depends on the block. In blocks 1-5 had positive slopes while block 6 had a negative slope. None of the simple slopes were significantly different from zero.

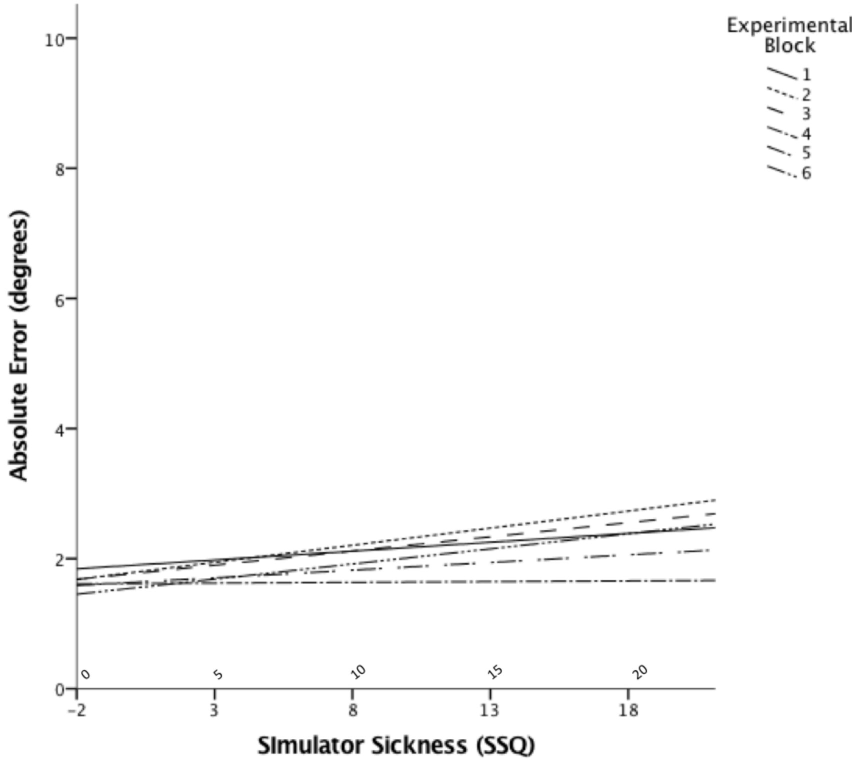


Figure 46. Interaction of block and simulator sickness (SSQ) predicting absolute error in the experimental blocks of experiment 2. The x-axis scale is the grand mean center simulator sickness (SSQ) variable with the translated actual values located above.

5.3.2. Pre-/ Post-test Analyses for Experiment 2

5.3.2.1. Absolute Error Primary Analysis for the Pre-/ Post-Test Block in Experiment 2

The only change from the experimental block analysis is that in the secondary analysis MSAQ-pre and –post is grouped into a single variable for the pre-/post analysis creating a level 2 variable. The F-Test results from the hierarchical linear modeling for accuracy as the outcome can be seen in Table 20. Due to the size of the complete coefficient table, only the main effects' and significant interactions' coefficients and standard errors are included in the table. Please see Appendix P for the comprehensive coefficient table.

Table 20. Fixed Coefficients, Standard Errors and $R^2\Delta$ for Absolute Error in the Pre-/ Post Blocks of Experiment 2.

Fixed Effects						
				ΔR^2		
Predictor	Coefficient (SE)	F-Test	P-value	L1	L2	Cross-Level Interaction
Intercept	2.16 (0.25)	--	--	--	--	--
Block	--	43.638	<0.001	.0393	--	--
Block Trial (Btrial)	0.09 (0.03)	13.457	<0.001	.0224	--	--
Location (Loc)	--	7.66	0.006	.0064	--	--
Action Requirement (AR)	--	5.454	0.02	.0035	--	--
Directionality (Dir)	--	3.395	0.066	--	--	--
Condition (Cond)	--	0.601	0.553	--	--	--
Block * Btrial	--	0.768	0.381	--	--	--
Block * Loc	--	0.167	0.683	--	--	--
Block * AR	--	0.288	0.591	--	--	--
Block * Dir	--	13.507	<0.001	.0127	--	--
Loc * Btrial	--	0.288	0.591	--	--	--
AR * Btrial	--	3.557	0.06	--	--	--
Dir * Btrial	--	1.003	0.317	--	--	--
Loc * AR	--	0.06	0.807	--	--	--
Dir * AR	--	4.615	0.032	.0046	--	--
Loc * Dir	--	3.462	0.063	--	--	--
Block * Cond	--	3.15	0.043	--	--	.0039
Cond * Btrial	--	0.658	0.521	--	--	--
Cond * Loc	--	3.084	0.046	--	--	.0045
Cond * AR	--	0.02	0.98	--	--	--
Cond * Dir	--	1.592	0.204	--	--	--
Block * Loc * Btrial	--	5.199	0.023	.0048	--	--
Block * AR * Btrial	--	1.252	0.263	--	--	--
Block * Dir * Btrial	--	1.638	0.201	--	--	--
Block * Loc * AR	--	0.34	0.56	--	--	--
Block * Loc * Dir	--	4.662	0.031	.0031	--	--
Block * Dir * AR	--	0.943	0.332	--	--	--
Loc * AR * Btrial	--	1.718	0.19	--	--	--
Loc * Dir * Btrial	--	2.366	0.124	--	--	--
Dir * AR * Btrial	--	22.945	<0.001	.0297	--	--
Loc * Dir * AR	--	0.535	0.465		--	--
Loc * AR * Btrial	--	1.143	0.319	--	--	--
Block * Cond * Btrial	--	0.843	0.431	--	--	--
Block * Cond * Loc	--	0.454	0.635	--	--	--
Block * Cond * AR	--	2.316	0.099	--	--	--
Block * Cond * Dir	--	2.442	0.088	--	--	--
Cond * Loc * Btrial	--	0.53	0.589	--	--	--
Cond * AR * Btrial	--	1.327	0.266	--	--	--
Cond * Dir * Btrial	--	1.236	0.295	--	--	--
Cond * Loc * AR	--	0.072	0.931	--	--	--
Cond * Loc * Dir	--	0.462	0.63	--	--	--
Cond * Dir * AR	--	2.595	0.075	--	--	--
Block * Loc * Dir * AR	--	0.74	0.39	--	--	--

Loc * Dir * AR * Btrial	--	1.055	0.305	--	--	--
Block * Loc * AR * Btrial	--	0.08	0.778	--	--	--
Block * Loc * Dir * Btrial	--	0.528	0.468	--	--	--
Block * Cond * Loc * Btrial	--	0.179	0.672	--	--	--
Block * Cond * AR * Btrial	--	1.269	0.282	--	--	--
Block * Cond * Dir * Btrial	--	0.519	0.595	--	--	--
Block * Cond * Loc * AR	--	2.258	0.105	--	--	--
Block * Cond * Loc * Dir	--	1.922	0.147	--	--	--
Block * Cond * Dir * AR	--	1.949	0.143	--	--	--
Cond * Loc * AR * Btrial	--	3.059	0.047	--	--	.0047
Cond * Loc * Dir * Btrial	--	0.079	0.924	--	--	--
Cond * Dir * AR * Btrial	--	0.401	0.67	--	--	--
Cond * Loc * Dir * AR	--	1.319	0.268	--	--	--
Block * Loc * Dir * AR * Btrial	--	1.204	0.3	--	--	--
Block * Cond * Loc * Dir * AR	--	0.784	0.376	--	--	--
Cond * Loc * Dir * AR * Btrial	--	3.104	0.045	--	--	.1112
Block * Cond * Loc * AR * Btrial	--	0.248	0.781	--	--	--
Block * Cond * Loc * Dir * Btrial	--	0.278	0.757	--	--	--
Block * Cond * Dir * AR * Btrial	--	0.896	0.408	--	--	--
Block * Cond * Loc * Dir * AR * Btrial	--	0.427	0.653			
			Total ΔR^2	.1265	--	.1243

There were four significant main effects: block, block trial, and target location and action requirement. For the main effect of block, the pre-test block had more absolute error (M = 3.20, SD = 2.51) than the post-test block (M = 2.38, SD = 1.84). This effect accounts for a total of 3.93% of explained variance. The block trials main effect can be seen in Figure 47. As participants go through the trials within the pre and post-test block on average they are increasing their absolute error amount by 0.09 degrees per block. This indicates that without visual feedback, calibration is not occurring within these blocks on average. This effect account for a total of 2.24% of explained variance. Target location had a significant main effect with a total of 0.64% of the explained variance There were greater amounts of absolute error in the peripheral target (i.e., targets 1 and 4) estimates (M = 2.97, SD = 2.37) than the frontal target (i.e. targets 2 and 3) estimates (M=2.61, SD = 2.07). Lastly, the main effect of action requirement accounted for 0.35% of explained variance. Cross-body targets had more error in their estimation (M = 2.95, SD = 2.31) than open-body targets (M = 2.63, SD = 2.14).

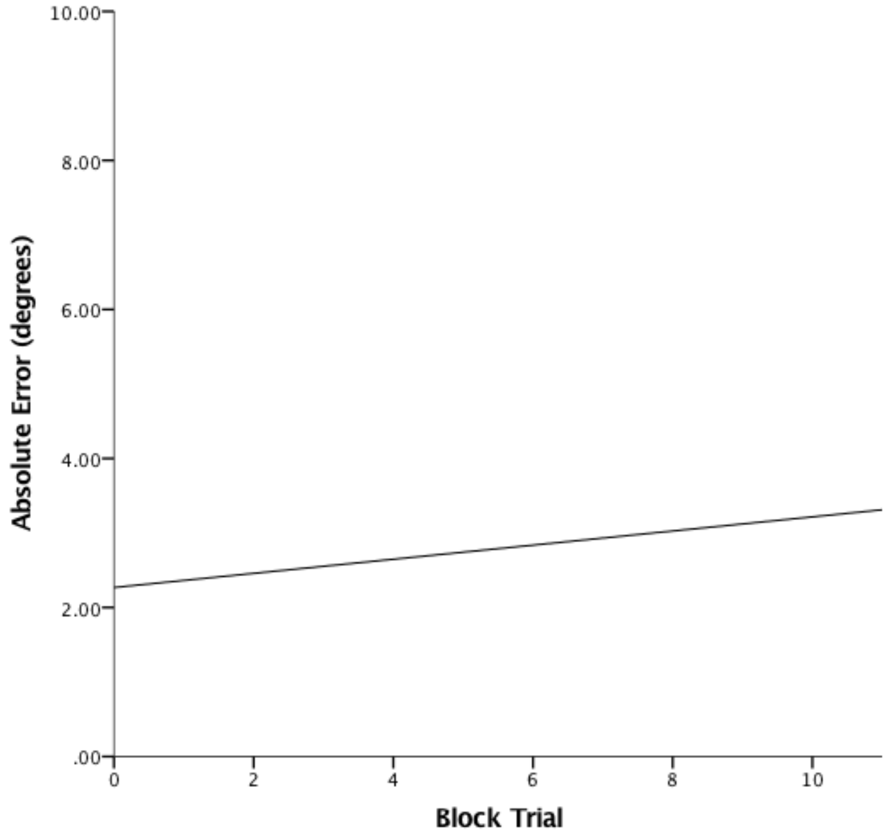


Figure 47. Main effect of trials within block on absolute error in the pre-/post-test blocks of Experiment 2. Note that the first trial in a block is considered trial 0 in the analysis and graph.

There were two Level 1 moderating Level 1 interactions that were significant: directionality moderating the effect of block on absolute error and directionality moderating the effect of action requirement on absolute error. To determine the simple effects, the data file was split by directionality to determine the simple effects of block and action requirement. Both under- and over-estimations had significant simple effects of block. The means and standard deviations for this interaction can be found in Table 21 and seen in Figure 48. Both under- and over-rotational estimations reduced from pre-test to post-test. In essence, calibration occurred for over- and

under-estimations. However, over-rotation estimates calibrated the most seeing the greatest decrease in absolute error from pre- to post-tests. This effect accounts for 1.27 % of the variance.

Table 21. Means and standard deviations of absolute error for the interaction of directionality and block in the pre- and post-test blocks of Experiment 2.

	Mean (SD)	
Estimate Directionality	Pre-Test	Post-Test
Under rotation	3.12 (2.32)	2.69 (1.96)
Over rotation	3.27 (2.68)	1.94 (1.55)

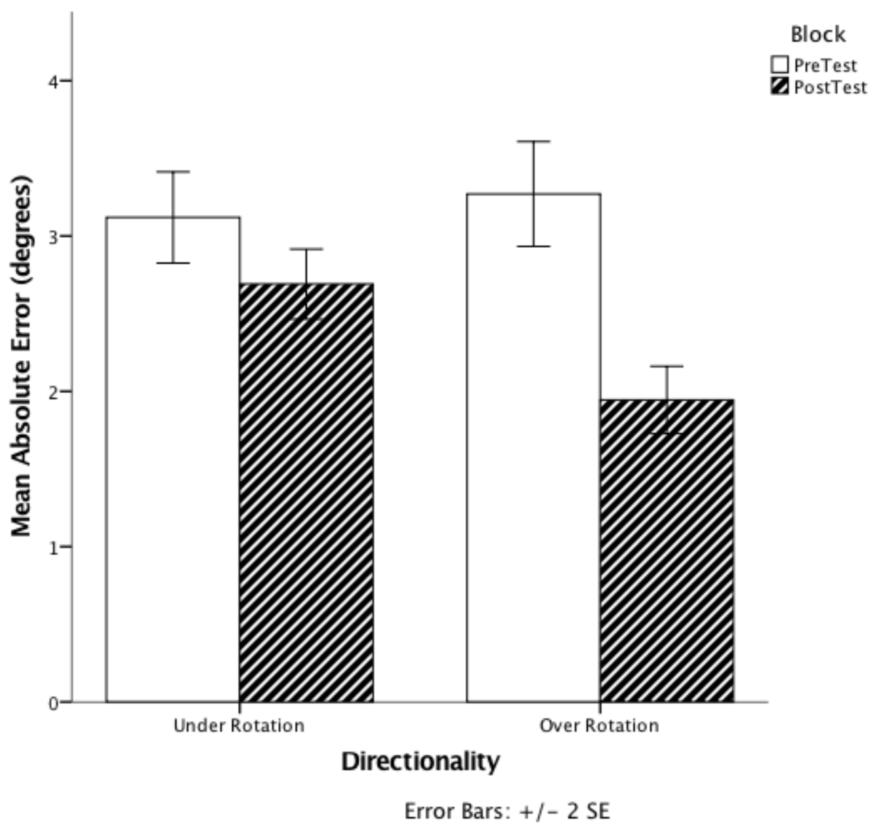


Figure 48. Interaction of directionality and block predicting absolute error (degrees) in experiment 2 pre- and post-test blocks.

The simple effect of action requirement also was significant in both under-rotation and over-rotation estimates. The means for this interaction can be found in Table 22 and seen in Figure 49. For cross-body targets, participants had larger under-rotated estimates than when they over-rotated. For open-body targets, participants over-rotated more than they under rotated. This effect explained 0.46 % of the variance.

Table 22. Means and standard deviations of absolute error for the interaction of directionality and block in the pre- and post-test blocks of Experiment 2.

	Mean (SD)	
	Cross-Body	Open-Body
Under-Rotation	3.28 (2.28)	2.32 (1.78)
Over-Rotation	2.35 (2.25)	2.89 (2.37)

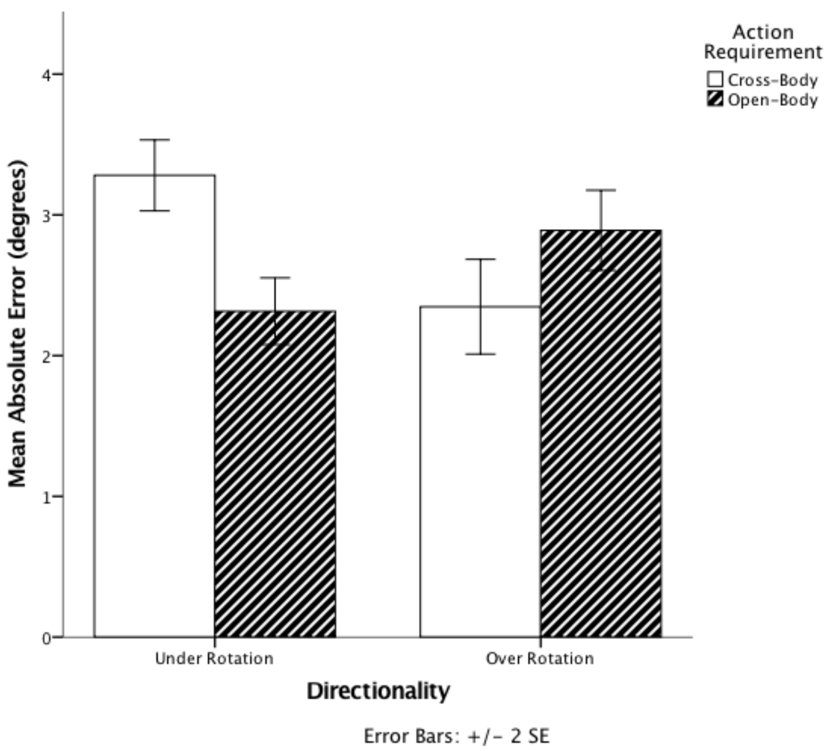


Figure 49. Interaction of directionality and action requirement predicting absolute error (degrees) in experiment 2 pre- and post-test blocks.

The two cross-level two-way interaction: block by condition and location by condition. The block by condition interaction accounted for 0.39% of the variance. All three conditions significantly decreased the amount of error in the post test (see Table 23 for means and standard deviations). This interaction can be seen in Figure 50. What is most interesting is that the absolute error is approximately the same across conditions in the post-test, indicating that condition did not affect calibration in general.

Table 23. Means and standard deviations of absolute error for the interaction of condition and block in the pre- and post-test blocks of Experiment 2.

	Mean (SD)	
Condition	Pre-Test	Post-Test
Control	3.29 (2.62)	2.27 (1.72)
Oscillating	2.79 (2.33)	2.42 (1.78)
Constant Increase	3.56 (2.53)	2.48 (2.02)

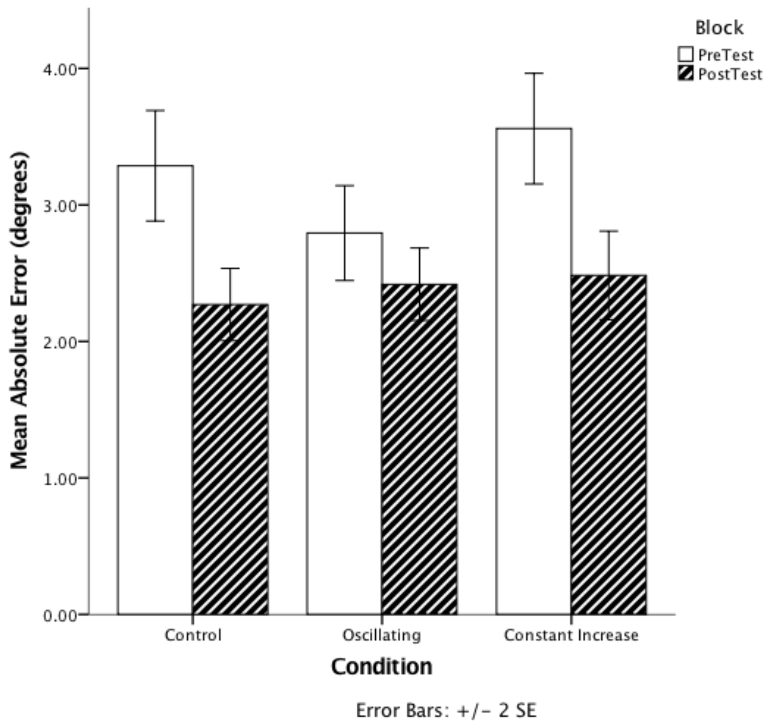


Figure 50. Interaction of block and condition predicting absolute error (degrees) in experiment 2 pre- and post-test blocks.

The second cross-level interaction was between condition and location. This interaction accounted for 0.45% of explained variance. The simple effect of location is significant only in the control and constant increase conditions. The means and standard deviations can be found in Table 24 and the interaction can be seen in Figure 51. Both the control and constant increase conditions had significantly more error for peripheral targets and frontal targets.

Table 24. Means and standard deviations of absolute error for the interaction of location and condition in the pre- and post-test blocks of Experiment 2.

	Mean (SD)	
Condition	Frontal	Peripheral
Control	2.53 (1.97)	3.02 (2.50
Oscillating	2.61 (2.10)	2.60 (2.07)
Constant Increase	2.69 (2.14)	3.35 (2.51)

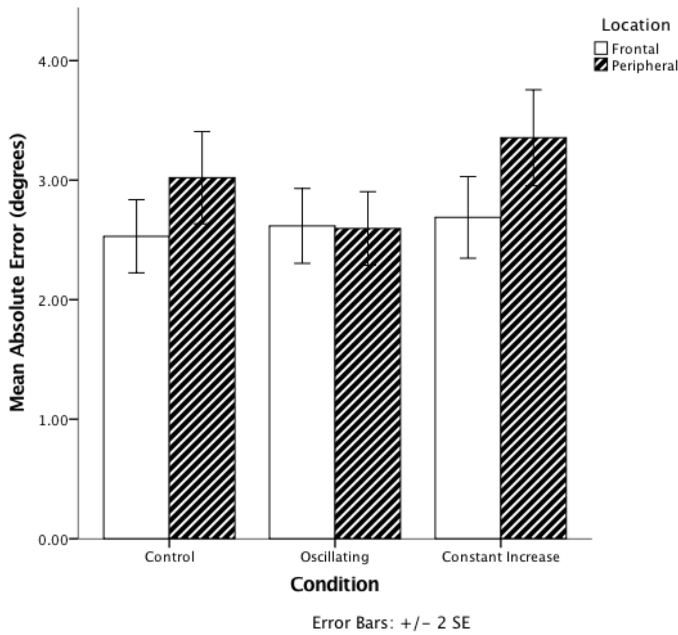


Figure 51. Interaction of location and condition predicting absolute error (degrees) in experiment 2 pre- and post-test blocks.

There were three three-way significant level 1 interactions. This first was block by block trial by target location. Decomposed into simple effects found that the pre tests, the frontal targets had a significant slope of block and in the post-test the peripheral targets had a significant slope. This three-way interact can be seen in Figure 52. As block trials increased in the pre-test for the frontal targets, the amount of error increases by 0.12 per trial. As block trials increase in

the post-test for the peripheral targets, the amount of error increases by 0.15 per trial. This interaction accounted for 0.48% of explained variance.

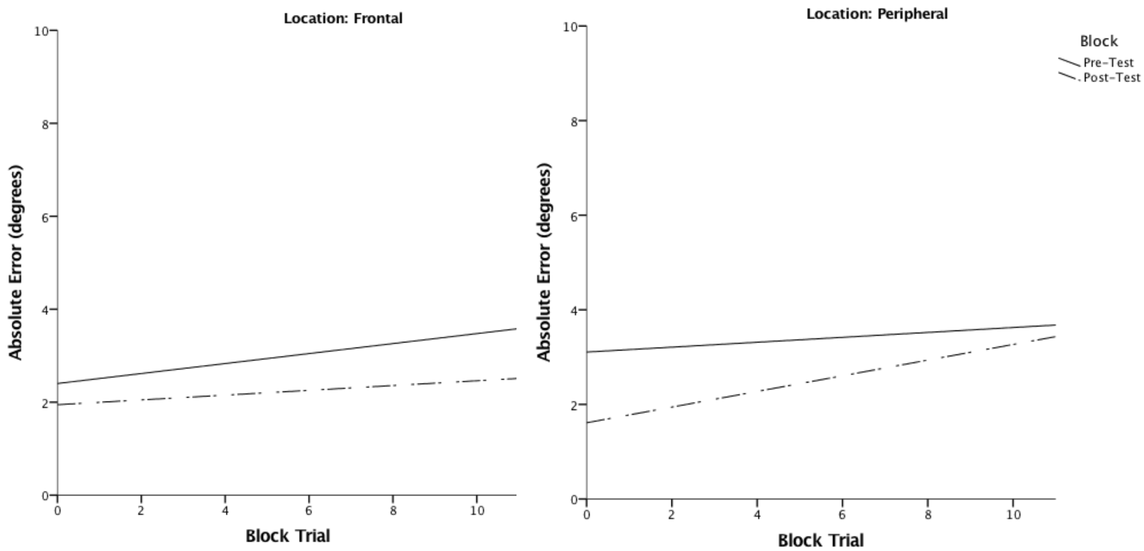


Figure 52. Three-way interaction of block trial by block by target location for the pre-/ post- test blocks of Experiment 2. There was a significant slope for frontal targets in the pre-test and peripheral targets in the post-test. Note that the first trial in a block is considered trial 0 in the analysis and graph.

The second three-way interaction was between target location, block, and estimate directionality. When decomposed into simple effects, directionality was significant in both blocks for frontal targets but over-rotation was significant for the peripheral targets between blocks. This interaction can be seen in Figure 53. There was a decrease in the amount of error from pre- to post-test in general for both target locations. Under-rotated estimates remained about the same in the pre-tests for peripheral targets. This indicates that calibration did not occur significantly for peripheral targets if participants underestimated. This interaction accounts for 0.31% of explained variance.

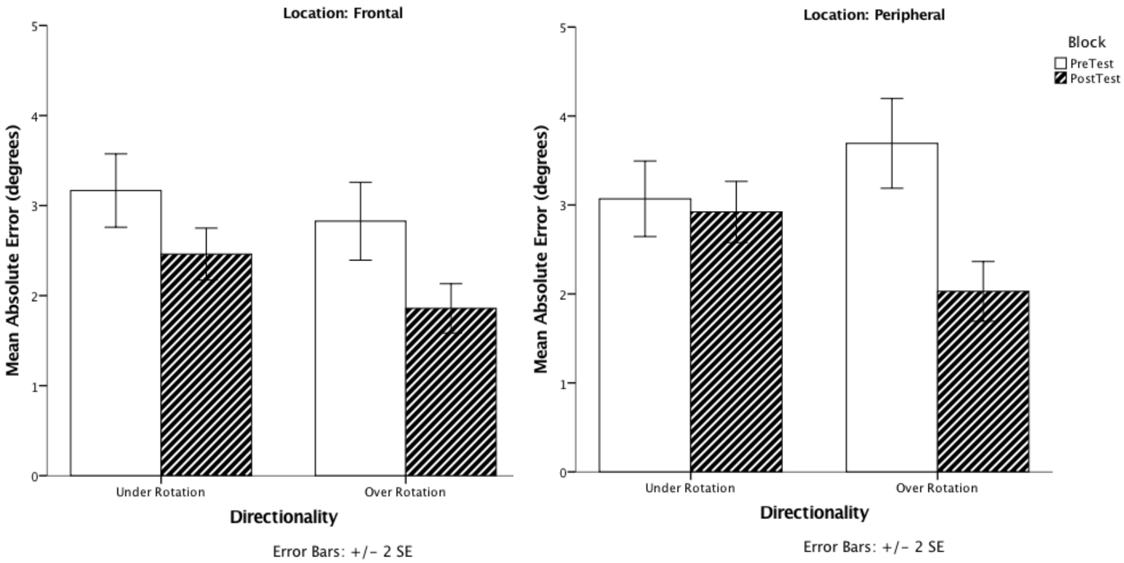


Figure 53. Three-way interaction between target location, block, and directionality predicting absolute error (degrees) in the pre-/ post-test blocks in Experiment 2.

The third significant L1 three-way interaction was block trial by action requirement by directionality. When decomposed into simple effects, cross-body targets had a significant slope of block trial for estimations that were under-rotated while open-body targets had a significant slop of over rotation across block trials. These effects can be seen in Figure 54. In essence, for cross-body targets, as the participants went through the trials within the blocks, the amount of error increased (i.e., they under rotated more) by 0.25 degrees per trial increase. However, for open-body targets. participants began over-rotating their estimates increased by 0.13 in error per trial increase. This account for 2.97% of the explain variance.

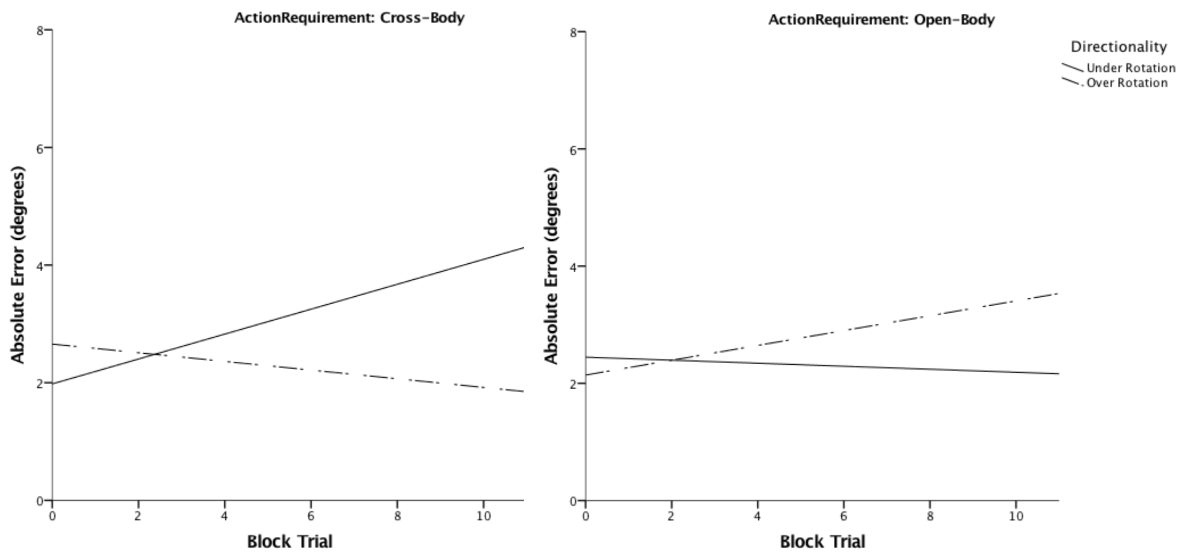


Figure 54. Three-way interaction of block trial by action requirement by directionality in pre-/ post-test blocks of experiment 2. Upon investigating the simple effects of the interaction, it was determined targets requiring a cross-body movement increased in absolute error for under-rotated estimates as participants continued through the blocks. For open-body movement, absolute error increased for over-rotated estimates as the trials continued. Note that the first trial in a block is considered trial 0 in the analysis and graph.

There was one significant four-way cross-level interaction between condition, block, action requirement and directionality accounting for 0.47% of the explained variance in the model. After decomposing this interaction, it was determined that the effect was located in the open-body targets for under-estimations (see Figure 55). The control and oscillating conditions had significant differences between the pre-test and post-test. The decrease pattern shown in the control condition is a typical pattern seen in calibration studies (i.e., a reduction in error) while the increase in the oscillating condition is typical of the perturbed conditions of past research where participants calibrate to the perturbed state. What is interesting is this is a similar pattern as the constant condition in experiment 1. Lastly, the constant increase condition was not

significantly different in the post-test from the pre-test; however, they did decrease which is opposite of the expected finding.

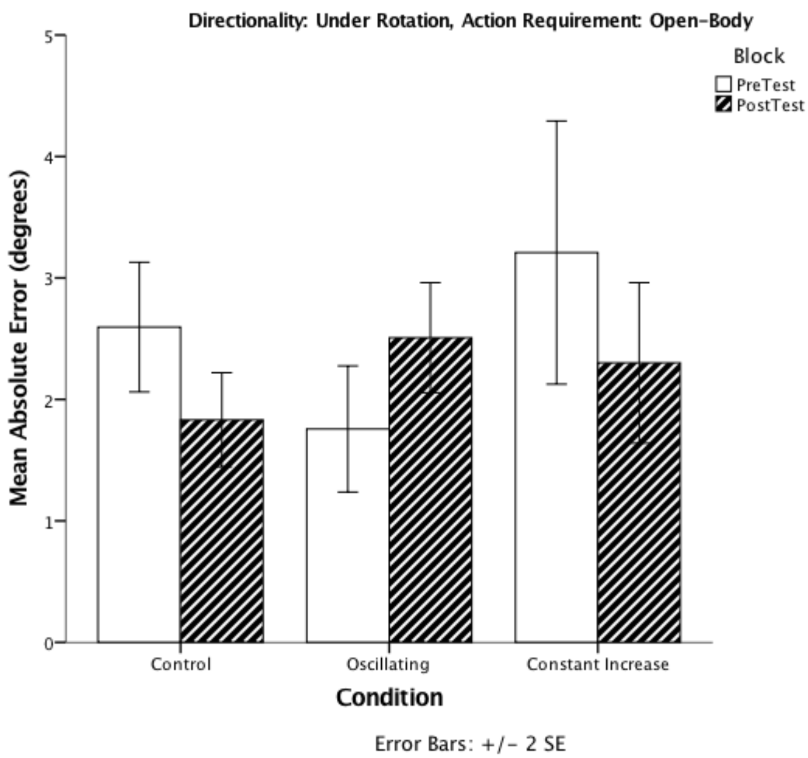


Figure 55. Three-way interaction of block by action requirement by directionality by condition for pre-/ post-test blocks in experiment 2.

Lastly, there was a significant five-way interaction between condition, target location, action requirement, estimation directionality, and block trial. When decomposed to determine significant simple slopes it was determined that the significant simple slopes were for under-rotation estimates. For the control condition there was a significant slope for peripheral targets that required cross-body action (i.e., target 1; see Figure 56). As participants in the control

condition increased by 1 block trial the amount of error increased by 0.40 degrees per trial increase for target 1. For the oscillating condition there were two significant slopes. Both were under-rotation estimates for frontal targets. For cross-body frontal targets (i.e., target 2), error increased by 0.25 degrees per block and for open-body frontal targets (i.e., target 3), error decreased by 18 degrees per block (see Figure 57). There were no significant simple slopes for the constant increase condition. The negative slope shows a calibration relationship while the positive slopes show an increasingly disoriented system.

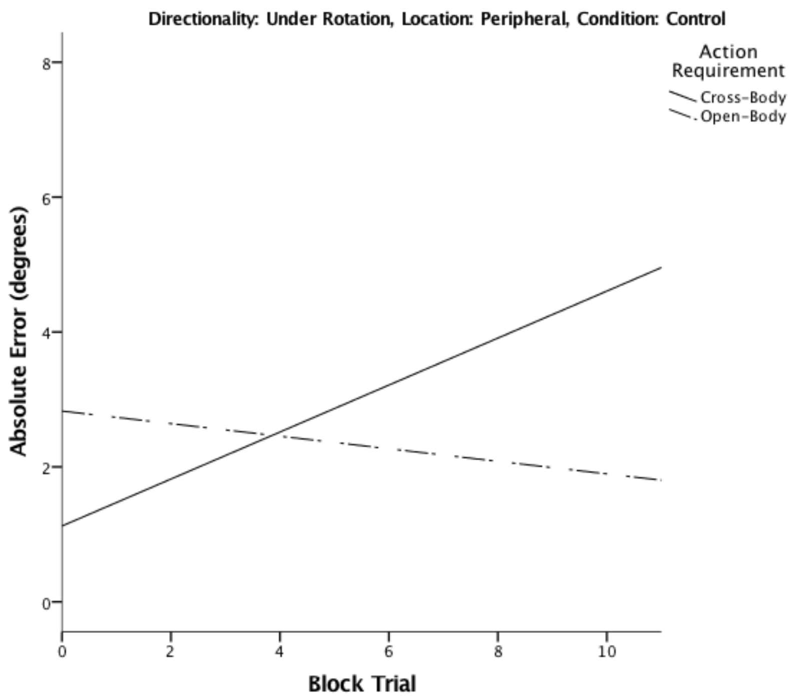


Figure 56. The five-way interaction for control condition, peripheral target, under-rotation estimation, block trial, and action requirement in experiment 2 pre-/ post-test blocks. A significant simple slope was for the cross-body action. Note that the first trial in a block is considered trial 0 in the analysis and graph.

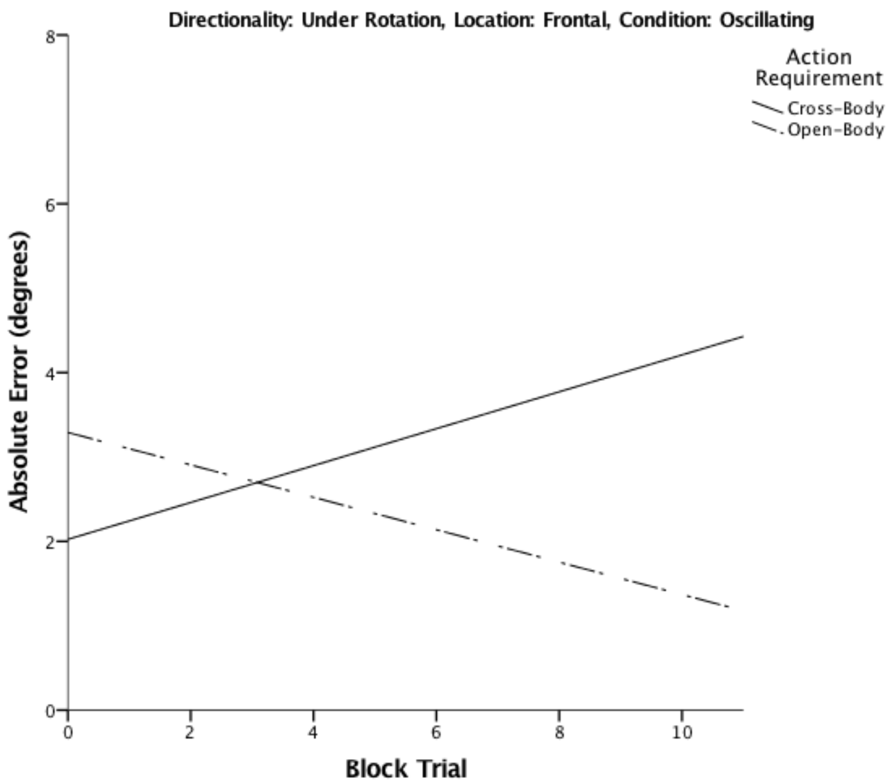


Figure 57. The five-way interaction for oscillating condition, frontal target, under-rotation estimation, block trial, and action requirement in experiment 2 pre-/ post-test blocks. A significant simple slope was for both the cross-body and the open-body actions. Note that the first trial in a block is considered trial 0 in the analysis and graph.

5.3.2.2. Absolute Error Secondary Analysis for the Pre-/ Post-Test Block in Experiment 2

This is the same analyses as used for the experimental blocks. However, MSAQ was turned into a Level 1 variables as it varies between these two blocks. Again, due to the high correlation between max head rotation and total head rotation, these two variables were analyzed in their perspective models without the inclusion of the other. This was to guard against any suppression that may occur with both variables in the model simultaneously. Since primary models and interactions have been discussed previous, only the significant new effects will be discussed. The

F-Test results from the hierarchical linear modeling for accuracy as the outcome including secondary variables can be seen in Table 25. Only continuous variables will have coefficients and standard errors included in the model. For a full table of all coefficients please refer to Appendix Q.

Table 25: Fixed Coefficients, Standard Errors and $R^2\Delta$ for Absolute Error for the Secondary Variables in pre-/ post-test analyses in Experiment 2.

Fixed Effects						
				ΔR^2		
Predictor	Coefficient (SE)	F-Test	P-value	L1	L2	Cross-Level Interaction
Intercept	3.28 (0.32)	--	--	--	--	--
Block		32.419	<0.001	.0275	--	--
	0.09 (0.03)				--	--
Block trial		12.601	0.001	.0196		
Location		24.035	<0.001	.0192	--	--
Action Requirement		10	0.002	.0076	--	--
Directionality		33.234	<0.001	.0290	--	--
Total Rotation	0.01 (0.01)	3.429	0.064		--	--
Max Rotation	0.10 (0.02)	27.398	<0.001	.0185	--	--
Rotation Difference	0.17 (0.02)	62.697	<0.001	.0564	--	--
SampEn-X	-0.9 (4.60)	0.038	0.845		--	--
SampEn-Y	6.01 (4.50)	1.785	0.184		--	--
MSAQ		1.354	0.246		--	--
Condition		0.093	0.911		--	--
Block * Total Rotation		0.891	0.346		--	--
Block * Max Rotation		1.167	0.28		--	--
Block * Rotation Difference		4.408	0.036	.0029	--	--
Condition * MSAQ		1.165	0.314		--	--
Condition * Total Rotation		3.1	0.045		--	.0029
Condition * Max Rotation		2.804	0.061		--	--
Condition * Rotation Difference		6.301	0.002		--	.0011
Block * Condition		2.334	0.097		--	--
Condition * Btrial		0.648	0.527		--	--
Block * Condition * Total Rotation		0.218	0.804		--	--
Block * Condition * Max Rotation		0.109	0.897		--	--
Block * Condition * Rotation Difference		2.719	0.066		--	--
			TotalΔR^2	.1807	--	.0040

There were two significant secondary variables: max rotation and rotational difference. The main effect of max rotation accounted for 1.85% of the explained variance. As shown in

Figure 58, as the max rotation increased by one degree, error increased by 0.10 degrees. Meaning that the greater the maximum rotation was the more error for the estimation.

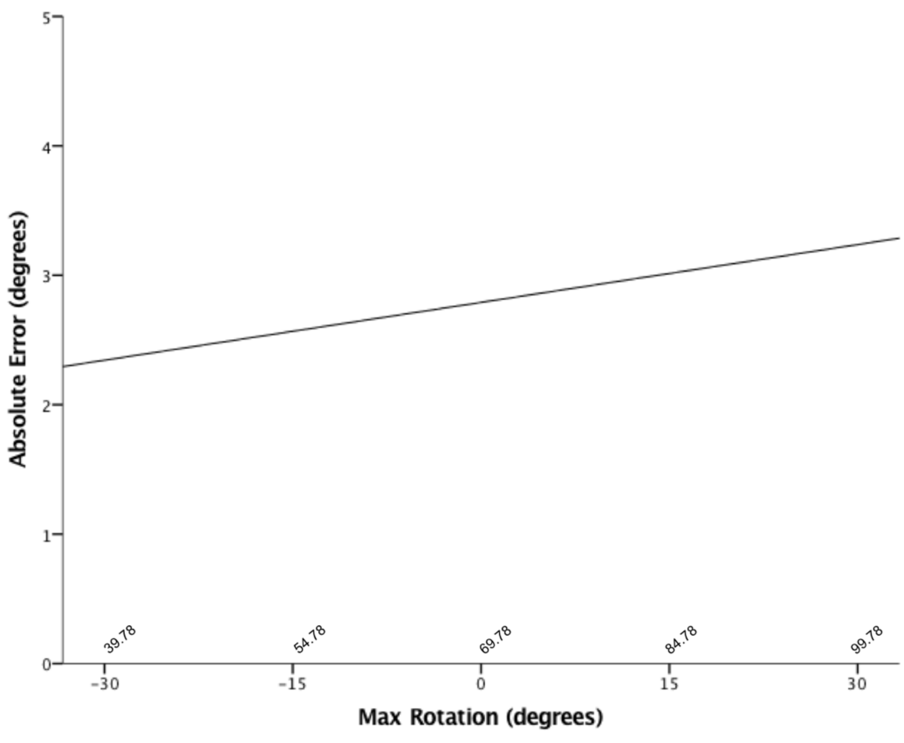


Figure 58. The main effect of max rotation on absolute error in the pre- and post-test blocks of Experiment 2. The x-axis scale is the grand mean center max rotation variable with the translated actual values located above.

The main effect was the rotational difference between the head rotation and the target estimation. This effect accounts for 5.64% of the total explained variance. As depicted in Figure 59, as the difference between the head rotation and estimation rotation increases by 1 degree, absolute error increases by 0.17 degrees. Meaning that more accurate estimations occur when there are smaller disparities between the angle of the head and the the angle of the estimating arm.

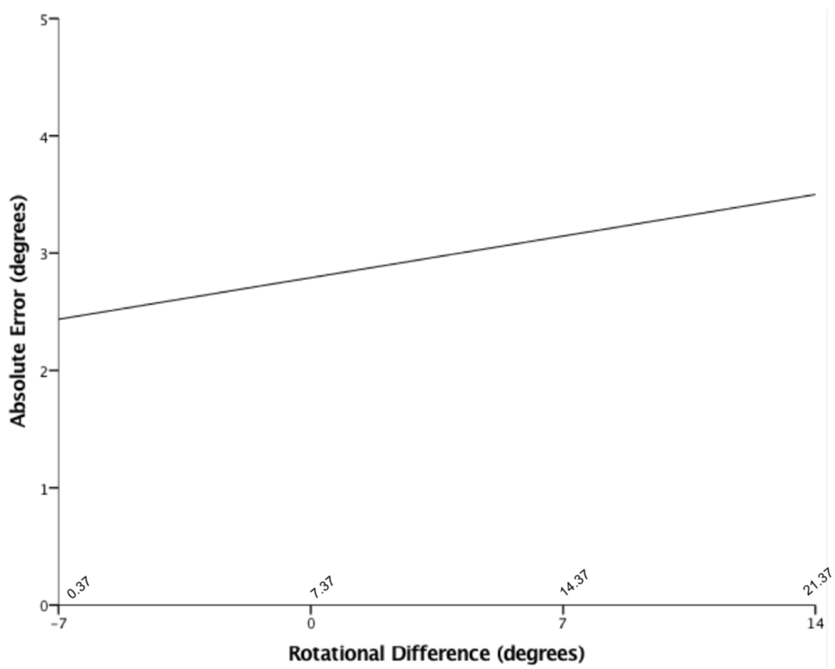


Figure 59. The main effect of rotational difference between head rotation and estimating arm rotation on absolute error in the pre- and post-test blocks of Experiment 2. The x-axis scale is the grand mean center rotational difference variable with the translated actual values located above.

There was a significant two-way interaction between rotational differences and block. Simple slopes were conducted to determine how the slopes vary between blocks. Only the pre-test block had a significant simple slope (see Figure 60). In this figure you can see that in the pre-test as the degree of rotational difference between the head angle and the estimation angle increases, the absolute error also increases by about 0.23 degrees. Essentially, in the pre- test, the difference between head degree and estimation of the pointing arm greatly influenced the accuracy of the estimate. What is also noteworthy is that this effect is not seen in the post-test block. This effect account for 0.29% of the explained variance in the model.

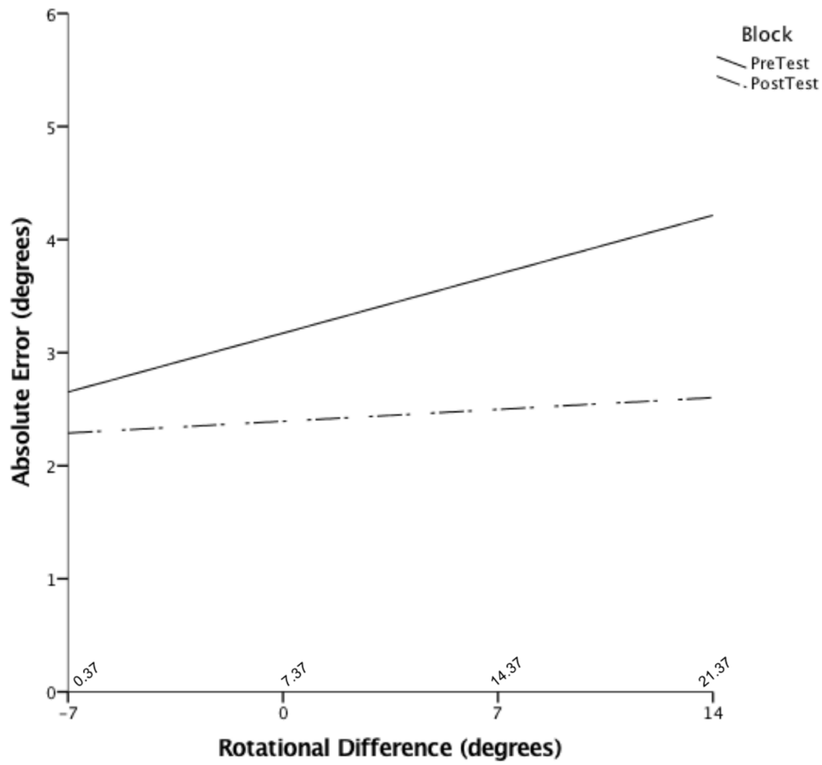


Figure 60. The interaction effect of block and the rotational difference between head rotation and estimating arm rotation on absolute error for the pre- and post-tests of Experiment 2. Only the pre-test slope was significant. The x-axis scale is the grand mean center rotational difference variable with the translated actual values located above.

There were two significant cross-level two-way interaction with condition moderating total rotation and rotational difference. The first was condition and total rotation. When decomposed into simple slopes, only the constant increase condition had a significant positive slope (see Figure 61). As participants in this condition increased the total rotation by one degree, their absolute error increased by 0.03 degrees.

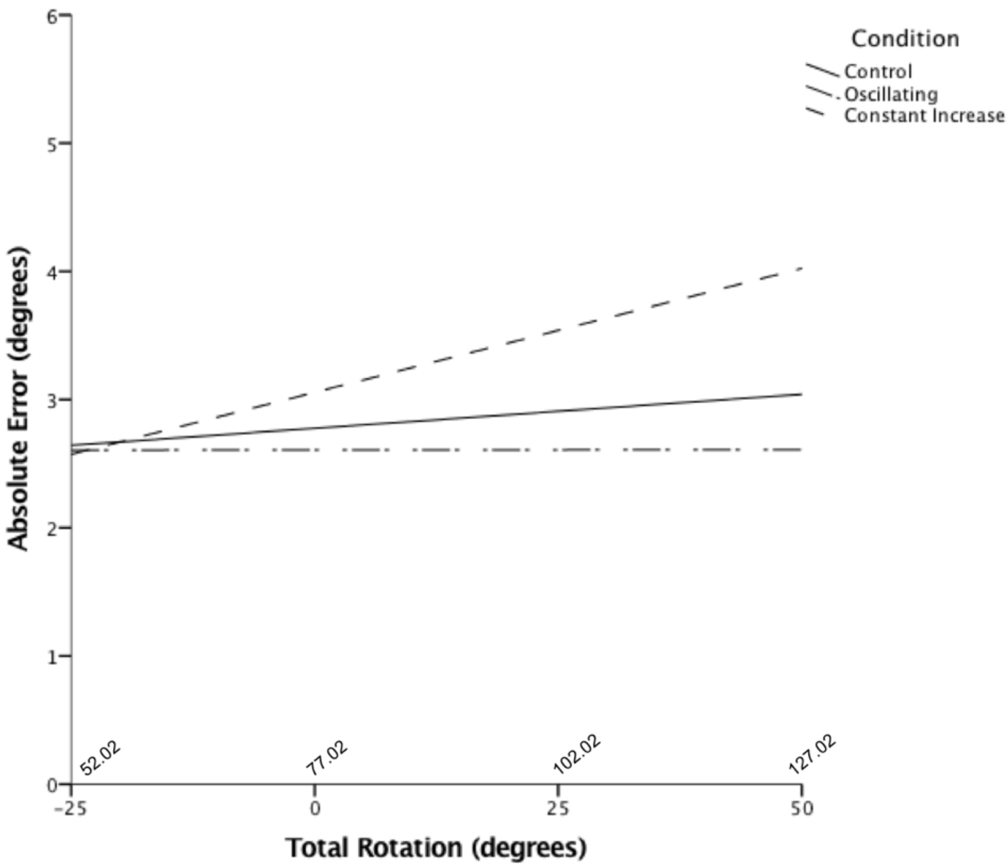


Figure 61. The interaction effect of condition and the total rotation on absolute error in the pre- and post-test blocks of Experiment 2. Only the constant-increase conditions had significant simple slopes. The x-axis scale is the grand mean center total rotation variable with the translated actual values located above.

The second cross-level two-way interaction was between condition and rotational difference. Decomposing the effect found that only control and constant increase conditions had significant rotational difference slopes (see Figure 62). Investigating this interaction found the effect of rotational difference on absolute error is in the post-test phase in the control and constant increase condition. As the rotational difference increased, individuals in the control condition increased their estimation error by about 0.16 degrees for every rotational difference increased. Those in the constant increase condition decreased their absolute error by about 0.11

for every rotational difference increase. This indicates that rotational difference did not affect those in the oscillating condition, but did for those in the control and constant increase condition.

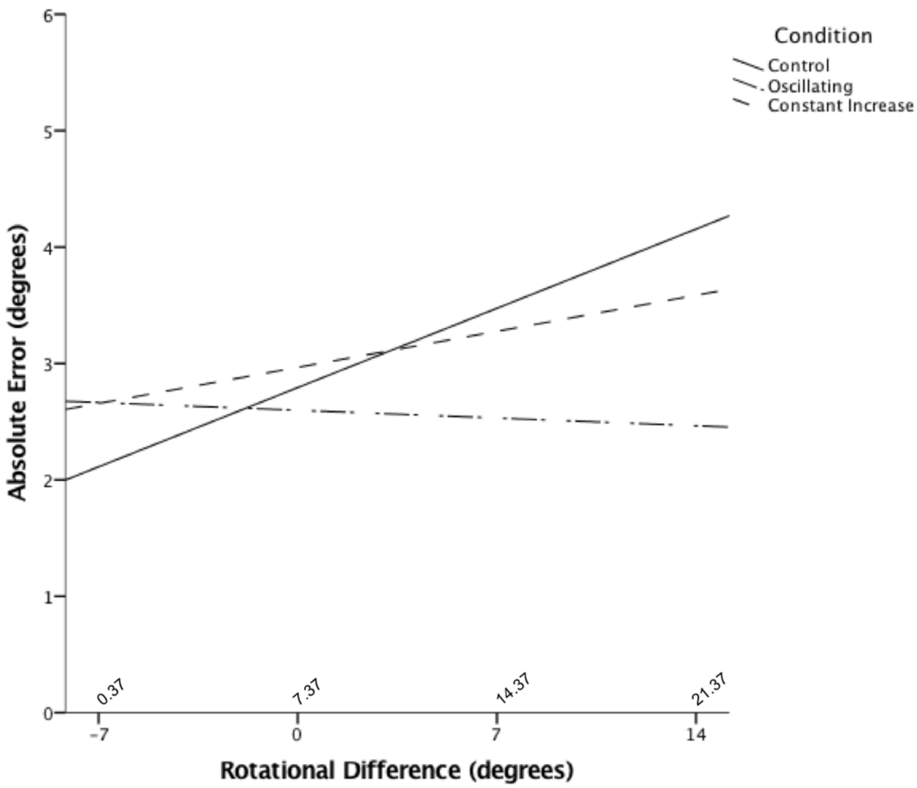


Figure 62. The interaction effect of condition and the rotational difference between head rotation and estimating arm rotation on absolute error in the pre- and post-test blocks of Experiment 2. Only the control and constant -increase conditions had significant simple slopes. The x-axis scale is the grand mean center rotational difference variable with the translated actual values located above.

5.4. Postural Sway: Entropy for Experiment 2

The predictors for the dependent variable of postural sway are block, condition and the two-way interaction. There are two measures of the entropy, the mediolateral sway (SampEn-X) and the posterior-anterior sway (SampEn-Y). Both of these variables are measured at the block level and therefore, trials within blocks cannot be used as a variable. The postural sway indexed by the

SampEn-X variable is the shifting of the COP by shifting weight to either side of the body (i.e., left to right). While the SampEn-Y variable is the shifting of the COP by shifting weight forward and backward (i.e., between the toes and heels of the foot).

5.4.1. Postural Sway Analysis for the Experimental Blocks in Experiment 2

The F-Test results from the hierarchical linear modeling for SampEn-X and SampEn-Y as the outcome can be seen in Table 26.

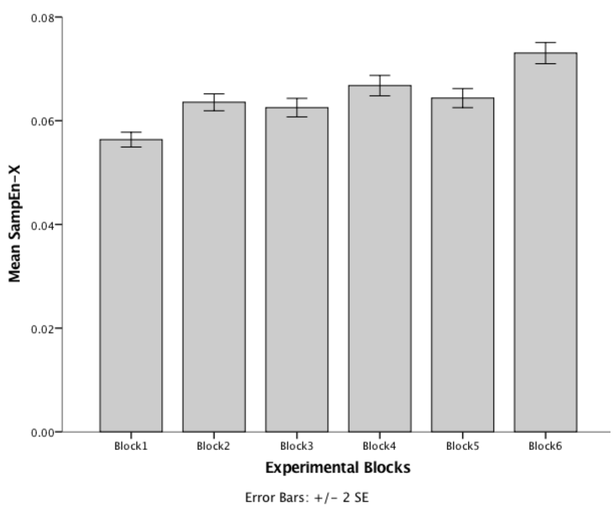
Table 26. F-tests for SampEn-X and –Y for the experimental blocks in experiment 2.

				ΔR^2		
Outcome Variable	Model	F-Test	P-value	L1	L2	Cross-Level Interaction
SampEn-X	Block	106.58	<0.001	.1506	--	--
	Condition	0.30	0.74	--	--	--
	Block*Condition	27.47	<0.001	--	--	.0663
SampEn-Y	Block	18.38	<0.001	.0245	--	--
	Condition	2.40	0.10	--	--	--
	Block*Condition	36.93	<0.001	--	--	.1050

Both outcome variables had significant main effects of block. The means for block can be found in Table 27 and visualized in Figure 63. For SampEn-X all blocks were significantly different from block 1, but only blocks 5 and 6 were significantly different than block 1 for SampEn-Y. LSD post hoc analyses can be found in Appendix R for SampEn-X and Appendix S for SampEn-Y. In general entropy increases across blocks for SampEn-X. However, for SampEn-Y, the first 4 blocks were not significantly different, but the last two blocks decreased. This effect accounted for 15.06% of explained variance of the SampEn-X variable and 2.45% of the explained variance of the SampEn-Y variable.

Table 27. Mean and standard deviations of the main effect of block on SampEn-X and SampEn-Y in the experimental blocks of Experiment 2.

	Mean (SD)	
Block	SampEn-X	SampEn-Y
1	0.0563 (0.02)	0.0620 (0.02)
2	0.0636 (0.02)	0.0610 (0.02)
3	0.0625 (0.02)	0.0631 (0.02)
4	0.0668 (0.02)	0.0627 (0.02)
5	0.0644 (0.02)	0.0582 (0.02)
6	0.0730 (0.02)	0.0597 (0.02)



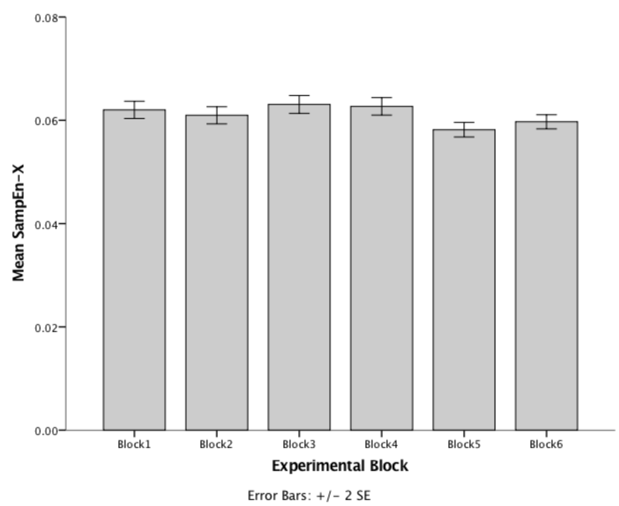


Figure 63. Means and standard errors of the main effect of block on SampEn-X and SampEn-Y for the experimental blocks in Experiment 2.

Additionally, the two-way interaction between block and condition was significant for both entropy outcome variables. For SampEn-X, the interaction accounted for 6.63% in explained variance while it accounted for 10.50% in explained variance for SampEn-Y. The means for block can be found in Table 28 and visualized in Figure 64. When the interaction was analyzed for the simple effects, there were significant simple effect of block in all conditions for both SampEn-X and –Y. In general, there was more mediolateral sway than posterior-anterior

sway. What is most interesting is the pattern of the oscillating condition and the experimental condition. In the oscillating condition, an oscillating pattern can be seen in both SampEn-X and –Y. In this condition blocks 4 and 6 have the highest postural sway amounts, which is the opposite effect of what was hypothesized (calibration would create less postural sway). For the constant increase condition, a pattern of increase can be seen for SampEn-X but a decreasing pattern can be seen in SampEn-Y. In essence, as the mediolateral sway increased the posterior-anterior sway decreased. The constant increase demonstrates the most variability between the three conditions for the SampEn-X.

Table 28. Mean and standard deviations of the interaction effect of block and condition on SampEn-X and SampEn-Y for the experimental blocks of Experiment 2.

	SampEn-X			*SampEn-Y*		
Experimental Block	Control	Oscillating	Random Increase	Control	Oscillating	Random Increase
1	0.0579 (0.02)	0.0560 (0.01)	0.0551 (0.02)	0.0517 (0.01)	0.0677 (0.02)	0.0666 (0.02)
2	0.0664 (0.02)	0.0620 (0.02)	0.0623 (0.02)	0.0507 (0.01)	0.0659 (0.02)	0.0663 (0.02)
3	0.0650 (0.02)	0.0589 (0.02)	0.0641 (0.02)	0.0546 (0.01)	0.0694 (0.02)	0.0649 (0.02)
4	0.0610 (0.02)	0.0704 (0.03)	0.0689 (0.02)	0.0598 (0.01)	0.0656 (0.02)	0.0625 (0.02)
5	0.0638 (0.02)	0.0573 (0.02)	0.0732 (0.02)	0.0548 (0.01)	0.0669 (0.02)	0.0517 (0.01)
6	0.0695 (0.02)	0.0701 (0.02)	0.0802 (0.03)	0.0573 (0.01)	0.0652 (0.02)	0.0560 (0.02

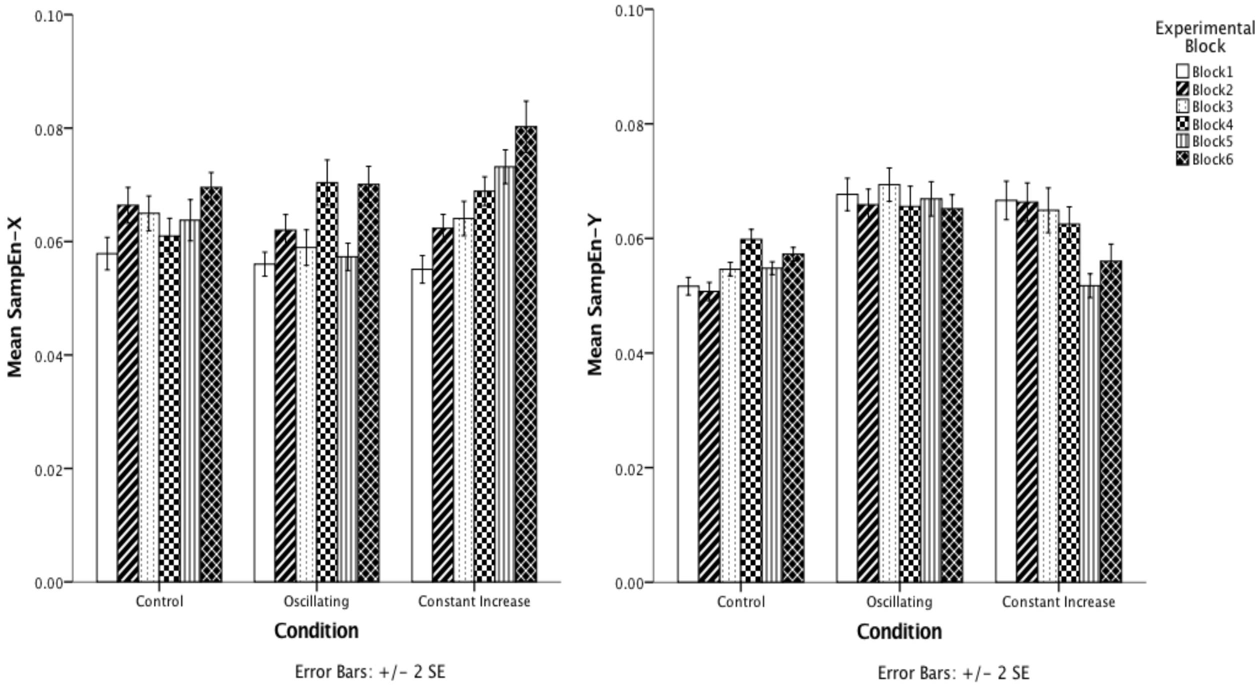


Figure 64. Means and standard errors of the interaction of block and condition on SampEn-X and SampEn-Y for the experimental blocks in Experiment 2.

5.4.1.2. Postural Sway Analysis for the Pre-/ Post-Test Blocks in Experiment 2

The F-Test results from the hierarchical linear modeling for SampEn-X and SampEn-Y as the outcome can be seen in Table 29.

Table 29. F-tests for SampEn-X and –Y for the pre- and post-test blocks in experiment 2.

						ΔR^2
Outcome Variable	Model	F-Test	P-value	L1%	L2 %	Cross-Level Interaction%
SampEn-X	Block	2.04	0.15	--	--	--
	Condition	1.10	0.35	--	--	--
	Block*Condition	11.532	<0.001	--	--	.0248
SampEn-Y	Block	0.29	0.59	--	--	--
	Condition	1.78	0.18	--	--	--
	Block*Condition	67.504	0	--	--	.1206

The two-way interaction was the only significance for both SampEn-X and –Y. This accounted for 2.48% in explained variance for SampEn-X and 12.06% for SampEn-Y. There was a significant simple effects of block in all conditions for both outcome variables (see Table 30 for means and standard deviations). For SampEn-X, the control and constant increase conditions decreased from pre- to post-test while the oscillating condition increased (see Figure 65).

For the SampEn-Y, the control and oscillating condition increased from pre- to post while the constant increase condition decreased. The control condition significantly increased from pre- to post-test, while the constant increase condition significantly decreased from pre- to post-test (see Figure 65). In essence, the posterior-anterior sway increased from pre- to post-test for the control condition and decreased for the constant increase condition.

Table 30. Mean and standard deviations of the interaction effect of block and condition on SampEn-X and SampEn-Y for pre- and post-test blocks in Experiment 2.

	Mean (SD)			
	SampEn-X		SampEn-Y	
Condition	Pre	Post	Pre	Post
Control	0.0705 (0.02)	0.0662 (0.02)	0.0563 (0.01)	0.0634 (0.01)
Oscillating	0.0602 (0.02)	0.0635 (0.02)	0.0719 (0.02)	0.0745 (0.03)
Constant Increase	0.0627 (0.02)	0.0604 (0.02)	0.0738 (0.03)	0.0643 (0.02)

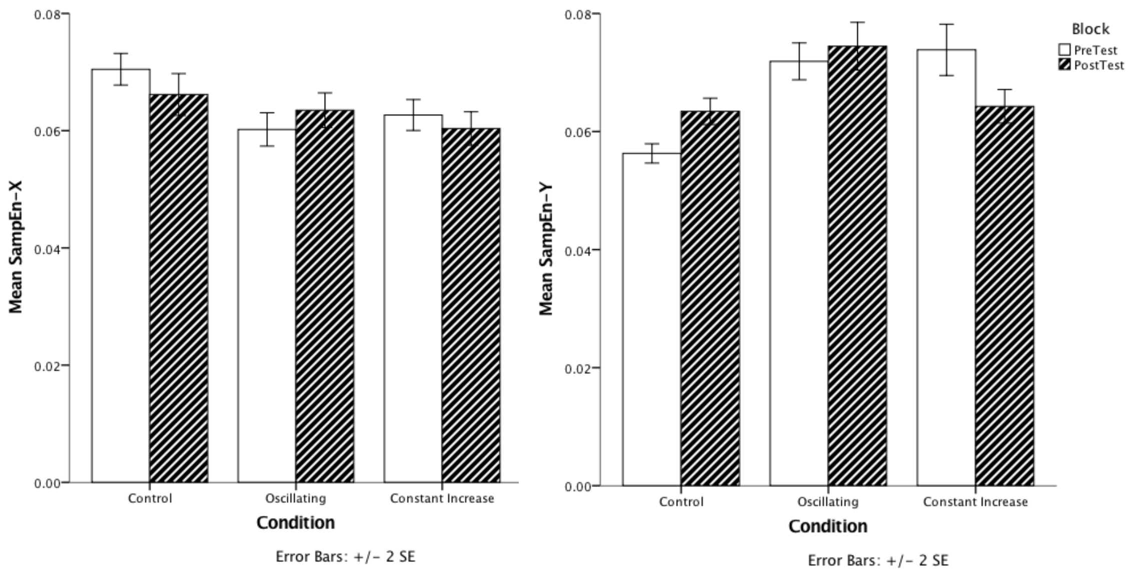


Figure 65. Means and standard errors of the interaction of block and condition on SampEn-X (left) and SampEn-Y (right) for the pre- and post-test in Experiment 2.

5.5. *Mediation Modeling for Experiment 2*

To determine if condition impacted participants' accuracy (i.e., absolute error) and if this influence was mediated by the amount of postural sway (i.e., SampEn) in the blocks, a statistical test of the proposed mediating effect was conducted. Since there were two SampEn measurements, one measuring the mediolateral sway (SampEn-X) and one measuring the posterior-anterior sway (SampEn-Y), this mediation model has two mediators (see Figure 66).

Both the constant condition and the constant increase condition were compared individually with the control condition. The mediated effect was then modeled with block as a moderating effect. Both the full model and moderated mediations by block for experimental blocks results can be seen in Table 31 and for pre-/post-test blocks can be seen in Table 32 (refer to Figure 66 for pathway locations).

The pathways within the mediation model are regressions with the point of the arrow indicating the prediction direction. Therefore, these simple effects of block were already analyzed in the MLM analyses above. This model is to determine if there are significant indirect effects with SampEn mediating the effects of condition on absolute error.

The first initial model was all the data regardless of block. This mediation model was a 2-1-1 (i.e., condition-L2, SampEn-X/Y-L1, and absolute error-L1). Then to determine if block moderated this mediation, the model was split by block and reanalyzed as a 2-2-1 model (condition and SampEn-X/Y are level 2 variables while absolute error remains at a measurement level 1).

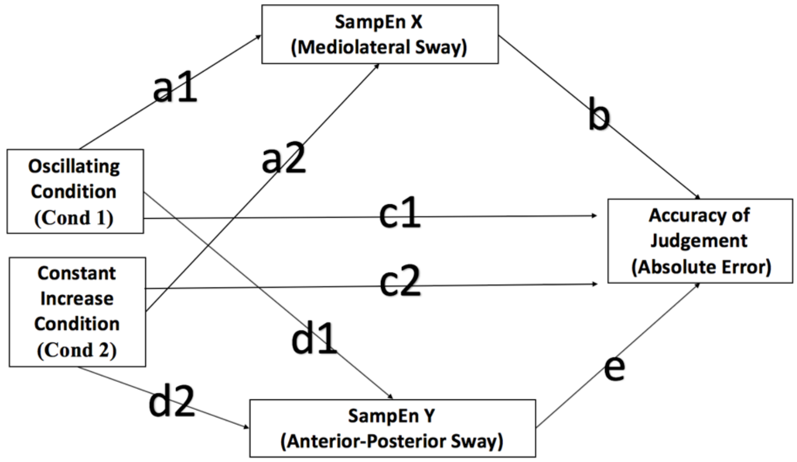


Figure 66. Pathway map of mediation for experiment 2.

5.5.1. Mediation Modeling of Experimental Blocks in Experiment 2

Table 31. Coefficient estimates and standard errors for the different experimental models for the various paths, indirect effects and direct effects for the experimental blocks in experiment 2.

		Estimate (SE)													
		Pathways								Indirect Effects				Direct Effects	
										SampEn-X		SampEn-Y			
		a1	a2	b	c1	c2	d1	d2	e	Cond 1[a] (a1*b)	Cond 2[b] (a2*b)	Cond 1[a] (d1*e)	Cond 2[b] (d1*e)	Cond 1[a] (c1)	Cond 2[b] (c2)
Full Model		0.002 (0.01)	0.003 (0.01)	-7.42 (2.50)*	0.24 (0.21)	0.25 (0.14)	0.004 (0.003)	0.002 (0.01)	0.70 (3.42	-0.02 (0.05)	-0.03 (0.05)	0.003 (0.01)	0.002 (0.01)	0.24 (0.21)	0.25 (0.14)
Block	1	0.01 (0.01)*	0.01 (0.01)	-11.75 (6.01)	-0.02 (0.22)	-0.02 (0.25)	0.01 (0.01)*	0.01 (0.01)	3.74 (4.65)	0.01 (0.07)	0.02 (0.08)	0.04 (0.05)	0.04 (0.05)	-0.02 (0.22)	-0.02 (0.25)
	2	-0.003 (0.01)	-0.003 (0.01)	-2.16 (4.09)	-0.01 (0.18)	-0.06 (0.21)	0.01 (0.01)*	0.01 (0.01)	-4.16 (3.68)	0.01 (0.2)	0.01 (0.2)	-0.05 (0.05)	-0.05 (0.06)	-0.01 (0.18)	-0.06 (0.21)
	3	-0.005 (0.01)	0.001 (0.01)	-3.07 (5.19)	0.26 (0.21)	-0.01 (0.19)	0.01 (0.01)	0.01 (0.01)	-1.60 (6.68)	0.01 (0.03)	-0.002 (0.02)	-0.02 (0.07)	-0.01 (0.04)	0.26 (0.21)	-0.01 (0.19)
	4	0.01 (0.01)	0.01 (0.01)	-3.1 (3.17)	0.27 (0.14)*	-0.07 (0.15)	0.002 (0.01)	-0.002 (0.01)	-0.22 (3.01)	-0.03 (0.05)	-0.03 (0.04)	>0.001 (0.005)	>0.001 (0.004)	-0.27 (0.14)*	-0.07 (0.15)
	5	-0.01 (0.01)	0.01 (0.01)	-2.39 (3.0)	-0.19 (0.13)	-0.16 (0.16)	0.01 (0.01)	-0.01 (0.01)	9.01 (5.83)	0.01 (0.02)	-0.03 (0.04)	0.07 (0.07)	-0.07 (0.05)	-0.19 (0.13)	-0.16 (0.16)
	6	0.002 (0.01)	0.01 (0.01)	-0.99 (2.61)	0.14 (0.15)	0.10 (0.18)	0.004 (0.01)	-0.01 (0.01)	-2.43 (4.41)	-0.002 (0.01)	-0.01 (0.03)	-0.01 (0.02)	0.01 (0.02)	0.14 (0.15)	0.10 (0.18)

*p<0.05, **p<0.01, ***p<0.001, a= Comparison of control and constant conditions, b= comparison of constant increase and control group.

The path coefficients and standard errors of the full model can be seen in the model in Table 31. Please refer to Figure 66 for references of pathways. The only significant path for the

full model was SampEn-X predicting absolute error. There were no significant direct or indirect effects.

For the moderated mediation model, pathway coefficients, standard errors, and p-values for the different pathways can be found in Table 31 by block. In block 1 there were two significant paths a1 and d1. Both of these are a significant difference between the control and constant condition when predicting postural sway: SampEn X (a1) and SampEn Y (d1). In block 2 only d1 was significant (significant difference between control and constant conditions when predicting postural sway. In block 4 there was a significant direct effect which was the c1 path indicating that there was a significant difference between the control and constant condition when estimating absolute error. Unfortunately, there were no significant indirect pathways.

5.5.2. Mediation Modeling of Pre-/ Post-Test Blocks in Experiment

Table 32. Coefficient estimates and standard errors for the different experimental models for the various paths, indirect effects and direct effects for the pre- and post-test blocks of Experiment 2.

		Estimate (SE)													
		Pathways								Indirect Effects				Direct Effects	
										SampEn-X		SampEn-Y			
		a1	a2	b	c1	c2	d1	d2	e	Cond 1[a] (a1*b)	Cond 2[b] (a2*b)	Cond 1[a] (d1*e)	Cond 2[b] (d1*e)	Cond 1[a] (c1)	Cond 2[b] (c2)
Full Model		-0.01 (0.01)	-0.01 0.01)	1.27 (13.76)	-0.18 (0.30)	0.24 (0.32)	0.01 (0.004)	0.004 (0.01)	10.95 (13.99)	-0.01 (0.08)	-0.01 (0.09)	0.09 (0.11)	0.05 (0.14)	-0.18 (0.30)	0.24 (0.32)
Block	Pre-Test	-0.01 (0.01)	-0.01 (0.01)	-17.05 (8.88)	-0.58 (0.51)	-0.24 (0.58)	0.01 (0.01)	0.01 (0.01)	-4.76 (10.62)	0.15 (0.14)	0.11 (0.13)	-0.05 (0.12)	-0.06 (0.15)	-0.58 (0.51)	-0.24 (0.58)
	Post-Test	-0.003 (0.01)	-0.01 (0.01)	6.63 (6.78)	0.10 (0.28)	0.24 (0.34)	0.01 (0.01)*	-0.004 (0.01)	5.65 (5.73)	-0.02 (0.06)	-0.04 (0.07)	0.04 (0.07)	-0.02 (0.04)	0.10 (0.28)	0.24 (0.34)

*p<0.05, **p<0.01, ***p<0.001, a= Comparison of control and constant conditions, b= comparison of constant increase and control group.

The path coefficients and standard errors of the full model can be seen in the model in Table 32. Please refer to Figure 66 for reference of pathways. There were no significant pathways, direct or indirect effects in the full model.

For the moderated mediation model, pathway coefficients, standard errors, and p-values for the different pathways can be found in Table 32 by block. There were no significant paths in the pre-test. In the post-test block, there was only a significant path of condition 1 on SampEn-Y indicating a difference between control and oscillating conditions. There were no significant indirect or direct pathways.

In block 1 there were two significant paths a1 and d1. Both of these are a significant difference between the control and constant condition when predicting postural sway: SampEn X (a1) and SampEn Y (d1). In block 2 only d1 was significant (significant difference between control and constant conditions when predicting postural sway. In block 4 there was a significant direct effect which was the c1 path indicating that there was a significant difference between the control and constant condition when estimating absolute error. Unfortunately, there were no significant indirect pathways.

6. **Discussion of Experiment 2 Results**

The findings of second experiment are very similar to those of the first. In general, the pattern of calibration occurred across experimental blocks, across trials within blocks, and from the pre-to the post-test. Participants calibrated target estimations across the blocks of experimental trials and from the pre- to the post-test. This indicates that regardless of condition, there was a level of calibration that occurred. This finding supports previous research that task-relevant feedback can overcome systemic distortions or perturbations. On average, participants

tended to have higher under-rotation estimations than over-rotation estimation indicating that their errors were greater if they did not rotate far enough to the target. These under-rotation estimations reduced across the experimental blocks and trials within blocks indicating a high level of calibration effect from them. Target location and action requirement also affected the accuracy of estimates. These variables moderated the lower-order interactions and main effects.

The current study had three primary hypotheses: (1) the rate of recalibration across consecutive trials will be faster in the oscillating condition than in the constant gain increase condition. (2) However, this recalibration rate will be slower than that of the constant condition in experiment 1. (3) postural sway (e.g., entropy) will mediate the relationship between the type of perturbation condition (i.e., type of environment) and target estimation errors (see Figure 2).

While all of these hypotheses can be analyzed with the primary variables of interest, there were concerns of the effect of secondary variables such as simulator sickness and head movement during trials. These variables were analyzed in secondary models while keeping the primary variables in the models as constants. Even though there were main effects and interactions of the secondary variables, the effect sizes were not large enough to create concerns for the validity of the primary variables and their interactions.

The first hypothesis of this study was that more unstable environments will take longer to calibrate. This hypothesis can be found with any interaction in which block and condition interact within the experimental blocks. Unlike experiment 1, the conditions in this experiment did not show the significant differences to that of the control condition in terms of absolute error. However, there were significant findings in the postural sway analyses with the SampEn-X outcome variable showing specific patterns associated with the oscillating condition and random increase. The variability within the entropy variables follows similar results of the first

experiment in which the more unstable environment, the constant increase, demonstrated higher levels of variability across blocks of trials than the oscillating condition or the control condition.

Similarly, the second hypothesis can be found viewing the interaction of block and condition and/or block trial and condition. While these interactions were not significant in the model of absolute error, comparing the simple slope estimates of the three-way interaction of block, condition and block trial found that the oscillating condition actually calibrated in the first perturbation change block at a fast rate (negative slope of 0.06) than the constant condition (negative slope of 0.03). Additionally, across blocks, the oscillating condition had less variance than the constant condition.

Hypothesis 3 in this experiment was the same as the 4th hypothesis in experiment 1. This hypothesis was that the relationship between the condition and absolute error would be mediated through postural sway. Again, this analysis was essentially an assimilation of both the absolute error analysis and the postural sway analysis into a singular integrated model to potentially explain a relationship between the three variables. The findings for this hypothesis was similar to those in experiment 1. In the full model in both the experimental blocks and the pre-/ post-test block analyses, there was not an indirect effect. To determine if block moderated the mediation model, it was included as a moderator. Again, no indirect effects were found. Therefore, hypothesis 3 does not have sufficient evidence to be supported from this current study.

CHAPTER IV.

GENERAL DISCUSSION

Previous research has demonstrated that people are able to adapt to perceptual distortions or perturbations (e.g., Day et al., 2017; Altenhoff, et al., 2012, Bingham & Romack, 1999; Bingham & Pagano, 1998). However, the majority of the literature investigating the effect of perturbations on prospective control have involved relatively stable and constant perturbations. These two experiments were conducted to examine the effects of different types of unstable environments on calibration. Specifically, how environments that change in relatively short time frames can affect the rate and amount of calibration.

The current studies investigated perturbation calibration through a series of intricate and comprehensive analytical models that allowed for the complexity of the study and subsequent rich data to be examined and explained. Both experiments utilized a visual rotation perturbation at varying levels. The perturbation levels were manipulated through the gain increase amount in experiment 1 and the pattern of the gain amount in experiment 2.

In both experiments, it was hypothesized that the more unstable an environment, either through the rate of perturbation change or the pattern of change, the more difficult calibration would be. Calibration effects were examined using the primary outcome variable of absolute error and the secondary outcome variable of entropy in postural sway. While the gain amounts were found to affect the amount of postural sway between blocks the effect was more visible through the examination of the variability of the patterns within the conditions. The effect of the different environments on absolute error were also evident within and between blocks. However,

the constant rate of the pattern in the experimental groups of experiment 2 demonstrated similar calibration effects as the control condition.

While the main mediation model and the moderated-mediation models did not find the proposed indirect effects, there were effects of the perceptual gains on postural sway in both experiments. These effects can be seen on both the SampEn-X outcome variable measuring mediolateral sway and the SampEn-Y outcome variable measuring anterior-posterior sway. However, more perturbed conditions (i.e., the random increase and the constant increase conditions) demonstrated the most variability in their absolute error estimates and their postural sway. Therefore, while the effects of the perturbation levels can be seen within the experimental blocks, these participants still demonstrated a general decrease in their absolute error amounts. Any significant effects of the SampEn-Y variable are especially interesting as that type of postural sway would provide additional depth information. However, since the targets were located at the same distance, why did we see this type of movement so affected? Future research should analyze the head movement of the participant similar to postural sway to determine if the increase of the postural sway is an exploratory movement or an unconscious movement caused by the perceptual information change in the environment (i.e., the movement is due to compensatory movements; see Riccio & Stoffregen, 1991; Smart & Smith, 2001).

1. **Contribution to Calibration Literature**

In the current work, calibration was investigated within blocks of trials and between blocks of trials and in examining pre- and post-test differences. While the latter is commonly used to investigate calibration effects, the examination within blocks and between blocks of feedback calibration is not. These results provide a comprehensive examination of multiple

levels of calibration occurring: calibration within unique perturbation levels (investigation at trials within block level), across multiple blocks of either constant perturbation levels (control and constant conditions) or fluctuating perturbation levels (oscillating, constant increase and random increase).

Both experiments demonstrated general calibration effects within and across blocks as well as carry-over effects seen in the post-test block. These findings support previous research into task-relevant feedback calibration effects (e.g., Bingham & Pagano, 1998; Day, et al., submitted; Fajen, 2007; Iodice, Scuderi, Saggini & Pezzulo, 2015; Warren, 1984; Withagen & Michaels, 2004). Importantly, while participants experienced unstable environments (i.e., random increase and constant increase), they still had significant reductions in the absolute error of their estimations in the post-test.

Comparing the results of the first and second experiment, it can be seen in the post-test results of the accuracy measurement of absolute error that there was an effect of the patterning of the perturbation change. The participants in the two patterned gain change conditions (oscillating and constant increase) calibrated as well as the control condition (see Figure 50), while the carry-over effects for error in the constant and random increase condition in experiment 1 were more than the constant condition in an increasing pattern see Figure 21). This comparison supports the need for future research into the patterning and the gain amounts of unstable environment for calibration research.

Additionally, in the post-test it can be seen that errors start increasing as participants continue through the trials. This finding supports that perception drifts and becomes less accurate when feedback is removed (Bingham & Pagano, 1998). Additionally, there could be an effect of

speed and accuracy trade-off occurring in this block. However, it is important to note that the error amounts are minimal (generally under 6 degrees).

After the completion of the experiment, participants were asked if they had any knowledge of the study or if they had any hypotheses as to what was being investigated in the study. While the majority of participants could not articulate what they felt was being studied, there were several able to determine there were changes being made to the visual gain amount. Similar to Littman (2011), the participants that were able to determine the experimental effects were in the more complex environments (i.e., the more unstable environments, either the constant increase or random increase conditions). Anecdotally, the participants that were able to articulate the experimental manipulation, made exploratory head movements in the environment between the blocks while they answered the verbal SSQ. Unfortunately, the current study did not measure the pattern of head movements within blocks and between blocks of trials in a fashion that these movements could be investigated. In future research, it would be beneficial to use entropy not only for postural sway indexes but also for the head movement (to be discussed).

2. **Limitations and Future Studies**

Some limitations of the current included issues with measurement variables, task difficulty, task constraints, and pattern of change for the gain of perturbation. The first significant limitation was very little variability in both primary dependent variables (absolute error and entropy). The small amount of variance indicates that there was not a high level of individual differences which could be due to the experimental task. In essence, the lack of variability indicates that participants were very good at the task, the task lacked a level of difficulty to demonstrate the differences between the conditions, or the visual gains in the current

study were not sufficient to perturb the participants. This lack of variability could be a contributing factor to the inability to find indirect effects in the mediation models. Therefore, it is suggested that the task involved in future studies be adjusted in order to have a higher variability in the individual differences either by using more difficult tasks, different types of perturbations, or multiple simultaneous perturbations.

There were several limitations due to the gains selected in the current work. The first is the pattern of only increasing for both experiments. Patterns of decreasing and the mixture of increasing and decreasing should be investigated. Additionally, the rate of change in the introduction to new perturbation levels should be investigated. In the current study it is believed that the lack of variance could be due to the length of the blocks of trials. Future work could fluctuate gains at different intervals and different patterns to determine how these different patterns could affect the rate of calibration and the ability to calibrate in general. In addition, it would be beneficial to see if the level of perturbation before the post-test affects the level of the carry-over effects. This experiment would allow for the ability to discuss the carry-over effects seen in experiment 1. In essence, are the levels due to the changes in the environment or are they similar to other calibration research where they are maintaining the calibration of the last level of perturbation.

Another limitation was the inability to measure postural sway for the individual trials within blocks. Due to the rapid nature of the trials, there were not enough data points to create a SampEn analysis per trial. This inability to measure at the trial level did not allow for analyses of changes of postural sway to be at the trial level. In essence, any changes that occurred within the block of trials for calibration of the postural sway could not be analyzed. It could be that the mediation model proposed in this work is at this level and not across blocks. This issue was not

due to the equipment but the parameters for calculating SampEn at this time. One way to try to determine this would be to affect the gain amounts between trials and not simply between blocks.

Another measurement issue was the variable of *total rotation*. While this variable gave a coarse measurement of total head movement within trials, it is conflated with the directionality of head movement (i.e., the amount of changes in head rotation movements). In future work, this variable should be collected with the amount of times the head changed direction. Additionally, some participants occasionally started turning their head in the wrong direction in anticipation of a target. These values greatly influenced the amount of total head movement. By including the directionality of the head rotation, this could provide incites into these movements. The head rotation variable might also be treated as a time-series variable also instead of reducing down to a single number.

Lastly, while the secondary variables were not the focus of this experiment, the significant main effects of head movement and simulator sickness as well as their interactions with the primary variables of condition and block are note-worthy. Future analyses and research should be conducted to determine if the relationship between condition and absolute error are dependent on these measures or mediated by them.

3. **Application of Current Work**

The results of the current studies demonstrate calibration of the perception-action system under different unstable short-timescale changes. This provide further evidence for perception-action calibration mechanisms in terms of action-scaling from feedback. These results have several applied research implications within the human factors field specifically with training.

Virtual environments are used for many applied training applications. While our day-to-day environments have rapid changes and non-stable changes, many of these simulations only have stable perturbations. Since these types of simulations provide some amount of confidence in users of their abilities to engage in specific tasks under certain environments, they should be representative of more ecologically valid situations.

Additionally, research into technical fields such as aviation should be investigating not just the effects of a change in a specific variable but how changes within timeframe for that variable can also affect performance. For example, for pilots, many aspects within an environment change rapidly depending on speed, altitude, etc. However, most research is conducted examining only one aspect at one level of change.

4. **Conclusion**

Similar to Littman (2011), the current studies demonstrate that the investigations of more complex environments are necessary to understand the flexibility and calibration limits of the perception-action system. While all conditions in the current studies demonstrated a level of calibration, the effects of the different levels of perturbations can be seen in the performance of the participants and the affects of unconscious motor movements such as postural sway. Lastly, while the current study did not find the proposed mediated relationship, future research should continue to investigate the outcomes in a relational approach.

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APPENDIX A.

Experiment 1: Descriptive Statistics for Collected Predictors Experimental Blocks

PREDICTOR	N	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
TOTAL ROTATION (DEGREES)	3018	40.92	431.20	84.37	22.41
MAX ROTATION (DEGREES)	3018	40.92	139.65	73.72	14.48
ROTATIONAL DIFFERENCE (DEGREES)	3018	0.00	26.12	5.19	4.14
SSQ	3018	0.00	19.00	2.86	3.59
ML POSTURAL SWAY (ENTROPY)	3018	0.02	0.16	0.07	0.02
AP POSTURAL SWAY (ENTROPY)	3018	0.02	0.13	0.06	0.02

APPENDIX B.

Experiment 1: Descriptive Statistics for Collected Predictors Pre-/Post-Test Blocks

PREDICTOR	N	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
MSAQ PRE-TEST	1008	15.00	38.00	18.42	4.25
MSAQ POST-TEST	1008	16.00	71.00	22.76	10.55
TOTAL ROTATION (DEGREES)	1008	44.23	207.63	77.56	15.48
MAX ROTATION (DEGREES)	1008	39.91	108.18	70.37	13.93
ROTATIONAL DIFFERENCE (DEGREES)	1008	0.00	27.08	7.18	5.41
SSQ	1008	0.00	16.00	1.81	2.99

APPENDIX C.

Experiment 1: Experimental Block Primary Analysis Coefficients for the Outcome Variable of Absolute Error

Estimates of Fixed Effects

Predictors	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	1.73	0.16	10.73	<0.001	1.41	2.05
Block2	-0.19	0.10	-2.03	0.04	-0.38	-0.01
Block3	-0.28	0.10	-2.89	0.00	-0.46	-0.09
Block4	-0.26	0.10	-2.70	0.01	-0.44	-0.07
Block5	-0.46	0.10	-4.84	<0.001	-0.65	-0.28
Block6	-0.39	0.10	-4.10	<0.001	-0.58	-0.20
Block Trial (Btrial)	-0.01	0.01	-1.48	0.15	-0.04	0.01
Location (LOC)	0.08	0.06	1.40	0.16	-0.03	0.19
Action Requirement (AR)	0.12	0.08	1.58	0.12	-0.03	0.27
Direction (DIR)	0.40	0.11	3.61	0.00	0.18	0.63
Constant COND	0.18	0.17	1.01	0.32	-0.17	0.53
Random Increase COND	0.24	0.17	1.42	0.16	-0.10	0.59
*Block2 * Btrial*	-0.03	0.03	-1.07	0.29	-0.08	0.02
*Block3 * Btrial*	-0.02	0.03	-0.86	0.39	-0.08	0.03
*Block4 * Btrial*	0.05	0.03	1.73	0.08	-0.01	0.10
*Block5 * Btrial*	0.02	0.03	0.66	0.51	-0.04	0.07
*Block6 * Btrial*	0.00	0.03	-0.08	0.94	-0.06	0.05
*Block2 * LOC*	0.11	0.19	0.58	0.56	-0.27	0.49
*Block3 * LOC*	0.15	0.19	0.78	0.44	-0.23	0.52
*Block4 * LOC*	0.12	0.19	0.61	0.54	-0.26	0.49
*Block5 * LOC*	0.04	0.19	0.18	0.86	-0.34	0.41
*Block6 * LOC*	0.04	0.19	0.21	0.83	-0.34	0.42
*Block2 * AR*	0.010327	0.191588	0.054	0.957	-0.365337	0.38599
*Block3 * AR*	-0.186625	0.191648	-0.974	0.33	-0.562405	0.189155
*Block4 * AR*	-0.252932	0.191478	-1.321	0.187	-0.628379	0.122516
*Block5 * AR*	-0.093802	0.191795	-0.489	0.625	-0.469869	0.282265
*Block6 * AR*	0.094208	0.191883	0.491	0.623	-0.282033	0.470449
*Block2 * Dir*	-0.11	0.20	-0.58	0.56	-0.50	0.27
*Block3 * Dir*	-0.23	0.20	-1.16	0.25	-0.62	0.16
*Block4 * Dir*	0.11	0.20	0.59	0.56	-0.27	0.50
*Block5 * Dir*	-0.45	0.20	-2.29	0.02	-0.84	-0.07
*Block6 * Dir*	-0.52	0.20	-2.62	0.01	-0.91	-0.13
*LOC * Btrial*	-0.01	0.02	-0.81	0.42	-0.04	0.02

*AR * Btrial*	0.02	0.02	1.28	0.20	-0.01	0.05
*DIR * Btrial*	0.00	0.02	-0.16	0.87	-0.04	0.03
*LOC * AR*	0.14	0.11	1.24	0.22	-0.08	0.36
*DIR * AR*	0.05	0.12	0.46	0.65	-0.18	0.29
*LOC * DIR*	-0.34	0.12	-2.92	0.00	-0.56	-0.11
*Block2 * Random Increase COND*	-0.41	0.23	-1.75	0.08	-0.87	0.05
*Block2 * Constant COND*	0.07	0.23	0.29	0.77	-0.39	0.53
*Block3 * Random Increase COND*	-0.10	0.23	-0.45	0.66	-0.56	0.35
*Block3 * Constant COND*	-0.01	0.23	-0.04	0.97	-0.47	0.45
*Block4 * Random Increase COND*	-0.09	0.23	-0.39	0.70	-0.55	0.37
*Block4 * Constant COND*	-0.18	0.23	-0.76	0.45	-0.64	0.28
*Block5 * Random Increase COND*	-0.59	0.23	-2.51	0.01	-1.05	-0.13
*Block5 * Constant COND*	-0.31	0.23	-1.35	0.18	-0.77	0.14
*Block6 * Random Increase COND*	0.04	0.23	0.17	0.87	-0.42	0.50
*Block6 * Constant COND*	-0.06	0.23	-0.27	0.79	-0.52	0.40
*Random Increase COND * Btrial*	0.03	0.02	1.13	0.26	-0.02	0.08
*Constant COND * Btrial*	-0.01	0.02	-0.30	0.77	-0.06	0.04
*Random Increase COND * LOC*	-0.03	0.14	-0.21	0.83	-0.30	0.24
*Constant COND * LOC*	-0.13	0.14	-0.97	0.33	-0.40	0.13
*Random Increase COND * AR*	-0.03	0.19	-0.18	0.86	-0.42	0.35
*Constant COND * AR*	-0.12	0.19	-0.63	0.53	-0.50	0.26
*Random Increase COND * DIR*	0.05	0.28	0.18	0.86	-0.52	0.62
*Constant COND * DIR*	-0.06	0.28	-0.21	0.84	-0.63	0.51
*Block2 * LOC * Btrial*	-0.03	0.06	-0.50	0.62	-0.14	0.08
*Block3 * LOC * Btrial*	-0.13	0.06	-2.23	0.03	-0.24	-0.02
*Block4 * LOC * Btrial*	-0.08	0.06	-1.49	0.14	-0.19	0.03
*Block5 * LOC * Btrial*	-0.01	0.06	-0.26	0.79	-0.12	0.10
*Block6 * LOC * Btrial*	-0.07	0.06	-1.25	0.21	-0.18	0.04
*Block2 * AR * Btrial*	-0.11	0.06	-1.99	0.05	-0.22	0.00
*Block3 * AR * Btrial*	-0.03	0.06	-0.48	0.63	-0.14	0.08
*Block4 * AR * Btrial*	0.00	0.06	-0.07	0.94	-0.11	0.11
*Block5 * AR * Btrial*	-0.07	0.06	-1.29	0.20	-0.18	0.04
*Block6 * AR * Btrial*	-0.07	0.06	-1.22	0.22	-0.18	0.04
*Block2 * DIR * Btrial*	0.04	0.06	0.66	0.51	-0.07	0.15
*Block3 * DIR * Btrial*	0.01	0.06	0.23	0.82	-0.10	0.13
*Block4 * DIR * Btrial*	-0.05	0.06	-0.87	0.38	-0.16	0.06
*Block5 * DIR * Btrial*	0.01	0.06	0.10	0.92	-0.11	0.12
*Block6 * DIR * Btrial*	0.02	0.06	0.27	0.79	-0.10	0.13
*Block2 * LOC * AR*	-0.42	0.38	-1.09	0.28	-1.17	0.33
*Block3 * LOC * AR*	-0.07	0.38	-0.18	0.86	-0.82	0.68

*Block4 * LOC * AR*	-0.45	0.38	-1.17	0.24	-1.20	0.30
*Block5 * LOC * AR*	-0.09	0.38	-0.22	0.82	-0.84	0.67
*Block6 * LOC * AR*	-0.39	0.38	-1.01	0.31	-1.14	0.37
*Block2 * LOC * DIR*	0.28	0.39	0.70	0.48	-0.49	1.05
*Block3 * LOC * DIR*	-0.08	0.39	-0.21	0.83	-0.86	0.69
*Block4 * LOC * DIR*	0.52	0.39	1.34	0.18	-0.25	1.29
*Block5 * LOC * DIR*	0.58	0.39	1.48	0.14	-0.19	1.35
*Block6 * LOC * DIR*	-0.35	0.40	-0.89	0.37	-1.13	0.43
*Block2 * DIR * AR*	-0.25	0.40	-0.63	0.53	-1.02	0.53
*Block3 * DIR * AR*	-0.52	0.40	-1.31	0.19	-1.29	0.26
*Block4 * DIR * AR*	-0.48	0.39	-1.21	0.23	-1.25	0.29
*Block5 * DIR * AR*	-0.36	0.40	-0.91	0.36	-1.13	0.42
*Block6 * DIR * AR*	-0.81	0.40	-2.05	0.04	-1.59	-0.03
*LOC * DIR * Btrial*	0.03	0.03	0.95	0.34	-0.03	0.10
*DIR * AR * Btrial*	0.14	0.03	4.16	0.00	0.07	0.21
*LOC * DIR * AR*	0.39	0.23	1.68	0.09	-0.06	0.84
*Block2 * Random Increase COND * Btrial*	-0.03	0.07	-0.45	0.66	-0.16	0.10
*Block2 * Constant COND * Btrial*	-0.03	0.07	-0.46	0.65	-0.16	0.10
*Block3 * Random Increase COND * Btrial*	-0.06	0.07	-0.84	0.40	-0.19	0.08
*Block3 * Constant COND * Btrial*	0.04	0.07	0.53	0.60	-0.10	0.17
*Block4 * Random Increase COND * Btrial*	0.06	0.07	0.82	0.41	-0.08	0.19
*Block4 * Constant COND * Btrial*	0.08	0.07	1.13	0.26	-0.06	0.21
*Block5 * Random Increase COND * Btrial*	-0.07	0.07	-1.09	0.28	-0.21	0.06
*Block5 * Constant COND * Btrial*	-0.02	0.07	-0.30	0.77	-0.15	0.11
*Block6 * Random Increase COND * Btrial*	-0.11	0.07	-1.58	0.12	-0.24	0.03
*Block6 * Constant COND * Btrial*	0.05	0.07	0.78	0.44	-0.08	0.19
*Block2 * Random Increase COND * LOC*	0.02	0.47	0.04	0.97	-0.90	0.94
*Block2 * Constant COND * LOC*	0.06	0.47	0.13	0.89	-0.86	0.99
*Block3 * Random Increase COND * LOC*	0.08	0.47	0.18	0.86	-0.83	1.00
*Block3 * Constant COND * LOC*	-0.01	0.47	-0.01	0.99	-0.93	0.91
*Block4 * Random Increase COND * LOC*	-0.86	0.47	-1.85	0.07	-1.78	0.05
*Block4 * Constant COND * LOC*	-0.22	0.47	-0.47	0.64	-1.14	0.70
*Block5 * Random Increase COND * LOC*	-0.19	0.47	-0.40	0.69	-1.11	0.73
*Block5 * Constant COND * LOC*	0.70	0.47	1.49	0.14	-0.22	1.62
*Block6 * Random Increase COND * LOC*	0.12	0.47	0.25	0.81	-0.80	1.03
*Block6 * Constant COND * LOC*	0.61	0.47	1.30	0.20	-0.31	1.54
*Block2 * Random Increase COND * DIR*	0.50	0.49	1.02	0.31	-0.46	1.46
*Block2 * Constant COND * DIR*	0.55	0.48	1.14	0.26	-0.40	1.49
*Block3 * Random Increase COND * DIR*	0.15	0.49	0.30	0.76	-0.81	1.11
*Block3 * Constant COND * DIR*	0.83	0.48	1.71	0.09	-0.12	1.77

*Block4 * Random Increase COND * DIR*	0.24	0.49	0.49	0.62	-0.72	1.20
*Block4 * Constant COND * DIR*	0.39	0.48	0.82	0.42	-0.55	1.33
*Block5 * Random Increase COND * DIR*	0.62	0.49	1.26	0.21	-0.34	1.58
*Block5 * Constant COND * DIR*	0.43	0.48	0.90	0.37	-0.51	1.38
*Block6 * Random Increase COND * DIR*	0.06	0.49	0.13	0.90	-0.90	1.03
*Block6 * Constant COND * DIR*	-0.08	0.48	-0.17	0.87	-1.02	0.87
*Random Increase COND * LOC * Btrial*	0.02	0.04	0.56	0.58	-0.06	0.10
*Constant COND * LOC * Btrial*	0.01	0.04	0.30	0.77	-0.07	0.09
*Random Increase COND * AR * Btrial*	-0.04	0.04	-1.04	0.30	-0.12	0.04
*Constant COND * AR * Btrial*	-0.02	0.04	-0.51	0.61	-0.10	0.06
*Random Increase COND * DIR * Btrial*	0.02	0.03	0.63	0.53	-0.04	0.07
*Constant COND * DIR * Btrial*	-0.05	0.03	-1.79	0.07	-0.11	0.00
*Control COND * DIR * Btrial*	0.03	0.03	1.04	0.30	-0.03	0.09
*Random Increase COND * LOC * AR*	-0.32	0.27	-1.18	0.24	-0.86	0.21
*Constant COND * LOC * AR*	-0.29	0.27	-1.07	0.29	-0.83	0.24
*Random Increase COND * LOC * DIR*	-0.27	0.29	-0.94	0.35	-0.83	0.29
*Constant COND * LOC * DIR*	-0.30	0.28	-1.07	0.29	-0.86	0.25
*Random Increase COND * DIR * AR*	-0.11	0.29	-0.38	0.71	-0.68	0.46
*Constant COND * DIR * AR*	0.42	0.29	1.46	0.15	-0.14	0.99
*Block2 * LOC * DIR * AR*	0.24	0.79	0.30	0.76	-1.31	1.79
*Block3 * LOC * DIR * AR*	-0.40	0.79	-0.50	0.61	-1.96	1.16
*Block4 * LOC * DIR * AR*	-0.05	0.78	-0.06	0.95	-1.59	1.49
*Block5 * LOC * DIR * AR*	0.86	0.79	1.09	0.28	-0.69	2.41
*Block6 * LOC * DIR * AR*	0.31	0.80	0.39	0.69	-1.25	1.88
*LOC * DIR * AR * Btrial*	0.01	0.07	0.14	0.89	-0.12	0.14
*Block2 * LOC * AR * Btrial*	-0.07	0.11	-0.62	0.53	-0.29	0.15
*Block3 * LOC * AR * Btrial*	0.13	0.11	1.20	0.23	-0.09	0.36
*Block4 * LOC * AR * Btrial*	0.12	0.11	1.03	0.30	-0.11	0.34
*Block5 * LOC * AR * Btrial*	0.12	0.11	1.04	0.30	-0.10	0.34
*Block6 * LOC * AR * Btrial*	0.00	0.11	0.02	0.99	-0.22	0.22
*Block2 * LOC * DIR * Btrial*	0.07	0.12	0.57	0.57	-0.16	0.29
*Block3 * LOC * DIR * Btrial*	-0.18	0.12	-1.53	0.13	-0.40	0.05
*Block4 * LOC * DIR * Btrial*	-0.23	0.12	-1.98	0.05	-0.46	0.00
*Block5 * LOC * DIR * Btrial*	-0.03	0.12	-0.29	0.77	-0.26	0.19
*Block6 * LOC * DIR * Btrial*	-0.10	0.12	-0.88	0.38	-0.33	0.13
*Block2 * DIR * AR * Btrial*	0.02	0.12	0.13	0.90	-0.21	0.24
*Block3 * DIR * AR * Btrial*	0.14	0.12	1.21	0.23	-0.09	0.38
*Block4 * DIR * AR * Btrial*	0.06	0.12	0.50	0.62	-0.17	0.29
*Block5 * DIR * AR * Btrial*	0.14	0.12	1.18	0.24	-0.09	0.36
*Block6 * DIR * AR * Btrial*	0.15	0.12	1.29	0.20	-0.08	0.38

*Block2 * Random Increase COND * LOC * Btrial*	-0.01	0.14	-0.06	0.95	-0.28	0.26
*Block2 * Constant COND * LOC * Btrial*	0.06	0.14	0.46	0.65	-0.21	0.34
*Block3 * Random Increase COND * LOC * Btrial*	-0.01	0.14	-0.06	0.96	-0.28	0.26
*Block3 * Constant COND * LOC * Btrial*	-0.10	0.14	-0.69	0.49	-0.37	0.18
*Block4 * Random Increase COND * LOC * Btrial*	-0.02	0.14	-0.18	0.86	-0.30	0.25
*Block4 * Constant COND * LOC * Btrial*	0.16	0.14	1.20	0.23	-0.11	0.43
*Block5 * Random Increase COND * LOC * Btrial*	-0.12	0.14	-0.91	0.37	-0.39	0.15
*Block5 * Constant COND * LOC * Btrial*	0.02	0.14	0.13	0.90	-0.25	0.29
*Block6 * Random Increase COND * LOC * Btrial*	-0.20	0.14	-1.45	0.15	-0.47	0.07
*Block6 * Constant COND * LOC * Btrial*	-0.07	0.14	-0.54	0.59	-0.34	0.20
*Block2 * Random Increase COND * AR * Btrial*	0.41	0.14	2.96	0.00	0.14	0.67
*Block2 * Constant COND * AR * Btrial*	0.04	0.14	0.29	0.77	-0.23	0.31
*Block3 * Random Increase COND * AR * Btrial*	0.16	0.14	1.19	0.24	-0.11	0.43
*Block3 * Constant COND * AR * Btrial*	0.07	0.14	0.53	0.60	-0.20	0.34
*Block4 * Random Increase COND * AR * Btrial*	0.09	0.14	0.64	0.53	-0.18	0.36
*Block4 * Constant COND * AR * Btrial*	-0.04	0.14	-0.33	0.74	-0.31	0.22
*Block5 * Random Increase COND * AR * Btrial*	0.20	0.14	1.47	0.14	-0.07	0.47
*Block5 * Constant COND * AR * Btrial*	-0.07	0.14	-0.48	0.63	-0.33	0.20
*Block6 * Random Increase COND * AR * Btrial*	-0.06	0.14	-0.44	0.66	-0.33	0.21
*Block6 * Constant COND * AR * Btrial*	-0.07	0.14	-0.49	0.63	-0.33	0.20
*Block2 * Random Increase COND * DIR * Btrial*	0.06	0.14	0.45	0.66	-0.22	0.34
*Block2 * Constant COND * DIR * Btrial*	-0.05	0.14	-0.39	0.70	-0.33	0.22
*Block3 * Random Increase COND * DIR * Btrial*	0.13	0.14	0.90	0.37	-0.15	0.41
*Block3 * Constant COND * DIR * Btrial*	0.12	0.14	0.86	0.39	-0.16	0.40
*Block4 * Random Increase COND * DIR * Btrial*	0.13	0.14	0.93	0.36	-0.15	0.41
*Block4 * Constant COND * DIR * Btrial*	0.14	0.14	1.00	0.32	-0.14	0.42
*Block5 * Random Increase COND * DIR * Btrial*	0.19	0.14	1.34	0.18	-0.09	0.47
*Block5 * Constant COND * DIR * Btrial*	0.19	0.14	1.34	0.18	-0.09	0.46
*Block6 * Random Increase COND * DIR * Btrial*	0.13	0.14	0.93	0.35	-0.15	0.42
*Block6 * Constant COND * DIR * Btrial*	0.16	0.14	1.12	0.26	-0.12	0.43
*Block2 * Random Increase COND * LOC * AR*	1.86	0.94	1.98	0.05	0.02	3.70
*Block2 * Constant COND * LOC * AR*	-1.76	0.94	-1.88	0.06	-3.60	0.08
*Block3 * Random Increase COND * LOC * AR*	0.29	0.94	0.31	0.76	-1.54	2.12
*Block3 * Constant COND * LOC * AR*	-1.22	0.94	-1.30	0.19	-3.06	0.62
*Block4 * Random Increase COND * LOC * AR*	0.54	0.94	0.58	0.57	-1.29	2.37
*Block4 * Constant COND * LOC * AR*	-1.61	0.94	-1.72	0.09	-3.45	0.22
*Block5 * Random Increase COND * LOC * AR*	1.75	0.94	1.87	0.06	-0.09	3.59
*Block5 * Constant COND * LOC * AR*	-1.22	0.94	-1.30	0.19	-3.05	0.62
*Block6 * Random Increase COND * LOC * AR*	1.04	0.94	1.11	0.27	-0.80	2.88
*Block6 * Constant COND * LOC * AR*	-1.02	0.94	-1.09	0.28	-2.87	0.82

*Block2 * Random Increase COND * LOC * DIR*	0.58	0.98	0.58	0.56	-1.36	2.51
*Block2 * Constant COND * LOC * DIR*	0.63	0.96	0.65	0.51	-1.26	2.51
*Block3 * Random Increase COND * LOC * DIR*	0.08	0.98	0.08	0.94	-1.84	2.00
*Block3 * Constant COND * LOC * DIR*	1.10	0.96	1.14	0.25	-0.79	2.99
*Block4 * Random Increase COND * LOC * DIR*	-0.34	0.98	-0.35	0.73	-2.26	1.59
*Block4 * Constant COND * LOC * DIR*	0.15	0.96	0.15	0.88	-1.74	2.03
*Block5 * Random Increase COND * LOC * DIR*	1.09	0.98	1.11	0.27	-0.83	3.00
*Block5 * Constant COND * LOC * DIR*	0.46	0.96	0.47	0.64	-1.43	2.34
*Block6 * Random Increase COND * LOC * DIR*	0.96	0.99	0.98	0.33	-0.97	2.89
*Block6 * Constant COND * LOC * DIR*	0.35	0.98	0.36	0.72	-1.57	2.27
*Block2 * Random Increase COND * DIR * AR*	-0.71	0.99	-0.71	0.48	-2.65	1.24
*Block2 * Constant COND * DIR * AR*	-0.82	0.97	-0.84	0.40	-2.72	1.09
*Block3 * Random Increase COND * DIR * AR*	-0.98	0.99	-0.99	0.32	-2.92	0.97
*Block3 * Constant COND * DIR * AR*	-2.10	0.98	-2.15	0.03	-4.01	-0.19
*Block4 * Random Increase COND * DIR * AR*	-0.29	0.99	-0.30	0.77	-2.24	1.65
*Block4 * Constant COND * DIR * AR*	-0.67	0.97	-0.69	0.49	-2.57	1.24
*Block5 * Random Increase COND * DIR * AR*	-0.27	0.99	-0.27	0.79	-2.21	1.67
*Block5 * Constant COND * DIR * AR*	-0.53	0.97	-0.54	0.59	-2.44	1.38
*Block6 * Random Increase COND * DIR * AR*	-1.69	1.00	-1.69	0.09	-3.65	0.27
*Block6 * Constant COND * DIR * AR*	-1.55	0.98	-1.59	0.11	-3.47	0.37
*Random Increase COND * LOC * AR * Btrial*	-0.09	0.08	-1.20	0.23	-0.25	0.06
*Constant COND * LOC * AR * Btrial*	-0.08	0.08	-0.96	0.34	-0.23	0.08
*Random Increase COND * LOC * DIR * Btrial*	0.02	0.08	0.21	0.84	-0.14	0.18
*Constant COND * LOC * DIR * Btrial*	0.00	0.08	-0.05	0.96	-0.16	0.16
*Random Increase COND * DIR * AR * Btrial*	-0.02	0.08	-0.25	0.81	-0.19	0.14
*Constant COND * DIR * AR * Btrial*	-0.09	0.08	-1.07	0.28	-0.25	0.07
*Random Increase COND * LOC * DIR * AR*	-0.65	0.58	-1.13	0.26	-1.78	0.48
*Constant COND * LOC * DIR * AR*	-0.39	0.57	-0.68	0.50	-1.50	0.73
*Block2 * LOC * DIR * AR * Btrial*	0.33	0.24	1.42	0.16	-0.13	0.80
*Block3 * LOC * DIR * AR * Btrial*	0.02	0.24	0.10	0.92	-0.45	0.49
*Block4 * LOC * DIR * AR * Btrial*	0.31	0.24	1.30	0.19	-0.16	0.78
*Block5 * LOC * DIR * AR * Btrial*	-0.03	0.24	-0.11	0.91	-0.49	0.44
*Block6 * LOC * DIR * AR * Btrial*	0.19	0.24	0.80	0.43	-0.28	0.66
*Block2 * Random Increase COND * LOC * DIR * AR*	0.33	2.01	0.17	0.87	-3.62	4.28
*Block2 * Constant COND * LOC * DIR * AR*	-1.32	1.97	-0.67	0.50	-5.18	2.54
*Block3 * Random Increase COND * LOC * DIR * AR*	-0.58	2.01	-0.29	0.77	-4.52	3.36
*Block3 * Constant COND * LOC * DIR * AR*	-0.44	1.97	-0.22	0.82	-4.30	3.43
*Block4 * Random Increase COND * LOC * DIR * AR*	0.53	2.00	0.26	0.79	-3.39	4.44
*Block4 * Constant COND * LOC * DIR * AR*	-1.46	1.96	-0.74	0.46	-5.30	2.38
*Block5 * Random Increase COND * LOC * DIR * AR*	1.29	2.00	0.65	0.52	-2.63	5.20

*Block5 * Constant COND * LOC * DIR * AR*	-1.01	1.97	-0.51	0.61	-4.88	2.85
*Block6 * Random Increase COND * LOC * DIR * AR*	1.59	2.01	0.79	0.43	-2.35	5.52
*Block6 * Constant COND * LOC * DIR * AR*	1.66	2.00	0.83	0.41	-2.26	5.58
*Random Increase COND * LOC * DIR * AR * Btrial*	0.01	0.17	0.08	0.94	-0.32	0.34
*Constant COND * LOC * DIR * AR * Btrial*	-0.09	0.17	-0.53	0.60	-0.41	0.24
*Block2 * Random Increase COND * LOC * AR * Btrial*	0.20	0.28	0.70	0.48	-0.35	0.75
*Block2 * Constant COND * LOC * AR * Btrial*	0.06	0.28	0.23	0.82	-0.49	0.62
*Block3 * Random Increase COND * LOC * AR * Btrial*	0.39	0.28	1.41	0.16	-0.15	0.94
*Block3 * Constant COND * LOC * AR * Btrial*	0.25	0.28	0.91	0.37	-0.29	0.80
*Block4 * Random Increase COND * LOC * AR * Btrial*	0.28	0.28	1.00	0.32	-0.27	0.83
*Block4 * Constant COND * LOC * AR * Btrial*	0.03	0.28	0.12	0.90	-0.51	0.58
*Block5 * Random Increase COND * LOC * AR * Btrial*	0.23	0.28	0.81	0.42	-0.32	0.77
*Block5 * Constant COND * LOC * AR * Btrial*	-0.10	0.28	-0.36	0.72	-0.65	0.45
*Block6 * Random Increase COND * LOC * AR * Btrial*	-0.02	0.28	-0.06	0.95	-0.56	0.53
*Block6 * Constant COND * LOC * AR * Btrial*	-0.26	0.28	-0.92	0.36	-0.81	0.29
*Block2 * Random Increase COND * LOC * DIR * Btrial*	0.43	0.29	1.48	0.14	-0.14	1.00
*Block2 * Constant COND * LOC * DIR * Btrial*	0.08	0.29	0.29	0.77	-0.48	0.64
*Block3 * Random Increase COND * LOC * DIR * Btrial*	0.21	0.29	0.72	0.47	-0.36	0.78
*Block3 * Constant COND * LOC * DIR * Btrial*	-0.44	0.29	-1.52	0.13	-1.00	0.13
*Block4 * Random Increase COND * LOC * DIR * Btrial*	0.42	0.29	1.42	0.16	-0.16	0.99
*Block4 * Constant COND * LOC * DIR * Btrial*	0.13	0.29	0.46	0.65	-0.43	0.69
*Block5 * Random Increase COND * LOC * DIR * Btrial*	0.37	0.29	1.30	0.19	-0.19	0.94
*Block5 * Constant COND * LOC * DIR * Btrial*	0.07	0.29	0.24	0.81	-0.49	0.63
*Block6 * Random Increase COND * LOC * DIR * Btrial*	-0.08	0.29	-0.28	0.78	-0.66	0.50
*Block6 * Constant COND * LOC * DIR * Btrial*	-0.33	0.29	-1.11	0.27	-0.90	0.25
*Block2 * Random Increase COND * DIR * AR * Btrial*	0.18	0.30	0.62	0.53	-0.40	0.76
*Block2 * Constant COND * DIR * AR * Btrial*	-0.31	0.29	-1.07	0.28	-0.88	0.26
*Block3 * Random Increase COND * DIR * AR * Btrial*	-0.39	0.30	-1.28	0.20	-0.98	0.21
*Block3 * Constant COND * DIR * AR * Btrial*	-0.01	0.30	-0.02	0.99	-0.59	0.57
*Block4 * Random Increase COND * DIR * AR * Btrial*	-0.51	0.30	-1.71	0.09	-1.11	0.08
*Block4 * Constant COND * DIR * AR * Btrial*	-0.32	0.30	-1.09	0.27	-0.91	0.26
*Block5 * Random Increase COND * DIR * AR * Btrial*	-0.30	0.30	-1.01	0.31	-0.88	0.28
*Block5 * Constant COND * DIR * AR * Btrial*	-0.16	0.29	-0.53	0.59	-0.73	0.42
*Block6 * Random Increase COND * DIR * AR * Btrial*	-0.32	0.30	-1.06	0.29	-0.91	0.27
*Block6 * Constant COND * DIR * AR * Btrial*	-0.17	0.29	-0.58	0.56	-0.74	0.40
*Block2 * Random Increase COND * LOC * DIR * AR * Btrial*	-0.87	0.63	-1.37	0.17	-2.11	0.37
*Block2 * Constant COND * LOC * DIR * AR * Btrial*	-0.45	0.61	-0.74	0.46	-1.65	0.74
*Block3 * Random Increase COND * LOC * DIR * AR * Btrial*	-1.01	0.65	-1.56	0.12	-2.27	0.26
*Block3 * Constant COND * LOC * DIR * AR * Btrial*	-0.54	0.61	-0.88	0.38	-1.74	0.67
*Block4 * Random Increase COND * LOC * DIR * AR * Btrial*	-1.39	0.65	-2.16	0.03	-2.66	-0.13

*Block4 * Constant COND * LOC * DIR * AR * Btrial*	-0.06	0.63	-0.09	0.93	-1.28	1.17
*Block5 * Random Increase COND * LOC * DIR * AR * Btrial*	-1.31	0.63	-2.09	0.04	-2.55	-0.08
*Block5 * Constant COND * LOC * DIR * AR * Btrial*	-0.13	0.61	-0.22	0.83	-1.33	1.07
*Block6 * Random Increase COND * LOC * DIR * AR * Btrial*	-0.80	0.65	-1.24	0.21	-2.07	0.46
*Block6 * Constant COND * LOC * DIR * AR * Btrial*	-0.26	0.64	-0.41	0.68	-1.52	0.99

APPENDIX D.

LSD Post Hoc Analysis of Block for Experimental Blocks Primary Variable Analysis of Absolute Error in Experiment 1.

Pairwise Comparisons

(I) Block	(J) Block	Mean Difference (I-J)	Std. Error	P-value	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Block1	Block2	.194*	0.096	0.043	0.006	0.381
	Block3	.276*	0.096	0.004	0.088	0.464
	Block4	.258*	0.095	0.007	0.07	0.445
	Block5	.463*	0.096	0	0.276	0.651
	Block6	.392*	0.096	0	0.204	0.579
Block2	Block1	-.194*	0.096	0.043	-0.381	-0.006
	Block3	0.082	0.095	0.389	-0.105	0.269
	Block4	0.064	0.095	5.03E-01	-0.123	0.251
	Block5	.269*	0.096	0.005	0.082	0.457
	Block6	.198*	0.096	0.039	0.01	0.385
Block3	Block1	-.276*	0.096	0.004	-0.464	-0.088
	Block2	-0.082	0.095	0.389	-0.269	0.105
	Block4	-0.018	0.095	0.847	-0.206	0.169
	Block5	0.187	0.095	0.05	-5.49E-05	0.374
	Block6	0.115	0.095	0.226	-0.072	0.303
Block4	Block1	-.258*	0.095	0.007	-0.445	-0.07
	Block2	-0.064	0.095	0.503	-2.51E-01	0.123
	Block3	0.018	0.095	0.847	-0.169	0.206
	Block5	.205*	0.095	0.031	0.018	0.393
	Block6	0.134	0.095	0.161	-0.053	0.321
Block5	Block1	-.463*	0.096	0	-0.651	-0.276
	Block2	-.269*	0.096	0.005	-0.457	-0.082
	Block3	-0.187	0.095	0.05	-0.374	5.49E-05
	Block4	-.205*	0.095	0.031	-0.393	-0.018
	Block6	-0.072	0.095	0.453	-0.259	0.115
Block6	Block1	-.392*	0.096	0	-0.579	-0.204
	Block2	-.198*	0.096	0.039	-0.385	-0.01
	Block3	-0.115	0.095	0.226	-0.303	0.072
	Block4	-0.134	0.095	0.161	-0.321	0.053
	Block5	0.072	0.095	0.453	-0.115	0.259

Based on estimated marginal means

** The mean difference is significant at the .05 level.*

APPENDIX E.

Experiment 1: Experimental Block Secondary Analysis Coefficients of Absolute Error

Estimates of Fixed Effects

Predictors	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Block 2	-0.184738	0.098248	-1.88	0.06	-0.377381	0.007905
Block 3	-0.275753	0.099152	-2.781	0.005	-0.470168	-0.081337
Block 4	-0.264104	0.102754	-2.57	0.01	-0.465582	-0.062627
Block 4	-0.441092	0.105937	-4.164	0	-0.648811	-0.233374
Block 5	-0.361632	0.109512	-3.302	0.001	-0.576361	-0.146902
Block Trial	-0.015464	0.010293	-1.502	0.138	-0.036051	0.005123
Location	0.144144	0.155035	0.93	0.353	-0.159875	0.448163
Action Requirement	0.13751	0.077211	1.781	0.082	-0.018237	0.293257
Directionality	0.401304	0.112871	3.555	0.001	0.173176	0.629432
Total Rotation	0.00352	0.002186	1.61	0.108	-0.000768	0.007807
Max Rotation	-0.006296	0.006733	-0.935	0.35	-0.019501	0.006909
Rotational Difference	0.003401	0.010013	0.34	0.734	-0.016234	0.023035
SampEn-X	-4.405331	1.843828	-2.389	0.017	-8.022835	-0.787827
SampEn-Y	0.064608	2.839855	0.023	0.982	-5.511665	5.64088
SSQ	0.001851	0.016947	0.109	0.913	-0.031379	0.03508
Pre-MSAQ	-0.029078	0.017407	-1.67	0.104	-0.0644	0.006245
Post-MSAQ	0.007004	0.006991	1.002	0.323	-0.007172	0.021179
Constant Condition	0.200735	0.180022	1.115	0.272	-0.163794	0.565263
Random Increase Condition	0.291151	0.180114	1.616	0.114	-0.073596	0.655898
*Block 2 * SSQ*	0.005204	0.046031	0.113	0.91	-0.085052	0.095461
*Block 3 * SSQ*	0.03279	0.043399	0.756	0.45	-0.052305	0.117885
*Block 4 * SSQ*	-0.041172	0.041091	-1.002	0.316	-0.121742	0.039398
*Block 4 * SSQ*	-0.062646	0.041415	-1.513	0.13	-0.143851	0.018559
*Block 5 * SSQ*	0.001235	0.040452	0.031	0.976	-0.078082	0.080553
*Block 2 * Total Rotation*	0.00027	0.003973	0.068	0.946	-0.00752	0.00806
*Block 3 * Total Rotation*	0.00631	0.004752	1.328	0.184	-0.003008	0.015627
*Block 4 * Total Rotation*	0.001406	0.00485	0.29	0.772	-0.008103	0.010915
*Block 4 * Total Rotation*	-0.000504	0.004889	-0.103	0.918	-0.010091	0.009082
*Block 5 * Total Rotation*	0.004089	0.004946	0.827	0.408	-0.005609	0.013787
*Block 2 * Max Rotation*	-0.000395	0.006714	-0.059	0.953	-0.01356	0.012771
*Block 3 * Max Rotation*	0.000415	0.006851	0.061	0.952	-0.013018	0.013849
*Block 4 * Max Rotation*	0.001161	0.006904	0.168	0.867	-0.012376	0.014697
*Block 4 * Max Rotation*	-0.006896	0.006997	-0.986	0.324	-0.020616	0.006824

*Block 5 * Max Rotation*	0.002945	0.006935	0.425	0.671	-0.010652	0.016543
*Block 2 * Rotational Difference*	0.081751	0.023703	3.449	0.001	0.035274	0.128228
*Block 3 * Rotational Difference*	0.080879	0.023039	3.511	0	0.035705	0.126053
*Block 4 * Rotational Difference*	0.030495	0.023214	1.314	0.189	-0.015023	0.076013
*Block 4 * Rotational Difference*	0.086534	0.022951	3.77	0	0.041532	0.131536
*Block 5 * Rotational Difference*	0.047988	0.022205	2.161	0.031	0.00445	0.091527
*Constant Condition * SSQ*	0.000946	0.037273	0.025	0.98	-0.072321	0.074213
*Random Increase Condition * SSQ*	-0.01239	0.037356	-0.332	0.74	-0.085883	0.061104
*Constant Condition * Total Rotation*	0.001485	0.004383	0.339	0.735	-0.007108	0.010078
*Random Increase Condition * Total Rotation*	0.002896	0.00405	0.715	0.475	-0.005045	0.010837
*Constant Condition * Max Rotation*	-0.002627	0.005179	-0.507	0.612	-0.012782	0.007527
*Random Increase Condition * Max Rotation*	0.001237	0.005157	0.24	0.81	-0.008876	0.011349
*Constant Condition * Rotational Difference*	0.012742	0.020451	0.623	0.533	-0.027375	0.052859
*Random Increase Condition * Rotational Difference*	0.021331	0.019974	1.068	0.286	-0.017844	0.060506
*Block 2 * Constant Condition*	-0.457101	0.234573	-1.949	0.051	-0.917049	0.002848
*Block 2 * Random Increase Condition*	0.03978	0.237908	0.167	0.867	-0.426707	0.506267
*Block 3 * Constant Condition*	-0.111831	0.237077	-0.472	0.637	-0.576689	0.353026
*Block 3 * Random Increase Condition*	-0.057746	0.237637	-0.243	0.808	-0.5237	0.408207
*Block 4 * Constant Condition*	-0.069598	0.241603	-0.288	0.773	-0.54333	0.404133
*Block 4 * Random Increase Condition*	-0.192771	0.23938	-0.805	0.421	-0.662143	0.276601
*Block 4 * Constant Condition*	-0.547692	0.240633	-2.276	0.023	-1.019521	-0.075863
*Block 4 * Random Increase Condition*	-0.303065	0.235923	-1.285	0.199	-0.765659	0.15953
*Block 5 * Constant Condition*	0.049631	0.240158	0.207	0.836	-0.421265	0.520528
*Block 5 * Random Increase Condition*	-0.059355	0.237031	-0.25	0.802	-0.524122	0.405411
*Block 2 * Constant Condition * SSQ*	0.0953	0.141596	0.673	0.501	-0.182339	0.37294
*Block 2 * Random Increase Condition * SSQ*	0.067526	0.120293	0.561	0.575	-0.168342	0.303393
*Block 3 * Constant Condition * SSQ*	0.260667	0.134576	1.937	0.053	-0.003208	0.524542
*Block 3 * Random Increase Condition * SSQ*	0.122156	0.120139	1.017	0.309	-0.113412	0.357723
*Block 4 * Constant Condition * SSQ*	0.201591	0.130684	1.543	0.123	-0.054653	0.457835
*Block 4 * Random Increase Condition * SSQ*	0.080887	0.115136	0.703	0.482	-0.144871	0.306645
*Block 4 * Constant Condition * SSQ*	0.240532	0.129803	1.853	0.064	-0.013987	0.495051
*Block 4 * Random Increase Condition * SSQ*	0.087146	0.114336	0.762	0.446	-0.137043	0.311335
*Block 5 * Constant Condition * SSQ*	0.177499	0.125163	1.418	0.156	-0.067928	0.422925
*Block 5 * Random Increase Condition * SSQ*	0.066691	0.110349	0.604	0.546	-0.149688	0.28307
*Block 2 * Constant Condition * Total Rotation*	-0.003039	0.016103	-0.189	0.85	-0.034615	0.028536
*Block 2 * Random Increase Condition * Total Rotation*	0.010142	0.012553	0.808	0.419	-0.014472	0.034757
*Block 3 * Constant Condition * Total Rotation*	-0.006491	0.015315	-0.424	0.672	-0.03652	0.023538
*Block 3 * Random Increase Condition * Total Rotation*	-0.003609	0.01326	-0.272	0.786	-0.02961	0.022392
*Block 4 * Constant Condition * Total Rotation*	-0.025306	0.015104	-1.675	0.094	-0.054922	0.00431
*Block 4 * Random Increase Condition * Total Rotation*	-0.003625	0.012928	-0.28	0.779	-0.028974	0.021724

*Block 4 * Constant Condition * Total Rotation*	-0.007916	0.015289	-0.518	0.605	-0.037895	0.022063
*Block 4 * Random Increase Condition * Total Rotation*	0.008105	0.013112	0.618	0.537	-0.017605	0.033815
*Block 5 * Constant Condition * Total Rotation*	0.008253	0.014567	0.567	0.571	-0.02031	0.036816
*Block 5 * Random Increase Condition * Total Rotation*	0.013445	0.012689	1.06	0.289	-0.011435	0.038326
*Block 2 * Constant Condition * Max Rotation*	-0.000676	0.017557	-0.039	0.969	-0.035102	0.03375
*Block 2 * Random Increase Condition * Max Rotation*	0.017683	0.016452	1.075	0.283	-0.014576	0.049943
*Block 3 * Constant Condition * Max Rotation*	-0.003343	0.01719	-0.194	0.846	-0.037049	0.030364
*Block 3 * Random Increase Condition * Max Rotation*	0.007054	0.016877	0.418	0.676	-0.026039	0.040147
*Block 4 * Constant Condition * Max Rotation*	-0.038254	0.017133	-2.233	0.026	-0.071848	-0.004661
*Block 4 * Random Increase Condition * Max Rotation*	-0.00409	0.017039	-0.24	0.81	-0.0375	0.02932
*Block 4 * Constant Condition * Max Rotation*	-0.01724	0.017317	-0.996	0.32	-0.051195	0.016716
*Block 4 * Random Increase Condition * Max Rotation*	0.011879	0.017292	0.687	0.492	-0.022028	0.045786
*Block 5 * Constant Condition * Max Rotation*	0.004692	0.017154	0.274	0.784	-0.028944	0.038328
*Block 5 * Random Increase Condition * Max Rotation*	0.027182	0.017232	1.577	0.115	-0.006606	0.060971
*Block 2 * Constant Condition * Rotational Difference*	0.003202	0.056068	0.057	0.954	-0.106735	0.11314
*Block 2 * Random Increase Condition * Rotational Difference*	0.04954	0.065055	0.762	0.446	-0.078019	0.177099
*Block 3 * Constant Condition * Rotational Difference*	0.018187	0.054214	0.335	0.737	-0.088114	0.124489
*Block 3 * Random Increase Condition * Rotational Difference*	-0.032821	0.060426	-0.543	0.587	-0.151302	0.085661
*Block 4 * Constant Condition * Rotational Difference*	0.01245	0.055975	0.222	0.824	-0.097305	0.122205
*Block 4 * Random Increase Condition * Rotational Difference*	-0.009164	0.058379	-0.157	0.875	-0.123632	0.105305
*Block 4 * Constant Condition * Rotational Difference*	0.047801	0.059434	0.804	0.421	-0.068736	0.164338
*Block 4 * Random Increase Condition * Rotational Difference*	0.058134	0.057261	1.015	0.31	-0.054143	0.170411
*Block 5 * Constant Condition * Rotational Difference*	0.048525	0.054078	0.897	0.37	-0.05751	0.154559
*Block 5 * Random Increase Condition * Rotational Difference*	0.019472	0.056363	0.345	0.73	-0.091045	0.129988

APPENDIX F.

Experiment 1: Pre-/ Post Block Primary Analysis Coefficients

Estimates of Fixed Effects						
Parameter	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
Intercept	1.904127	0.338111	5.632	0	1.230626	2.577629
Post-Test	-0.493274	0.127038	-3.883	0	-0.742598	-0.24395
Block Trial	0.114009	0.026897	4.239	0	0.060123	0.167894
Location	0.267379	0.126041	2.121	0.034	0.020011	0.514747
Action Requirement	0.459198	0.239252	1.919	0.062	-0.024023	0.942418
Directionality	0.197335	0.20585	0.959	0.344	-0.219515	0.614185
Constant Condition	0.586038	0.400993	1.461	0.152	-0.224681	1.396757
Random Increase Condition	0.096294	0.400574	0.24	0.811	-0.713695	0.906283
Post-Test * Block Trial	-0.00768	0.036673	-0.209	0.834	-0.079655	0.064294
Post-Test * Location	-0.06169	0.251626	-0.245	0.806	-0.555525	0.432145
Post-Test * Action Requirement	-0.097004	0.258346	-0.375	0.707	-0.604069	0.41006
Post-Test * Directionality	0.803943	0.272485	2.95	0.003	0.269186	1.338699
Location * Block Trial	0.02387	0.037553	0.636	0.525	-0.049828	0.097567
Action Requirement * Block Trial	0.065865	0.037899	1.738	0.083	-0.008513	0.140242
Directionality * Block Trial	0.04251	0.039552	1.075	0.283	-0.035109	0.120129
Location * Action Requirement	0.24322	0.250797	0.97	0.332	-0.249001	0.73544
Directionality * Action Requirement	0.722653	0.312884	2.31	0.021	0.108649	1.336657
Location * Directionality	-0.479625	0.258024	-1.859	0.063	-0.986025	0.026774
Post-Test * Constant Condition	0.497467	0.307943	1.615	0.107	-0.106904	1.101838
Post-Test * Random Increase Condition	1.132617	0.305914	3.702	0	0.532226	1.733007
Constant Condition * Block Trial	-0.005145	0.067003	-0.077	0.939	-0.139505	0.129215
Random Increase Condition * Block Trial	-0.026974	0.067094	-0.402	0.689	-0.1615	0.107552
Constant Condition * Location	-0.258068	0.308735	-0.836	0.403	-0.863984	0.347848
Random Increase Condition * Location	-0.246185	0.308022	-0.799	0.424	-0.850707	0.358338
Constant Condition * Action Requirement	0.629595	0.577605	1.09	0.283	-0.539415	1.798604
Random Increase Condition * Action Requirement	-0.323794	0.573937	-0.564	0.576	-1.486418	0.83883
Constant Condition * Directionality	0.495232	0.506637	0.977	0.335	-0.533803	1.524266
Random Increase Condition * Directionality	0.141246	0.497	0.284	0.778	-0.870406	1.152899
Location * Block Trial	-0.05708	0.052996	-1.077	0.282	-0.161087	0.046927
Post-Test * Location * Block Trial	0.163618	0.07564	2.163	0.031	0.015173	0.312063
Action Requirement * Block Trial	-0.01037	0.060734	-0.171	0.865	-0.130337	0.109596
Post-Test * Action Requirement * Block Trial	0.158642	0.073105	2.17	0.03	0.015167	0.302117

Post-Test * Directionality * Block Trial	-0.070267	0.075762	-0.927	0.354	-0.218955	0.07842
Post-Test * Location * Action Requirement	0.602448	0.502688	1.198	0.231	-0.384128	1.589024
Post-Test * Location * Directionality	0.839868	0.515712	1.629	0.104	-0.172272	1.852009
Post-Test * Directionality * Action Requirement	-0.557124	0.556612	-1.001	0.317	-1.649471	0.535223
Location * Action Requirement * Block Trial	-0.000195	0.075415	-0.003	0.998	-0.148199	0.147808
Location * Directionality * Block Trial	0.107803	0.077375	1.393	0.164	-0.044046	0.259651
Directionality * Action Requirement * Block Trial	0.361276	0.083195	4.343	0	0.198	0.524553
Location * Directionality * Action Requirement	0.583538	0.520815	1.12	0.263	-0.438618	1.605693
Location * Action Requirement * Block Trial	0.017628	0.0538	0.328	0.743	-0.087956	0.123213
Location * Cross-AR * Block Trial	0.021213	0.052404	0.405	0.686	-0.081633	0.12406
Post-Test * Constant Condition * Block Trial	-0.177004	0.088861	-1.992	0.047	-0.351405	-0.002603
Post-Test * Random Increase Condition * Block Trial	-0.162035	0.08924	-1.816	0.07	-0.337177	0.013107
Post-Test * Constant Condition * Location	0.279533	0.613908	0.455	0.649	-0.925316	1.484382
Post-Test * Random Increase Condition * Location	0.607079	0.612381	0.991	0.322	-0.594782	1.808941
Post-Test * Constant Condition * Action Requirement	-0.755278	0.62648	-1.206	0.228	-1.984857	0.474302
Post-Test * Random Increase Condition * Action Requirement	0.825834	0.627084	1.317	0.188	-0.404926	2.056593
Post-Test * Constant Condition * Directionality	1.009302	0.671964	1.502	0.133	-0.30945	2.328055
Post-Test * Random Increase Condition * Directionality	0.651773	0.65115	1.001	0.317	-0.626133	1.92968
Constant Condition * Location * Block Trial	0.036342	0.091945	0.395	0.693	-0.144103	0.216786
Random Increase Condition * Location * Block Trial	-0.096733	0.092054	-1.051	0.294	-0.277392	0.083926
Constant Condition * Action Requirement * Block Trial	0.119993	0.091889	1.306	0.192	-0.060345	0.300331
Random Increase Condition * Action Requirement * Block Trial	0.027334	0.092335	0.296	0.767	-0.153882	0.208551
Constant Condition * Directionality * Block Trial	0.06478	0.067581	0.959	0.338	-0.067851	0.19741
Random Increase Condition * Directionality * Block Trial	0.037763	0.069137	0.546	0.585	-0.097916	0.173441
Control Condition * Directionality * Block Trial	-0.0083	0.069696	-0.119	0.905	-0.145075	0.128475
Constant Condition * Location * Action Requirement	0.540547	0.613529	0.881	0.379	-0.663584	1.744677
Random Increase Condition * Location * Action Requirement	0.425631	0.614162	0.693	0.488	-0.779739	1.631
Constant Condition * Location * Directionality	-0.084344	0.644069	-0.131	0.896	-1.348393	1.179704
Random Increase Condition * Location * Directionality	-0.117275	0.630239	-0.186	0.852	-1.354187	1.119638
Post-Test * Location * Directionality * Action Requirement	0.948347	1.056316	0.898	0.37	-1.124764	3.021459
Location * Directionality * Action Requirement * Block Trial	0.107281	0.156478	0.686	0.493	-0.199814	0.414375
Post-Test * Location * Action Requirement * Block Trial	0.165433	0.151743	1.09	0.276	-0.132366	0.463232
Post-Test * Location * Directionality * Block Trial	0.001863	0.154228	0.012	0.99	-0.300811	0.304537
Post-Test * Constant Condition * Location * Block Trial	-0.237309	0.18582	-1.277	0.202	-0.601984	0.127367
Post-Test * Random Increase Condition * Location * Block Trial	-0.104203	0.183521	-0.568	0.57	-0.464373	0.255968
Post-Test * Constant Condition * Action Requirement * Block Trial	0.112711	0.179082	0.629	0.529	-0.238758	0.46418
Post-Test * Random Increase Condition * Action Requirement * Block Trial	0.059244	0.180514	0.328	0.743	-0.295033	0.413522

Post-Test * Constant Condition * Directionality * Block Trial	0.30724	0.189705	1.62	0.106	-0.065078	0.679558
Post-Test * Random Increase Condition * Directionality * Block Trial	0.3289	0.185802	1.77	0.077	-0.035755	0.693556
Post-Test * Constant Condition * Location * Action Requirement	1.741068	1.22613	1.42	0.156	-0.665359	4.147495
Post-Test * Random Increase Condition * Location * Action Requirement	2.289688	1.223829	1.871	0.062	-0.112242	4.691618
Post-Test * Constant Condition * Location * Directionality	0.062056	1.297763	0.048	0.962	-2.48498	2.609092
Post-Test * Random Increase Condition * Location * Directionality	0.610856	1.257829	0.486	0.627	-1.85779	3.079501
Post-Test * Constant Condition * Directionality * Action Requirement	-3.489596	1.391736	-2.507	0.012	-6.220863	-0.75833
Post-Test * Random Increase Condition * Directionality * Action Requirement	-2.989086	1.363203	-2.193	0.029	-5.664385	-0.313787
Constant Condition * Location * Action Requirement * Block Trial	0.134333	0.184318	0.729	0.466	-0.227405	0.496072
Random Increase Condition * Location * Action Requirement * Block Trial	0.151489	0.184982	0.819	0.413	-0.211553	0.514531
Constant Condition * Location * Directionality * Block Trial	0.178091	0.19717	0.903	0.367	-0.208861	0.565044
Random Increase Condition * Location * Directionality * Block Trial	0.091973	0.190394	0.483	0.629	-0.281689	0.465635
Constant Condition * Directionality * Action Requirement * Block Trial	-0.250049	0.206775	-1.209	0.227	-0.655874	0.155775
Random Increase Condition * Directionality * Action Requirement * Block Trial	-0.206778	0.205564	-1.006	0.315	-0.610203	0.196648
Constant Condition * Location * Directionality * Action Requirement	-0.450731	1.316913	-0.342	0.732	-3.03532	2.133858
Random Increase Condition * Location * Directionality * Action Requirement	1.035448	1.303162	0.795	0.427	-1.522142	3.593038
Post-Test * Location * Directionality * Action Requirement * Block Trial	-0.13697	0.317227	-0.432	0.666	-0.759548	0.485609
Post-Test * Constant Condition * Location * Directionality * Action Requirement	0.156055	2.678479	0.058	0.954	-5.100883	5.412993
Post-Test * Random Increase Condition * Location * Directionality * Action Requirement	-0.712189	2.632591	-0.271	0.787	-5.87904	4.454661
Constant Condition * Location * Directionality * Action Requirement * Block Trial	-0.996293	0.40988	-2.431	0.015	-1.800712	-0.191873
Random Increase Condition * Location * Directionality * Action Requirement * Block Trial	-0.46206	0.400505	-1.154	0.249	-1.248092	0.323973
Post-Test * Constant Condition * Location * Action Requirement * Block Trial	-0.249524	0.380343	-0.656	0.512	-0.995976	0.496928
Post-Test * Random Increase Condition * Location * Action Requirement * Block Trial	0.033306	0.376839	0.088	0.93	-0.706279	0.77289
Post-Test * Constant Condition * Location * Directionality * Block Trial	0.125619	0.39834	0.315	0.753	-0.656162	0.9074
Post-Test * Random Increase Condition * Location * Directionality * Block Trial	0.448353	0.388475	1.154	0.249	-0.314068	1.210774
Post-Test * Constant Condition * Directionality * Action Requirement * Block Trial	0.514922	0.387741	1.328	0.185	-0.246067	1.275912
Post-Test * Random Increase Condition * Directionality * Action Requirement * Block Trial	-0.170106	0.388396	-0.438	0.662	-0.932365	0.592153
Post-Test * Constant Condition * Location * Directionality * Action Requirement * Block Trial	0.980442	0.830125	1.181	0.238	-0.648881	2.609765
Post-Test * Random Increase Condition * Location * Directionality * Action Requirement * Block Trial	0.858463	0.808822	1.061	0.289	-0.729061	2.445987

APPENDIX G.

Experiment 1: Pre-/ Post-test Secondary Analysis Coefficients for Absolute Error

Estimates of Fixed Effects

Parameter	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	2.25	0.381711	5.885	0	1.490496	3.002067
Post-Test	-0.49	0.13986	-3.476	0.001	-0.760621	-0.211673
Block Trial	0.09	0.025566	3.628	0.001	0.041532	0.143954
Location	-0.72	0.470498	-1.526	0.127	-1.641397	0.205224
Action Requirement	0.71	0.252528	2.803	0.008	0.198317	1.217577
Directionality	0.52	0.163903	3.17	0.002	0.197969	0.841269
Constant Condition	0.56	0.391731	1.425	0.162	-0.234469	1.351168
Random Increase Condition	0.09	0.391466	0.228	0.821	-0.703271	0.881472
Total Rotation	-0.01	0.007993	-1.324	0.186	-0.026271	0.005101
Max Rotation	0.04	0.019643	1.907	0.057	-0.001093	0.076008
Rotational Difference	0.13	0.020275	6.217	0	0.08627	0.165845
SampEn-X	-6.24	5.256227	-1.186	0.236	-16.571009	4.09892
SampEn-Y	-3.73	6.209963	-0.601	0.548	-15.933424	8.465187
MSAQ	0.01	0.010882	0.469	0.639	-0.01627	0.026474
*Post-Test * MSAQ*	0.07	0.028812	2.519	0.012	0.016	0.129136
*Post-Test * Total Rotation*	0.00	0.008239	0.219	0.826	-0.014362	0.017977
*Post-Test * Max Rotation*	-0.01	0.009075	-0.925	0.355	-0.026202	0.009419
*Post-Test * Rotational Difference*	-0.10	0.024813	-4.192	0	-0.152697	-0.055309
*Constant Condition * MSAQ*	-0.02	0.030585	-0.715	0.475	-0.081931	0.038196
*Random Increase Condition * MSAQ*	-0.05	0.033124	-1.42	0.156	-0.112077	0.018024
*Constant Condition * Total Rotation*	-0.01	0.010808	-0.899	0.369	-0.030933	0.011491
*Random Increase Condition * Total Rotation*	0.00	0.009959	-0.165	0.869	-0.021191	0.017897
*Constant Condition * Max Rotation*	-0.01	0.011531	-0.903	0.367	-0.033043	0.012215
*Random Increase Condition * Max Rotation*	-0.02	0.011706	-1.402	0.161	-0.039381	0.006565
*Constant Condition * Rotational Difference*	-0.09	0.03666	-2.402	0.017	-0.160052	-0.016093
*Random Increase Condition * Rotational Difference*	-0.05	0.037462	-1.378	0.169	-0.125157	0.021926
*Post-Test * Constant Condition*	0.47	0.318983	1.484	0.138	-0.15263	1.099412
*Post-Test * Random Increase Condition*	1.06	0.305424	3.464	0.001	0.458551	1.657404
*Constant Condition * Block_Trial_0*	0.01	0.064594	0.165	0.87	-0.118904	0.140227
*Random Increase Condition * Block_Trial_0*	-0.02	0.064692	-0.368	0.714	-0.153548	0.105948
*Post-Test * Constant Condition * Total Rotation*	0.01	0.021205	0.578	0.563	-0.029355	0.053879
*Post-Test * Random Increase Condition * Total Rotation*	0.02	0.019513	0.78	0.435	-0.02307	0.053522
*Post-Test * Constant Condition * Max Rotation*	0.02	0.022276	0.83	0.407	-0.025221	0.062216
*Post-Test * Random Increase Condition * Max Rotation*	0.02	0.022293	0.963	0.336	-0.022276	0.065229

*Post-Test * Constant Condition * Rotational Difference*	-0.16	0.057752	-2.818	0.005	-0.276071	-0.049399
*Post-Test * Random Increase Condition * Rotational Difference*	-0.03	0.065218	-0.494	0.621	-0.160236	0.095735

APPENDIX H.

LSD Post Hoc Analysis of Block for Experimental Blocks for SampEn-X in Experiment 1.

Pairwise Comparisons

(I) Block	(J) Block	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Block1	Block2	-.006*	0.001	0	-0.008	-0.004
	Block3	-.004*	0.001	0	-0.005	-0.002
	Block4	-.002*	0.001	0.025	-0.004	0
	Block5	-.010*	0.001	0	-0.012	-0.008
	Block6	-.013*	0.001	0	-0.015	-0.011
Block2	Block1	.006*	0.001	0	0.004	0.008
	Block3	.003*	0.001	0.002	0.001	0.004
	Block4	.004*	0.001	0	0.002	0.006
	Block5	-.003*	0.001	0	-0.005	-0.002
	Block6	-.006*	0.001	0	-0.008	-0.005
Block3	Block1	.004*	0.001	0	0.002	0.005
	Block2	-.003*	0.001	0.002	-0.004	-0.001
	Block4	0.00	0.001	0.089	0	0.003
	Block5	-.006*	0.001	0	-0.008	-0.004
	Block6	-.009*	0.001	0	-0.011	-0.007
Block4	Block1	.002*	0.001	0.025	0	0.004
	Block2	-.004*	0.001	0	-0.006	-0.002
	Block3	0.00	0.001	0.089	-0.003	0
	Block5	-.007*	0.001	0	-0.009	-0.006
	Block6	-.010*	0.001	0	-0.012	-0.009
Block5	Block1	.010*	0.001	0	0.008	0.012
	Block2	.003*	0.001	0	0.002	0.005
	Block3	.006*	0.001	0	0.004	0.008
	Block4	.007*	0.001	0	0.006	0.009
	Block6	-.003*	0.001	0	-0.005	-0.001
Block6	Block1	.013*	0.001	0	0.011	0.015
	Block2	.006*	0.001	0	0.005	0.008
	Block3	.009*	0.001	0	0.007	0.011
	Block4	.010*	0.001	0	0.009	0.012
	Block5	.003*	0.001	0	0.001	0.005

Based on estimated marginal means

** The mean difference is significant at the .05 level.*

APPENDIX I.

LSD Post Hoc Analysis of Block for Experimental Blocks for SampEn-Y in Experiment 1.

Pairwise Comparisons

(I) Block	(J) Block	Mean Difference (I-J)	Std. Error	Sig	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Block1	Block2	.003*	0.001	0	0.002	0.004
	Block3	.004*	0.001	0	0.003	0.005
	Block4	.003*	0.001	0	0.002	0.004
	Block5	.003*	0.001	0	0.002	0.004
	Block6	.002*	0.001	0.004	0.001	0.003
Block2	Block1	-.003*	0.001	0	-0.004	-0.002
	Block3	.001*	0.001	0.046	2.02E-05	0.002
	Block4	0.00	0.001	0.625	-0.001	0.001
	Block5	0.00	0.001	0.851	-0.001	0.001
	Block6	0.00	0.001	0.057	-0.002	3.13E-05
Block3	Block1	-.004*	0.001	0	-0.005	-0.003
	Block2	-.001*	0.001	0.046	-0.002	-2.02E-05
	Block4	0.00	0.001	0.132	-0.002	0
	Block5	-.001*	0.001	0.029	-0.002	0
	Block6	-.002*	0.001	0	-0.003	-0.001
Block4	Block1	-.003*	0.001	0	-0.004	-0.002
	Block2	0.00	0.001	0.625	-0.001	0.001
	Block3	0.00	0.001	0.132	0	0.002
	Block5	0.00	0.001	0.499	-0.002	0.001
	Block6	-.001*	0.001	0.017	-0.002	0
Block5	Block1	-.003*	0.001	0	-0.004	-0.002
	Block2	0.00	0.001	0.851	-0.001	0.001
	Block3	.001*	0.001	0.029	0	0.002
	Block4	0.00	0.001	0.499	-0.001	0.002
	Block6	0.00	0.001	0.086	-0.002	0
Block6	Block1	-.002*	0.001	0.004	-0.003	-0.001
	Block2	0.00	0.001	0.057	-3.13E-05	0.002
	Block3	.002*	0.001	0	0.001	0.003
	Block4	.001*	0.001	0.017	0	0.002
	Block5	0.00	0.001	0.086	0	0.002

Based on estimated marginal means

** The mean difference is significant at the .05 level.*

APPENDIX J.

Experiment 2: Descriptive Statistics for Collected Predictors Experimental Blocks

PREDICTOR	N	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
TOTAL ROTATION (DEGREES)	3022	40.92	287.74	81.07	19.32
MAX ROTATION (DEGREES)	3022	29.20	107.04	71.92	13.76
ROTATIONAL DIFFERENCE (DEGREES)	3022	0.00	28.64	5.72	4.48
SSQ	3022	0.00	30.00	2.00	4.48
ML POSTURAL SWAY (ENTROPY)	3022	0.03	0.13	0.06	0.02
AP POSTURAL SWAY (ENTROPY)	3022	0.02	0.11	0.06	0.02

APPENDIX K.

Experiment 2: Descriptive Statistics for Collected Predictors Pre-/Post-Test Blocks

PREDICTOR	N	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
MSAQ PRE-TEST	1008	14.00	26.00	17.73	2.32
MSAQ POST-TEST	1008	16.00	42.00	19.59	5.37
TOTAL ROTATION (DEGREES)	1008	42.34	176.54	77.02	16.59
MAX ROTATION (DEGREES)	1008	38.91	101.60	69.78	13.76
ROTATIONAL DIFFERENCE (DEGREES)	1008	0.03	28.75	7.37	5.57
SSQ	1008	14.00	26.00	17.73	2.32

APPENDIX L.

Experiment 2: Experimental Block Primary Analysis Coefficients for the Outcome Variable of Absolute Error

Estimates of Fixed Effects

Parameter	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	1.632842	0.131993	12.371	0	1.371098	1.894586
Block 2	-0.119703	0.08135	-1.471	0.141	-0.279214	0.039807
Block 3	-0.131787	0.081485	-1.617	0.106	-0.291562	0.027988
Block 4	-0.264799	0.081432	-3.252	0.001	-0.42447	-0.105129
Block 5	-0.23412	0.081437	-2.875	0.004	-0.393802	-0.074438
Block 6	-0.266754	0.081509	-3.273	0.001	-0.426575	-0.106932
Block Trial	-0.023034	0.008917	-2.583	0.012	-0.04087	-0.005197
Location	0.060584	0.047317	1.28	0.201	-0.032194	0.153363
Action Requirement	0.310778	0.07864	3.952	0	0.151913	0.469643
Directionality	0.306499	0.082226	3.727	0.001	0.140193	0.472805
Oscillating Condition	-0.009347	0.137584	-0.068	0.946	-0.289611	0.270917
Constant Increase Condition	-0.062604	0.14225	-0.44	0.663	-0.352491	0.227283
*Block 2 * Block Trial*	0.018394	0.023867	0.771	0.441	-0.028404	0.065191
*Block 3 * Block Trial*	0.042854	0.023794	1.801	0.072	-0.0038	0.089508
*Block 4 * Block Trial*	0.041986	0.023775	1.766	0.078	-0.004632	0.088603
*Block 5 * Block Trial*	0.070396	0.02379	2.959	0.003	0.02375	0.117043
*Block 6 * Block Trial*	0.058455	0.023803	2.456	0.014	0.011783	0.105127
*Block 2 * Location*	-0.011009	0.163191	-0.067	0.946	-0.330992	0.308974
*Block 3 * Location*	-0.09863	0.163157	-0.605	0.546	-0.418544	0.221285
*Block 4 * Location*	0.177968	0.163025	1.092	0.275	-0.14169	0.497625
*Block 5 * Location*	-0.140184	0.163027	-0.86	0.39	-0.459845	0.179478
*Block 6 * Location*	-0.214393	0.163274	-1.313	0.189	-0.534538	0.105752
*Block 2 * Action Requirement*	-0.19872	0.163302	-1.217	0.224	-0.518921	0.12148
*Block 3 * Action Requirement*	-0.234456	0.163197	-1.437	0.151	-0.55445	0.085539
*Block 4 * Action Requirement*	-0.281406	0.163174	-1.725	0.085	-0.601356	0.038545
*Block 5 * Action Requirement*	-0.324876	0.163217	-1.99	0.047	-0.644909	-0.004843
*Block 6 * Action Requirement*	-0.123215	0.163465	-0.754	0.451	-0.443734	0.197304
*Block 2 * Directionality*	-0.379454	0.166543	-2.278	0.023	-0.706008	-0.0529
*Block 3 * Directionality*	-0.20478	0.168609	-1.215	0.225	-0.535386	0.125825

*Block 4 * Directionality*	-0.213319	0.167094	-1.277	0.202	-0.540953	0.114314
*Block 5 * Directionality*	-0.406763	0.168403	-2.415	0.016	-0.736964	-0.076562
*Block 6 * Directionality*	-0.522513	0.166462	-3.139	0.002	-0.848909	-0.196118
*Location * Block Trial*	-0.020885	0.013794	-1.514	0.13	-0.047931	0.006162
*Directionality * Block Trial*	0.009135	0.014301	0.639	0.523	-0.018906	0.037175
*Location * Action Requirement*	0.168578	0.094732	1.78	0.075	-0.017171	0.354328
*Directionality * Action Requirement*	0.013273	0.102209	0.13	0.897	-0.187136	0.213682
*Location * Directionality*	-0.240593	0.09813	-2.452	0.014	-0.433003	-0.048184
*Block 2 * Oscillating Condition*	-0.098538	0.19597	-0.503	0.615	-0.482796	0.285721
*Block 2 * Constant Increase Condition*	0.000724	0.203065	0.004	0.997	-0.397445	0.398893
*Block 3 * Oscillating Condition*	0.217546	0.196258	1.108	0.268	-0.167276	0.602369
*Block 3 * Constant Increase Condition*	0.101519	0.203063	0.5	0.617	-0.296646	0.499685
*Block 4 * Oscillating Condition*	-0.294391	0.195986	-1.502	0.133	-0.67868	0.089899
*Block 4 * Constant Increase Condition*	0.022933	0.203134	0.113	0.91	-0.375372	0.421239
*Block 5 * Oscillating Condition*	-0.102846	0.196061	-0.525	0.6	-0.487283	0.28159
*Block 5 * Constant Increase Condition*	-0.116757	0.203049	-0.575	0.565	-0.514896	0.281382
*Block 6 * Oscillating Condition*	0.156479	0.196325	0.797	0.425	-0.228473	0.541432
*Block 6 * Constant Increase Condition*	0.202111	0.203243	0.994	0.32	-0.196408	0.600629
*Oscillating Condition * Block Trial*	-0.001858	0.021869	-0.085	0.933	-0.04567	0.041955
*Constant Increase Condition * Block Trial*	-0.001343	0.022662	-0.059	0.953	-0.046746	0.04406
*Oscillating Condition * Location*	-0.08128	0.114129	-0.712	0.476	-0.305062	0.142501
*Constant Increase Condition * Location*	-0.151611	0.118255	-1.282	0.2	-0.383483	0.08026
*Oscillating Condition * Action Requirement*	0.228515	0.190347	1.201	0.237	-0.156655	0.613685
*Constant Increase Condition * Action Requirement*	0.172223	0.19734	0.873	0.388	-0.227088	0.571534
*Oscillating Condition * Directionality*	-0.260133	0.195585	-1.33	0.192	-0.656457	0.13619
*Constant Increase Condition * Directionality*	0.055558	0.201022	0.276	0.784	-0.352193	0.463309
*Block 2 * Location * Block Trial*	-0.000633	0.047882	-0.013	0.989	-0.094519	0.093253
*Block 3 * Location * Block Trial*	-0.053404	0.04792	-1.114	0.265	-0.147365	0.040557
*Block 4 * Location * Block Trial*	-0.057935	0.047683	-1.215	0.224	-0.15143	0.03556
*Block 5 * Location * Block Trial*	-0.039027	0.047669	-0.819	0.413	-0.132496	0.054442
*Block 6 * Location * Block Trial*	0.005996	0.047698	0.126	0.9	-0.08753	0.099522
*Block 2 * Action Requirement * Block Trial*	-0.05471	0.047521	-1.151	0.25	-0.147888	0.038468
*Block 3 * Action Requirement * Block Trial*	0.07674	0.047289	1.623	0.105	-0.015983	0.169464
*Block 4 * Action Requirement * Block Trial*	0.047887	0.047213	1.014	0.311	-0.044688	0.140463
*Block 5 * Action Requirement * Block Trial*	-0.017653	0.047204	-0.374	0.708	-0.110212	0.074905

*Block 6 * Action Requirement * Block Trial*	0.039361	0.047282	0.832	0.405	-0.05335	0.132072
*Block 2 * Location * Action Requirement*	-0.24689	0.327059	-0.755	0.45	-0.888183	0.394403
*Block 3 * Location * Action Requirement*	-0.194712	0.326168	-0.597	0.551	-0.834258	0.444833
*Block 4 * Location * Action Requirement*	-0.400487	0.326245	-1.228	0.22	-1.040186	0.239211
*Block 5 * Location * Action Requirement*	-0.421755	0.326183	-1.293	0.196	-1.061331	0.217821
*Block 6 * Location * Action Requirement*	-0.35727	0.326511	-1.094	0.274	-0.997489	0.282949
*Block 2 * Location * Directionality*	0.042797	0.337084	0.127	0.899	-0.618149	0.703742
*Block 3 * Location * Directionality*	-0.510748	0.338758	-1.508	0.132	-1.174976	0.15348
*Block 4 * Location * Directionality*	0.269405	0.336888	0.8	0.424	-0.391156	0.929967
*Block 5 * Location * Directionality*	0.116926	0.338618	0.345	0.73	-0.547028	0.78088
*Block 6 * Location * Directionality*	-0.464836	0.334758	-1.389	0.165	-1.121223	0.19155
*Block 2 * Directionality * Action Requirement*	-0.159879	0.334875	-0.477	0.633	-0.816498	0.49674
*Block 3 * Directionality * Action Requirement*	-0.12192	0.339083	-0.36	0.719	-0.786786	0.542947
*Block 4 * Directionality * Action Requirement*	-0.344384	0.335607	-1.026	0.305	-1.002437	0.313668
*Block 5 * Directionality * Action Requirement*	-0.434955	0.339676	-1.281	0.2	-1.100986	0.231076
*Block 6 * Directionality * Action Requirement*	-0.364246	0.334913	-1.088	0.277	-1.020936	0.292443
*Location * Action Requirement * Block Trial*	0.034021	0.027859	1.221	0.222	-0.020605	0.088647
*Location * Directionality * Block Trial*	0.067401	0.02819	2.391	0.017	0.012127	0.122675
*Action Requirement * Block Trial*	-0.026675	0.02205	-1.21	0.226	-0.069909	0.01656
*Directionality * Action Requirement * Block Trial*	0.081758	0.028488	2.87	0.004	0.0259	0.137616
*Location * Directionality * Action Requirement*	0.050721	0.196679	0.258	0.797	-0.334923	0.436365
*Location * Cross-Body * Block Trial*	-0.007403	0.019409	-0.381	0.703	-0.04546	0.030654
*Location * Open-Body* Block Trial*	-0.033708	0.019645	-1.716	0.086	-0.072227	0.004811
*Block 2 * Oscillating Condition * Block Trial*	0.046979	0.057209	0.821	0.412	-0.065195	0.159153
*Block 2 * Constant Increase Condition * Block Trial*	0.036488	0.05928	0.616	0.538	-0.079749	0.152725
*Block 3 * Oscillating Condition * Block Trial*	0.085403	0.056986	1.499	0.134	-0.026335	0.197141
*Block 3 * Constant Increase Condition * Block Trial*	0.095171	0.05914	1.609	0.108	-0.020791	0.211133
*Block 4 * Oscillating Condition * Block Trial*	0.042297	0.056974	0.742	0.458	-0.069416	0.154011
*Block 4 * Constant Increase Condition * Block Trial*	0.081128	0.059131	1.372	0.17	-0.034816	0.197072
*Block 5 * Oscillating Condition * Block Trial*	-0.011272	0.057058	-0.198	0.843	-0.123151	0.100607
*Block 5 * Constant Increase Condition * Block Trial*	0.099267	0.059246	1.676	0.094	-0.016902	0.215437
*Block 6 * Oscillating Condition * Block Trial*	0.039108	0.057066	0.685	0.493	-0.072785	0.151002
*Block 6 * Constant Increase Condition * Block Trial*	0.084736	0.059015	1.436	0.151	-0.030981	0.200452
*Block 2 * Oscillating Condition * Location*	-0.196203	0.393109	-0.499	0.618	-0.967008	0.574602
*Block 2 * Constant Increase Condition * Location*	-0.074386	0.406776	-0.183	0.855	-0.87199	0.723217

*Block 3 * Oscillating Condition * Location*	0.023108	0.392743	0.059	0.953	-0.746978	0.793193
*Block 3 * Constant Increase Condition * Location*	-0.740214	0.406426	-1.821	0.069	-1.537131	0.056703
*Block 4 * Oscillating Condition * Location*	-0.414541	0.392762	-1.055	0.291	-1.184667	0.355585
*Block 4 * Constant Increase Condition * Location*	-0.466084	0.406285	-1.147	0.251	-1.262727	0.330559
*Block 5 * Oscillating Condition * Location*	0.031022	0.392147	0.079	0.937	-0.737896	0.799941
*Block 5 * Constant Increase Condition * Location*	-0.02328	0.40657	-0.057	0.954	-0.82048	0.77392
*Block 6 * Oscillating Condition * Location*	0.35533	0.393863	0.902	0.367	-0.416953	1.127613
*Block 6 * Constant Increase Condition * Location*	-0.439372	0.406513	-1.081	0.28	-1.236461	0.357716
*Block 2 * Oscillating Condition * Action Requirement*	-0.214103	0.393096	-0.545	0.586	-0.984883	0.556677
*Block 2 * Constant Increase Condition * Action Requirement*	-0.871673	0.407547	-2.139	0.033	-1.670786	-0.072561
*Block 3 * Oscillating Condition * Action Requirement*	0.019228	0.392726	0.049	0.961	-0.750826	0.789283
*Block 3 * Constant Increase Condition * Action Requirement*	-0.539267	0.407574	-1.323	0.186	-1.338434	0.2599
*Block 4 * Oscillating Condition * Action Requirement*	-0.46561	0.393084	-1.185	0.236	-1.236365	0.305144
*Block 4 * Constant Increase Condition * Action Requirement*	-0.699098	0.407177	-1.717	0.086	-1.497487	0.09929
*Block 5 * Oscillating Condition * Action Requirement*	-0.584317	0.393391	-1.485	0.138	-1.355676	0.187043
*Block 5 * Constant Increase Condition * Action Requirement*	-0.839135	0.407669	-2.058	0.04	-1.638488	-0.039782
*Block 6 * Oscillating Condition * Action Requirement*	-0.522903	0.3937	-1.328	0.184	-1.294864	0.249059
*Block 6 * Constant Increase Condition * Action Requirement*	-0.822306	0.407627	-2.017	0.044	-1.621577	-0.023035
*Block 2 * Oscillating Condition * Directionality*	-0.1165	0.405242	-0.287	0.774	-0.911094	0.678093
*Block 2 * Constant Increase Condition * Directionality*	0.208715	0.416074	0.502	0.616	-0.607116	1.024547
*Block 3 * Oscillating Condition * Directionality*	0.312741	0.412637	0.758	0.449	-0.49635	1.121832
*Block 3 * Constant Increase Condition * Directionality*	0.628933	0.418582	1.503	0.133	-0.191815	1.449682
*Block 4 * Oscillating Condition * Directionality*	-0.551506	0.40521	-1.361	0.174	-1.346036	0.243023
*Block 4 * Constant Increase Condition * Directionality*	0.162518	0.419614	0.387	0.699	-0.660256	0.985292
*Block 5 * Oscillating Condition * Directionality*	0.292866	0.411538	0.712	0.477	-0.51407	1.099802
*Block 5 * Constant Increase Condition * Directionality*	0.848732	0.4189	2.026	0.043	0.027358	1.670106
*Block 6 * Oscillating Condition * Directionality*	-0.223711	0.405401	-0.552	0.581	-1.018613	0.571192
*Block 6 * Constant Increase Condition * Directionality*	0.18413	0.419021	0.439	0.66	-0.637479	1.005739
*Oscillating Condition * Location * Block Trial*	0.001215	0.033292	0.036	0.971	-0.064064	0.066494
*Constant Increase Condition * Location * Block Trial*	0.008075	0.034432	0.235	0.815	-0.059438	0.075588
*Oscillating Condition * Action Requirement * Block Trial*	-0.034279	0.033473	-1.024	0.306	-0.099911	0.031354
*Constant Increase Condition * Action Requirement * Block Trial*	-0.035815	0.034551	-1.037	0.3	-0.103562	0.031933
*Oscillating Condition * Directionality * Block Trial*	-0.041222	0.02415	-1.707	0.088	-0.088575	0.006131
*Constant Increase Condition * Directionality * Block Trial*	0.044963	0.025151	1.788	0.074	-0.004353	0.094278
*Control Condition * Directionality * Block Trial*	0.022518	0.025125	0.896	0.37	-0.026747	0.071783

*Oscillating Condition * Location * Directionality*	0.038471	0.239822	0.16	0.873	-0.431764	0.508705
*Constant Increase Condition * Location * Directionality*	-0.185764	0.246913	-0.752	0.452	-0.669903	0.298374
*Oscillating Condition * Location * Action Requirement*	-0.221132	0.22872	-0.967	0.334	-0.669602	0.227339
*Constant Increase Condition * Location * Action Requirement*	-0.335239	0.236548	-1.417	0.157	-0.799058	0.128581
*Oscillating Condition * Directionality * Action Requirement*	0.040649	0.247175	0.164	0.869	-0.444006	0.525304
*Constant Increase Condition * Directionality * Action Requirement*	0.047696	0.251659	0.19	0.85	-0.445747	0.54114
*Block 2 * Location * Directionality * Action Requirement*	0.985605	0.682533	1.444	0.149	-0.352695	2.323906
*Block 3 * Location * Directionality * Action Requirement*	0.155469	0.686754	0.226	0.821	-1.191109	1.502047
*Block 4 * Location * Directionality * Action Requirement*	0.486034	0.682613	0.712	0.477	-0.852422	1.82449
*Block 5 * Location * Directionality * Action Requirement*	-0.005554	0.686568	-0.008	0.994	-1.351766	1.340658
*Block 6 * Location * Directionality * Action Requirement*	0.171802	0.677142	0.254	0.8	-1.155925	1.49953
*Location * Directionality * Action Requirement * Block Trial*	0.055703	0.057212	0.974	0.33	-0.056476	0.167883
*Block 2 * Location * Action Requirement * Block Trial*	-0.052932	0.095949	-0.552	0.581	-0.241068	0.135203
*Block 3 * Location * Action Requirement * Block Trial*	-0.025659	0.095774	-0.268	0.789	-0.213452	0.162134
*Block 4 * Location * Action Requirement * Block Trial*	0.09711	0.095626	1.016	0.31	-0.090392	0.284611
*Block 5 * Location * Action Requirement * Block Trial*	0.010467	0.095622	0.109	0.913	-0.177026	0.197961
*Block 6 * Location * Action Requirement * Block Trial*	0.063588	0.095546	0.666	0.506	-0.123758	0.250934
*Block 2 * Location * Directionality * Block Trial*	0.061453	0.097331	0.631	0.528	-0.129391	0.252297
*Block 3 * Location * Directionality * Block Trial*	0.059591	0.098525	0.605	0.545	-0.133594	0.252776
*Block 4 * Location * Directionality * Block Trial*	-0.078934	0.097362	-0.811	0.418	-0.26984	0.111971
*Block 5 * Location * Directionality * Block Trial*	-0.001086	0.097333	-0.011	0.991	-0.191935	0.189763
*Block 6 * Location * Directionality * Block Trial*	0.046452	0.096355	0.482	0.63	-0.142478	0.235382
*Block 2 * Directionality * Action Requirement * Block Trial*	0.113184	0.099838	1.134	0.257	-0.082576	0.308944
*Block 3 * Directionality * Action Requirement * Block Trial*	0.028942	0.101035	0.286	0.775	-0.169166	0.227049
*Block 4 * Directionality * Action Requirement * Block Trial*	0.043036	0.09821	0.438	0.661	-0.149533	0.235605
*Block 5 * Directionality * Action Requirement * Block Trial*	0.107503	0.099402	1.082	0.28	-0.087401	0.302408
*Block 6 * Directionality * Action Requirement * Block Trial*	0.063449	0.098049	0.647	0.518	-0.128803	0.255702
*Block 2 * Oscillating Condition * Location * Block Trial*	0.00569	0.116178	0.049	0.961	-0.222111	0.233491
*Block 2 * Constant Increase Condition * Location * Block Trial*	0.167156	0.119998	1.393	0.164	-0.068136	0.402447
*Block 3 * Oscillating Condition * Location * Block Trial*	-0.015394	0.115803	-0.133	0.894	-0.242459	0.211671
*Block 3 * Constant Increase Condition * Location * Block Trial*	0.164781	0.119924	1.374	0.17	-0.070365	0.399926
*Block 4 * Oscillating Condition * Location * Block Trial*	0.154497	0.115341	1.339	0.181	-0.071663	0.380656
*Block 4 * Constant Increase Condition * Location * Block Trial*	0.085246	0.119257	0.715	0.475	-0.148593	0.319084
*Block 5 * Oscillating Condition * Location * Block Trial*	-0.110572	0.115275	-0.959	0.338	-0.336602	0.115459
*Block 5 * Constant Increase Condition * Location * Block Trial*	-0.015258	0.119703	-0.127	0.899	-0.249969	0.219454

*Block 6 * Oscillating Condition * Location * Block Trial*	-0.03459	0.115409	-0.3	0.764	-0.260884	0.191704
*Block 6 * Constant Increase Condition * Location * Block Trial*	0.000317	0.119241	0.003	0.998	-0.233489	0.234123
*Block 2 * Oscillating Condition * Action Requirement * Block Trial*	0.36605	0.115235	3.177	0.002	0.140098	0.592002
*Block 2 * Constant Increase Condition * Action Requirement * Block Trial*	0.279487	0.119632	2.336	0.02	0.044912	0.514061
*Block 3 * Oscillating Condition * Action Requirement * Block Trial*	0.350962	0.114902	3.054	0.002	0.125662	0.576262
*Block 3 * Constant Increase Condition * Action Requirement * Block Trial*	0.163009	0.119226	1.367	0.172	-0.070769	0.396787
*Block 4 * Oscillating Condition * Action Requirement * Block Trial*	0.174546	0.114516	1.524	0.128	-0.049997	0.399089
*Block 4 * Constant Increase Condition * Action Requirement * Block Trial*	0.02432	0.119149	0.204	0.838	-0.209306	0.257946
*Block 5 * Oscillating Condition * Action Requirement * Block Trial*	0.229627	0.114211	2.011	0.044	0.005681	0.453572
*Block 5 * Constant Increase Condition * Action Requirement * Block Trial*	0.072221	0.118859	0.608	0.543	-0.160838	0.305279
*Block 6 * Oscillating Condition * Action Requirement * Block Trial*	0.161293	0.114495	1.409	0.159	-0.063209	0.385795
*Block 6 * Constant Increase Condition * Action Requirement * Block Trial*	0.031873	0.118932	0.268	0.789	-0.201329	0.265076
*Block 2 * Oscillating Condition * Directionality * Block Trial*	-0.261758	0.11901	-2.199	0.028	-0.495111	-0.028404
*Block 2 * Constant Increase Condition * Directionality * Block Trial*	-0.089638	0.123618	-0.725	0.468	-0.332027	0.152751
*Block 3 * Oscillating Condition * Directionality * Block Trial*	-0.238385	0.122699	-1.943	0.052	-0.478971	0.002202
*Block 3 * Constant Increase Condition * Directionality * Block Trial*	0.018511	0.1237	0.15	0.881	-0.224039	0.261061
*Block 4 * Oscillating Condition * Directionality * Block Trial*	0.005122	0.1196	0.043	0.966	-0.229387	0.239631
*Block 4 * Constant Increase Condition * Directionality * Block Trial*	-0.112725	0.124273	-0.907	0.364	-0.356397	0.130947
*Block 5 * Oscillating Condition * Directionality * Block Trial*	-0.073302	0.120535	-0.608	0.543	-0.309645	0.163041
*Block 5 * Constant Increase Condition * Directionality * Block Trial*	0.029015	0.123715	0.235	0.815	-0.213564	0.271595
*Block 6 * Oscillating Condition * Directionality * Block Trial*	-0.065344	0.119257	-0.548	0.584	-0.299181	0.168493
*Block 6 * Constant Increase Condition * Directionality * Block Trial*	0.002656	0.123758	0.021	0.983	-0.240007	0.245319
*Block 2 * Oscillating Condition * Location * Action Requirement*	-0.056564	0.789606	-0.072	0.943	-1.604821	1.491694
*Block 2 * Constant Increase Condition * Location * Action Requirement*	0.519046	0.817359	0.635	0.525	-1.08363	2.121722
*Block 3 * Oscillating Condition * Location * Action Requirement*	-1.044536	0.785759	-1.329	0.184	-2.585253	0.49618
*Block 3 * Constant Increase Condition * Location * Action Requirement*	-0.338473	0.814773	-0.415	0.678	-1.936079	1.259134
*Block 4 * Oscillating Condition * Location * Action Requirement*	-0.623424	0.78535	-0.794	0.427	-2.16334	0.916491
*Block 4 * Constant Increase Condition * Location * Action Requirement*	-0.405466	0.814837	-0.498	0.619	-2.003198	1.192265
*Block 5 * Oscillating Condition * Location * Action Requirement*	-0.446303	0.785573	-0.568	0.57	-1.986657	1.094051
*Block 5 * Constant Increase Condition * Location * Action Requirement*	-0.106293	0.81548	-0.13	0.896	-1.705286	1.4927
*Block 6 * Oscillating Condition * Location * Action Requirement*	0.353806	0.787162	0.449	0.653	-1.189661	1.897273
*Block 6 * Constant Increase Condition * Location * Action Requirement*	-0.376442	0.815161	-0.462	0.644	-1.974811	1.221927
*Block 2 * Oscillating Condition * Location * Directionality*	0.616907	0.810419	0.761	0.447	-0.972159	2.205973
*Block 2 * Constant Increase Condition * Location * Directionality*	0.137111	0.83555	0.164	0.87	-1.50123	1.775452
*Block 3 * Oscillating Condition * Location * Directionality*	1.228259	0.82283	1.493	0.136	-0.385142	2.841661

*Block 3 * Constant Increase Condition * Location * Directionality*	-1.554441	0.832199	-1.868	0.062	-3.186215	0.077333
*Block 4 * Oscillating Condition * Location * Directionality*	-0.297778	0.809406	-0.368	0.713	-1.884858	1.289301
*Block 4 * Constant Increase Condition * Location * Directionality*	-1.038981	0.839032	-1.238	0.216	-2.68415	0.606189
*Block 5 * Oscillating Condition * Location * Directionality*	0.856763	0.816214	1.05	0.294	-0.743667	2.457193
*Block 5 * Constant Increase Condition * Location * Directionality*	-0.878335	0.83476	-1.052	0.293	-2.515129	0.75846
*Block 6 * Oscillating Condition * Location * Directionality*	0.871255	0.812928	1.072	0.284	-0.722725	2.465236
*Block 6 * Constant Increase Condition * Location * Directionality*	0.061764	0.835306	0.074	0.941	-1.576099	1.699626
*Block 2 * Oscillating Condition * Directionality * Action Requirement*	-0.100997	0.825123	-0.122	0.903	-1.718891	1.516898
*Block 2 * Constant Increase Condition * Directionality * Action Requirement*	-1.123208	0.852986	-1.317	0.188	-2.795735	0.54932
*Block 3 * Oscillating Condition * Directionality * Action Requirement*	-1.377057	0.838123	-1.643	0.1	-3.020436	0.266323
*Block 3 * Constant Increase Condition * Directionality * Action Requirement*	-0.450357	0.854812	-0.527	0.598	-2.126465	1.22575
*Block 4 * Oscillating Condition * Directionality * Action Requirement*	-0.824646	0.824639	-1	0.317	-2.441588	0.792297
*Block 4 * Constant Increase Condition * Directionality * Action Requirement*	0.453706	0.856617	0.53	0.596	-1.225942	2.133354
*Block 5 * Oscillating Condition * Directionality * Action Requirement*	-0.434726	0.840292	-0.517	0.605	-2.082364	1.212911
*Block 5 * Constant Increase Condition * Directionality * Action Requirement*	-0.466139	0.854591	-0.545	0.585	-2.141817	1.209538
*Block 6 * Oscillating Condition * Directionality * Action Requirement*	-1.346107	0.82416	-1.633	0.103	-2.96211	0.269896
*Block 6 * Constant Increase Condition * Directionality * Action Requirement*	-0.330884	0.85643	-0.386	0.699	-2.010165	1.348396
*Oscillating Condition * Location * Action Requirement * Block Trial*	0.00076	0.066763	0.011	0.991	-0.130147	0.131667
*Constant Increase Condition * Location * Action Requirement * Block Trial*	-0.005812	0.069092	-0.084	0.933	-0.141287	0.129663
*Oscillating Condition * Location * Directionality * Block Trial*	0.088961	0.068554	1.298	0.195	-0.045458	0.223379
*Constant Increase Condition * Location * Directionality * Block Trial*	0.031868	0.070394	0.453	0.651	-0.106159	0.169894
*Oscillating Condition * Directionality * Action Requirement * Block Trial*	-0.151172	0.070327	-2.15	0.032	-0.289067	-0.013277
*Constant Increase Condition * Directionality * Action Requirement * Block Trial*	-0.099393	0.071968	-1.381	0.167	-0.240506	0.041719
*Oscillating Condition * Location * Directionality * Action Requirement*	-0.727878	0.48035	-1.515	0.13	-1.669736	0.213979
*Constant Increase Condition * Location * Directionality * Action Requirement*	-1.258691	0.49678	-2.534	0.011	-2.232763	-0.284618
*Block 2 * Location * Directionality * Action Requirement * Block Trial*	0.24712	0.201441	1.227	0.22	-0.147864	0.642103
*Block 3 * Location * Directionality * Action Requirement * Block Trial*	0.259003	0.203731	1.271	0.204	-0.140471	0.658478
*Block 4 * Location * Directionality * Action Requirement * Block Trial*	0.073346	0.200112	0.367	0.714	-0.319033	0.465724
*Block 5 * Location * Directionality * Action Requirement * Block Trial*	0.23593	0.199801	1.181	0.238	-0.155838	0.627699
*Block 6 * Location * Directionality * Action Requirement * Block Trial*	0.019374	0.197228	0.098	0.922	-0.367349	0.406097
*Block 2 * Oscillating Condition * Location * Directionality * Action Requirement*	1.639288	1.663261	0.986	0.324	-1.622063	4.900639
*Block 2 * Constant Increase Condition * Location * Directionality * Action Requirement*	0.418882	1.729837	0.242	0.809	-2.973014	3.810777
*Block 3 * Oscillating Condition * Location * Directionality * Action Requirement*	1.116407	1.679887	0.665	0.506	-2.177547	4.41036
*Block 3 * Constant Increase Condition * Location * Directionality * Action Requirement*	0.168906	1.713851	0.099	0.921	-3.191648	3.52946
*Block 4 * Oscillating Condition * Location * Directionality * Action Requirement*	0.413856	1.648255	0.251	0.802	-2.81807	3.645783

*Block 4 * Constant Increase Condition * Location * Directionality * Action Requirement*	0.367752	1.726182	0.213	0.831	-3.016972	3.752476
*Block 5 * Oscillating Condition * Location * Directionality * Action Requirement*	-0.660629	1.682604	-0.393	0.695	-3.959911	2.638652
*Block 5 * Constant Increase Condition * Location * Directionality * Action Requirement*	-0.973461	1.721994	-0.565	0.572	-4.349976	2.403054
*Block 6 * Oscillating Condition * Location * Directionality * Action Requirement*	1.348822	1.655505	0.815	0.415	-1.897312	4.594956
*Block 6 * Constant Increase Condition * Location * Directionality * Action Requirement*	1.512282	1.717081	0.881	0.379	-1.854597	4.879161
*Oscillating Condition * Location * Directionality * Action Requirement * Block Trial*	-0.035803	0.14098	-0.254	0.8	-0.312233	0.240627
*Constant Increase Condition * Location * Directionality * Action Requirement * Block Trial*	0.066219	0.143898	0.46	0.645	-0.215933	0.348372
*Block 2 * Oscillating Condition * Location * Action Requirement * Block Trial*	0.065543	0.236127	0.278	0.781	-0.397457	0.528543
*Block 2 * Constant Increase Condition * Location * Action Requirement * Block Trial*	0.14885	0.242928	0.613	0.54	-0.327486	0.625185
*Block 3 * Oscillating Condition * Location * Action Requirement * Block Trial*	0.023106	0.234213	0.099	0.921	-0.436141	0.482353
*Block 3 * Constant Increase Condition * Location * Action Requirement * Block Trial*	0.126643	0.242936	0.521	0.602	-0.349708	0.602994
*Block 4 * Oscillating Condition * Location * Action Requirement * Block Trial*	0.091431	0.234314	0.39	0.696	-0.368014	0.550876
*Block 4 * Constant Increase Condition * Location * Action Requirement * Block Trial*	0.166749	0.242769	0.687	0.492	-0.309275	0.642773
*Block 5 * Oscillating Condition * Location * Action Requirement * Block Trial*	-0.048139	0.233662	-0.206	0.837	-0.506305	0.410028
*Block 5 * Constant Increase Condition * Location * Action Requirement * Block Trial*	-0.09793	0.242922	-0.403	0.687	-0.574254	0.378395
*Block 6 * Oscillating Condition * Location * Action Requirement * Block Trial*	-0.061739	0.234069	-0.264	0.792	-0.520706	0.397227
*Block 6 * Constant Increase Condition * Location * Action Requirement * Block Trial*	-0.038671	0.243501	-0.159	0.874	-0.51613	0.438788
*Block 2 * Oscillating Condition * Location * Directionality * Block Trial*	0.094267	0.239846	0.393	0.694	-0.376025	0.564559
*Block 2 * Constant Increase Condition * Location * Directionality * Block Trial*	0.152294	0.249224	0.611	0.541	-0.336387	0.640974
*Block 3 * Oscillating Condition * Location * Directionality * Block Trial*	0.0484	0.24834	0.195	0.845	-0.438547	0.535347
*Block 3 * Constant Increase Condition * Location * Directionality * Block Trial*	0.419893	0.249842	1.681	0.093	-0.07	0.909785
*Block 4 * Oscillating Condition * Location * Directionality * Block Trial*	0.333147	0.242695	1.373	0.17	-0.142732	0.809025
*Block 4 * Constant Increase Condition * Location * Directionality * Block Trial*	0.45959	0.251191	1.83	0.067	-0.032947	0.952128
*Block 5 * Oscillating Condition * Location * Directionality * Block Trial*	0.144619	0.241646	0.598	0.55	-0.329203	0.618441
*Block 5 * Constant Increase Condition * Location * Directionality * Block Trial*	0.496045	0.249536	1.988	0.047	0.006752	0.985338
*Block 6 * Oscillating Condition * Location * Directionality * Block Trial*	-0.043459	0.242353	-0.179	0.858	-0.518665	0.431747
*Block 6 * Constant Increase Condition * Location * Directionality * Block Trial*	0.042499	0.249522	0.17	0.865	-0.446766	0.531765
*Block 2 * Oscillating Condition * Directionality * Action Requirement * Block Trial*	0.166944	0.252062	0.662	0.508	-0.3273	0.661188
*Block 2 * Constant Increase Condition * Directionality * Action Requirement * Block Trial*	0.255835	0.25774	0.993	0.321	-0.249542	0.761211
*Block 3 * Oscillating Condition * Directionality * Action Requirement * Block Trial*	-0.350709	0.258354	-1.357	0.175	-0.85729	0.155872
*Block 3 * Constant Increase Condition * Directionality * Action Requirement * Block Trial*	-0.193531	0.260169	-0.744	0.457	-0.703672	0.316609
*Block 4 * Oscillating Condition * Directionality * Action Requirement * Block Trial*	-0.345573	0.249254	-1.386	0.166	-0.83431	0.143165
*Block 4 * Constant Increase Condition * Directionality * Action Requirement * Block Trial*	-0.393181	0.259672	-1.514	0.13	-0.902345	0.115983
*Block 5 * Oscillating Condition * Directionality * Action Requirement * Block Trial*	-0.130471	0.250478	-0.521	0.602	-0.621608	0.360667
*Block 5 * Constant Increase Condition * Directionality * Action Requirement * Block Trial*	-0.261377	0.258936	-1.009	0.313	-0.769098	0.246345

*Block 6 * Oscillating Condition * Directionality * Action Requirement * Block Trial*	-0.204662	0.245442	-0.834	0.404	-0.685927	0.276602
*Block 6 * Constant Increase Condition * Directionality * Action Requirement * Block Trial*	-0.305249	0.258714	-1.18	0.238	-0.812538	0.20204
*Block 2 * Oscillating Condition * Location * Directionality * Action Requirement * Block Trial*	-0.585955	0.539211	-1.087	0.277	-1.64326	0.47135
*Block 2 * Constant Increase Condition * Location * Directionality * Action Requirement * Block Trial*	-0.343353	0.544724	-0.63	0.529	-1.41147	0.724764
*Block 3 * Oscillating Condition * Location * Directionality * Action Requirement * Block Trial*	-0.22683	0.547882	-0.414	0.679	-1.301139	0.847479
*Block 3 * Constant Increase Condition * Location * Directionality * Action Requirement * Block Trial*	-0.055757	0.548474	-0.102	0.919	-1.131227	1.019712
*Block 4 * Oscillating Condition * Location * Directionality * Action Requirement * Block Trial*	-0.802474	0.541209	-1.483	0.138	-1.863697	0.25875
*Block 4 * Constant Increase Condition * Location * Directionality * Action Requirement * Block Trial*	-0.831738	0.549885	-1.513	0.131	-1.909975	0.246499
*Block 5 * Oscillating Condition * Location * Directionality * Action Requirement * Block Trial*	-0.074564	0.525018	-0.142	0.887	-1.10404	0.954913
*Block 5 * Constant Increase Condition * Location * Directionality * Action Requirement * Block Trial*	0.085154	0.543605	0.157	0.876	-0.980768	1.151076
*Block 6 * Oscillating Condition * Location * Directionality * Action Requirement * Block Trial*	-0.474687	0.524365	-0.905	0.365	-1.502883	0.553509
*Block 6 * Constant Increase Condition * Location * Directionality * Action Requirement * Block Trial*	-0.384838	0.552145	-0.697	0.486	-1.467505	0.697829

APPENDIX M.

LSD Post Hoc Analysis of Block for Experimental Blocks Primary Variable Analysis of Absolute Error in Experiment 2.

Pairwise Comparisons

(I) Block	(J) Block	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Block1	Block2	0.12	0.081	0.141	-0.04	0.279
	Block3	0.13	0.081	0.106	-0.028	0.292
	Block4	.265*	0.081	0.001	0.105	0.424
	Block5	.234*	0.081	0.004	0.074	0.394
	Block6	.267*	0.082	0.001	0.107	0.427
Block2	Block1	-0.12	0.081	0.141	-0.279	0.04
	Block3	0.01	0.081	0.882	-0.147	0.172
	Block4	0.15	0.082	0.075	-0.015	0.305
	Block5	0.11	0.081	0.16	-0.045	0.274
	Block6	0.15	0.082	0.072	-0.013	0.307
Block3	Block1	-0.13	0.081	0.106	-0.292	0.028
	Block2	-0.01	0.081	0.882	-0.172	0.147
	Block4	0.13	0.081	0.103	-0.027	0.293
	Block5	0.10	0.081	0.209	-0.057	0.262
	Block6	0.14	0.082	0.098	-0.025	0.295
Block4	Block1	-.265*	0.081	0.001	-0.424	-0.105
	Block2	-0.15	0.082	0.075	-0.305	0.015
	Block3	-0.13	0.081	0.103	-0.293	0.027
	Block5	-0.03	0.081	0.706	-0.19	0.129
	Block6	0.00	0.081	0.981	-0.158	0.162
Block5	Block1	-.234*	0.081	0.004	-0.394	-0.074
	Block2	-0.11	0.081	0.16	-0.274	0.045
	Block3	-0.10	0.081	0.209	-0.262	0.057
	Block4	0.03	0.081	0.706	-0.129	0.19
	Block6	0.03	0.081	0.689	-0.127	0.192
Block6	Block1	-.267*	0.082	0.001	-0.427	-0.107
	Block2	-0.15	0.082	0.072	-0.307	0.013
	Block3	-0.14	0.082	0.098	-0.295	0.025
	Block4	0.00	0.081	0.981	-0.162	0.158
	Block5	-0.03	0.081	0.689	-0.192	0.127

Based on estimated marginal means

** The mean difference is significant at the .05 level.*

APPENDIX N.

LSD Post Hoc Analysis of Location by Action Requirement by Condition by Directionality for Experimental Blocks Primary Variable Analysis of Absolute Error in Experiment 2.

Pairwise Comparisons

Location	Action Requirement	Condition	(I) Directionality	(J) Directionality	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
								Lower Bound	Upper Bound
Peripheral	Cross Body	Oscillating	Under Rotation	Over Rotation	0.067	0.204	0.744	-0.335	0.468
			Over Rotation	Under Rotation	-0.067	0.204	0.744	-0.468	0.335
		Constant Increase	Under Rotation	Over Rotation	0.184	0.205	0.37	-0.22	0.588
			Over Rotation	Under Rotation	-0.184	0.205	0.37	-0.588	0.22
		Control	Under Rotation	Over Rotation	0.246	0.23	0.285	-0.206	0.699
			Over Rotation	Under Rotation	-0.246	0.23	0.285	-0.699	0.206
	Open Body	Oscillating	Under Rotation	Over Rotation	-0.074	0.153	0.627	-0.375	0.227
			Over Rotation	Under Rotation	0.074	0.153	0.627	-0.227	0.375
		Constant Increase	Under Rotation	Over Rotation	0.3	0.158	0.06	-0.013	0.612
			Over Rotation	Under Rotation	-0.3	0.158	0.06	-0.612	0.013
		Control	Under Rotation	Over Rotation	0.155	0.183	0.397	-0.205	0.515
			Over Rotation	Under Rotation	-0.155	0.183	0.397	-0.515	0.205
Frontal	Cross Body	Oscillating	Under Rotation	Over Rotation	0.186	0.189	0.326	-0.186	0.558
			Over Rotation	Under Rotation	-0.186	0.189	0.326	-0.558	0.186
		Constant Increase	Under Rotation	Over Rotation	.772*	0.187	0	0.403	1.141
			Over Rotation	Under Rotation	-.772*	0.187	0	-1.141	-0.403
		Control	Under Rotation	Over Rotation	0.263	0.158	0.097	-0.048	0.573
			Over Rotation	Under Rotation	-0.263	0.158	0.097	-0.573	0.048
	Open Body	Oscillating	Under Rotation	Over Rotation	0.203	0.154	0.191	-0.102	0.507
			Over Rotation	Under Rotation	-0.203	0.154	0.191	-0.507	0.102
		Constant Increase	Under Rotation	Over Rotation	.450*	0.158	0.005	0.14	0.761
			Over Rotation	Under Rotation	-.450*	0.158	0.005	-0.761	-0.14
		Control	Under Rotation	Over Rotation	.647*	0.183	0.001	0.285	1.008
			Over Rotation	Under Rotation	-.647*	0.183	0.001	-1.008	-0.285

Based on estimated marginal means

APPENDIX O.

Experiment 2: Experimental Block Secondary Analysis Coefficients of Absolute Error

Estimates of Fixed Effects

Parameter	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	1.477945	0.165284	8.942	0	1.151289	1.804601
Block 2	-0.074378	0.083791	-0.888	0.375	-0.238673	0.089917
Block 3	-0.113312	0.083003	-1.365	0.172	-0.276063	0.049439
Block 4	-0.207809	0.085981	-2.417	0.016	-0.376398	-0.03922
Block 5	-0.218787	0.086258	-2.536	0.011	-0.387922	-0.049653
Block 6	-0.218835	0.091651	-2.388	0.017	-0.398557	-0.039113
Block Trial	-0.026052	0.008997	-2.896	0.005	-0.044089	-0.008015
Location	0.23019	0.184077	1.251	0.211	-0.130754	0.591135
Action Requirement	0.377181	0.08645	4.363	0	0.203101	0.551262
Directionality	0.305123	0.053659	5.686	0	0.199912	0.410335
Oscillating Condition	0.082659	0.148591	0.556	0.582	-0.221577	0.386895
Constant Increase Condition	-0.020462	0.153791	-0.133	0.895	-0.335646	0.294723
Total Rotation	1.50E-05	0.002121	0.007	0.994	-0.004143	0.004173
Max Rotation	-0.007285	0.007521	-0.969	0.333	-0.022032	0.007462
Rotational Difference	0.012117	0.009311	1.301	0.193	-0.006141	0.030375
Grand_sampEnm3x	-2.807348	1.804452	-1.556	0.12	-6.351331	0.736635
Grand_sampEnm3y	-0.133312	2.1235	-0.063	0.95	-4.30637	4.039746
SSQ	0.005856	0.012915	0.453	0.651	-0.019696	0.031409
Pre-MSAQ	0.013033	0.028602	0.456	0.652	-0.04565	0.071715
Post-MSAQ	0.017228	0.013891	1.24	0.223	-0.010967	0.045422
*Block 2 * SSQ*	0.035618	0.027849	1.279	0.201	-0.018988	0.090225
*Block 3 * SSQ*	0.032749	0.026872	1.219	0.223	-0.019943	0.08544
*Block 4 * SSQ*	-0.003773	0.026561	-0.142	0.887	-0.055876	0.048329
*Block 5 * SSQ*	0.01759	0.026543	0.663	0.508	-0.034488	0.069669
*Block 6 * SSQ*	0.045494	0.026679	1.705	0.089	-0.006878	0.097866
*Block 2 * Total Rotation*	0.001101	0.004071	0.271	0.787	-0.00688	0.009083
*Block 3 * Total Rotation*	-0.001096	0.004395	-0.249	0.803	-0.009713	0.007521
*Block 4 * Total Rotation*	0.007329	0.004666	1.571	0.116	-0.001821	0.016479
*Block 5 * Total Rotation*	0.004194	0.004359	0.962	0.336	-0.004352	0.01274
*Block 6 * Total Rotation*	-3.14E-06	0.004418	-0.001	0.999	-0.008667	0.00866
*Block 2 * Max Rotation*	-0.001807	0.006176	-0.293	0.77	-0.013916	0.010302
*Block 3 * Max Rotation*	-0.007244	0.006094	-1.189	0.235	-0.019193	0.004705
*Block 4 * Max Rotation*	0.00601	0.006044	0.994	0.32	-0.005841	0.017862
*Block 5 * Max Rotation*	-0.000749	0.006154	-0.122	0.903	-0.012816	0.011318

*Block 6 * Max Rotation*	-0.006256	0.006093	-1.027	0.305	-0.018203	0.00569
*Oscillating Condition * SSQ*	0.042619	0.035285	1.208	0.23	-0.027477	0.112716
*Constant Increase Condition * SSQ*	0.020915	0.030912	0.677	0.499	-0.040031	0.081861
*Oscillating Condition * Total Rotation*	0.000678	0.00352	0.193	0.847	-0.006223	0.007579
*Constant Increase Condition * Total Rotation*	-0.002271	0.003809	-0.596	0.551	-0.009738	0.005197
*Oscillating Condition * Max Rotation*	-0.000621	0.004388	-0.142	0.887	-0.009225	0.007983
*Constant Increase Condition * Max Rotation*	-0.005973	0.004542	-1.315	0.189	-0.014879	0.002933
*Oscillating Condition * Rotational Difference*	0.01753	0.015586	1.125	0.261	-0.013041	0.0481
*Constant Increase Condition * Rotational Difference*	0.014896	0.016529	0.901	0.368	-0.017522	0.047314
*Block 2 * Oscillating Condition*	-0.022963	0.198106	-0.116	0.908	-0.411408	0.365482
*Block 2 * Constant Increase Condition*	0.07853	0.204874	0.383	0.702	-0.323186	0.480246
*Block 3 * Oscillating Condition*	0.20204	0.196971	1.026	0.305	-0.184181	0.588262
*Block 3 * Constant Increase Condition*	0.185271	0.205726	0.901	0.368	-0.218116	0.588657
*Block 4 * Oscillating Condition*	-0.227972	0.200886	-1.135	0.257	-0.621866	0.165922
*Block 4 * Constant Increase Condition*	0.122017	0.209924	0.581	0.561	-0.289597	0.533632
*Block 5 * Oscillating Condition*	-0.157925	0.197344	-0.8	0.424	-0.544875	0.229026
*Block 5 * Constant Increase Condition*	-0.00564	0.213554	-0.026	0.979	-0.42437	0.413091
*Block 6 * Oscillating Condition*	0.206423	0.199045	1.037	0.3	-0.183864	0.596709
*Block 6 * Constant Increase Condition*	0.341844	0.213355	1.602	0.109	-0.076498	0.760185
*Block 2 * Oscillating Condition * SSQ*	0.154084	0.095522	1.613	0.107	-0.033214	0.341383
*Block 2 * Constant Increase Condition * SSQ*	0.147802	0.097429	1.517	0.129	-0.043234	0.338839
*Block 3 * Oscillating Condition * SSQ*	0.230399	0.096623	2.385	0.017	0.040943	0.419855
*Block 3 * Constant Increase Condition * SSQ*	0.140796	0.098518	1.429	0.153	-0.052379	0.333972
*Block 4 * Oscillating Condition * SSQ*	0.146175	0.094025	1.555	0.12	-0.038188	0.330538
*Block 4 * Constant Increase Condition * SSQ*	0.187449	0.096227	1.948	0.052	-0.001245	0.376143
*Block 5 * Oscillating Condition * SSQ*	0.257014	0.093307	2.754	0.006	0.074054	0.439974
*Block 5 * Constant Increase Condition * SSQ*	0.206863	0.094945	2.179	0.029	0.020671	0.393055
*Block 6 * Oscillating Condition * SSQ*	0.171174	0.089749	1.907	0.057	-0.004824	0.347171
*Block 6 * Constant Increase Condition * SSQ*	0.150569	0.092045	1.636	0.102	-0.029964	0.331102
*Block 2 * Oscillating Condition * Total Rotation*	0.011415	0.011493	0.993	0.321	-0.011119	0.03395
*Block 2 * Constant Increase Condition * Total Rotation*	0.004634	0.012535	0.37	0.712	-0.019944	0.029211
*Block 3 * Oscillating Condition * Total Rotation*	-0.005738	0.011744	-0.489	0.625	-0.028765	0.017289
*Block 3 * Constant Increase Condition * Total Rotation*	-0.017483	0.012432	-1.406	0.16	-0.04186	0.006893
*Block 4 * Oscillating Condition * Total Rotation*	-0.001257	0.011849	-0.106	0.916	-0.02449	0.021976
*Block 4 * Constant Increase Condition * Total Rotation*	-0.006638	0.012512	-0.531	0.596	-0.031172	0.017895
*Block 5 * Oscillating Condition * Total Rotation*	0.009521	0.011298	0.843	0.399	-0.012632	0.031673
*Block 5 * Constant Increase Condition * Total Rotation*	0.002512	0.012855	0.195	0.845	-0.022694	0.027718
*Block 6 * Oscillating Condition * Total Rotation*	0.012915	0.010841	1.191	0.234	-0.008343	0.034172
*Block 6 * Constant Increase Condition * Total Rotation*	-0.001695	0.01213	-0.14	0.889	-0.025479	0.022088
*Block 2 * Oscillating Condition * Max Rotation*	0.008997	0.014811	0.607	0.544	-0.020044	0.038039

*Block 2 * Constant Increase Condition * Max Rotation*	0.006811	0.015516	0.439	0.661	-0.023613	0.037235
*Block 3 * Oscillating Condition * Max Rotation*	0.001975	0.014737	0.134	0.893	-0.02692	0.030871
*Block 3 * Constant Increase Condition * Max Rotation*	-0.016828	0.015234	-1.105	0.269	-0.046698	0.013043
*Block 4 * Oscillating Condition * Max Rotation*	-0.011154	0.01459	-0.764	0.445	-0.039762	0.017454
*Block 4 * Constant Increase Condition * Max Rotation*	-0.012303	0.015181	-0.81	0.418	-0.04207	0.017464
*Block 5 * Oscillating Condition * Max Rotation*	0.009853	0.014843	0.664	0.507	-0.019251	0.038957
*Block 5 * Constant Increase Condition * Max Rotation*	0.003771	0.01542	0.245	0.807	-0.026464	0.034006
*Block 6 * Oscillating Condition * Max Rotation*	0.013969	0.014668	0.952	0.341	-0.014793	0.04273
*Block 6 * Constant Increase Condition * Max Rotation*	-0.00843	0.01538	-0.548	0.584	-0.038587	0.021727
*Block 2 * Oscillating Condition * Rotational Difference*	-0.102954	0.044989	-2.288	0.022	-0.191167	-0.014741
*Block 2 * Constant Increase Condition * Rotational Difference*	-0.062914	0.043491	-1.447	0.148	-0.14819	0.022363
*Block 3 * Oscillating Condition * Rotational Difference*	-0.041817	0.041527	-1.007	0.314	-0.123242	0.039609
*Block 3 * Constant Increase Condition * Rotational Difference*	-0.084955	0.045398	-1.871	0.061	-0.173969	0.004059
*Block 4 * Oscillating Condition * Rotational Difference*	0.019581	0.046528	0.421	0.674	-0.07165	0.110812
*Block 4 * Constant Increase Condition * Rotational Difference*	-0.020284	0.046181	-0.439	0.661	-0.110835	0.070267
*Block 5 * Oscillating Condition * Rotational Difference*	-0.050404	0.040023	-1.259	0.208	-0.128881	0.028073
*Block 5 * Constant Increase Condition * Rotational Difference*	-0.030972	0.046652	-0.664	0.507	-0.122445	0.060501
*Block 6 * Oscillating Condition * Rotational Difference*	-0.003156	0.04219	-0.075	0.94	-0.085882	0.079569
*Block 6 * Constant Increase Condition * Rotational Difference*	-0.042002	0.048599	-0.864	0.388	-0.137293	0.053289

APPENDIX P.

Experiment 2: Pre-/ Post-Test Primary Analysis Coefficients for the Outcome Variable of Absolute Error

Estimates of Fixed Effects

Parameter	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	2.16408	0.246898	8.765	0	1.672883	2.655277
Pre-test	-0.830237	0.125681	-6.606	0	-1.076886	-0.583588
Block Trial	0.092881	0.025319	3.668	0	0.042422	0.143341
Location	0.347905	0.1257	2.768	0.006	0.101222	0.594588
Action Requirement	0.30041	0.128634	2.335	0.02	0.047972	0.552848
Directionality	0.244851	0.132885	1.843	0.066	-0.015921	0.505623
Oscillating Condition	-0.011591	0.285046	-0.041	0.968	-0.58812	0.564939
Constant Increase Condition	0.274871	0.295571	0.93	0.358	-0.322932	0.872674
*Pre-test * Block Trial*	0.031951	0.036453	0.877	0.381	-0.039588	0.103491
*Pre-test * Location*	-0.102838	0.251871	-0.408	0.683	-0.597126	0.391451
*Pre-test * Action Requirement*	-0.135163	0.251731	-0.537	0.591	-0.629176	0.35885
*Pre-test * Directionality*	0.950214	0.258548	3.675	0	0.442839	1.457588
*Location * Block Trial*	0.019892	0.037043	0.537	0.591	-0.052803	0.092588
*Action Requirement * Block Trial*	0.071027	0.037662	1.886	0.06	-0.002882	0.144936
*Directionality * Block Trial*	0.038761	0.038707	1.001	0.317	-0.037197	0.114718
*Location * Action Requirement*	0.061774	0.252626	0.245	0.807	-0.433996	0.557543
*Directionality * Action Requirement*	0.641243	0.298502	2.148	0.032	0.055438	1.227048
*Location * Directionality*	-0.477933	0.256869	-1.861	0.063	-0.98202	0.026155
*Oscillating Condition * Block Trial*	-0.06607	0.061211	-1.079	0.284	-0.188131	0.05599
*Constant Increase Condition * Block Trial*	-0.012727	0.063542	-0.2	0.842	-0.139429	0.113974
*Oscillating Condition * Location*	-0.518895	0.302621	-1.715	0.087	-1.112782	0.074992
*Constant Increase Condition * Location*	0.219358	0.313836	0.699	0.485	-0.396538	0.835254
*Oscillating Condition * Action Requirement*	-0.014562	0.303308	-0.048	0.962	-0.609794	0.580669
*Constant Increase Condition * Action Requirement*	-0.060287	0.315729	-0.191	0.849	-0.679892	0.559318
*Oscillating Condition * Directionality*	0.494129	0.31262	1.581	0.114	-0.119356	1.107614
*Constant Increase Condition * Directionality*	0.030406	0.326182	0.093	0.926	-0.609686	0.670498
*Pre-test * Location * Block Trial*	0.168711	0.07399	2.28	0.023	0.023511	0.313912
*Pre-test * Action Requirement * Block Trial*	0.082865	0.074048	1.119	0.263	-0.062447	0.228178
*Pre-test * Directionality * Block Trial*	-0.096409	0.075338	-1.28	0.201	-0.244252	0.051433

*Pre-test * Location * Action Requirement*	0.294901	0.505394	0.584	0.56	-0.696912	1.286713
*Pre-test * Location * Directionality*	1.100396	0.509613	2.159	0.031	0.100317	2.100474
*Pre-test * Directionality * Action Requirement*	0.512872	0.528253	0.971	0.332	-0.523773	1.549518
*Location * Action Requirement * Block Trial*	-0.097105	0.074087	-1.311	0.19	-0.242496	0.048286
*Location * Directionality * Block Trial*	0.115462	0.07507	1.538	0.124	-0.031854	0.262778
*Directionality * Action Requirement * Block Trial*	0.38054	0.079443	4.79	0	0.224614	0.536467
*Location * Directionality * Action Requirement*	0.381088	0.521231	0.731	0.465	-0.641799	1.403975
*Location * Cross-body * Block Trial*	-0.02662	0.052336	-0.509	0.611	-0.129326	0.076086
*Location * Open-Body * Block Trial*	0.07466	0.05242	1.424	0.155	-0.028213	0.177532
*Pre-test * Oscillating Condition * Block Trial*	-0.095594	0.087535	-1.092	0.275	-0.267383	0.076196
*Pre-test * Constant Increase Condition * Block Trial*	-0.10486	0.090692	-1.156	0.248	-0.282844	0.073125
*Pre-test * Oscillating Condition * Location*	0.498387	0.603263	0.826	0.409	-0.685509	1.682284
*Pre-test * Constant Increase Condition * Location*	0.000656	0.627201	0.001	0.999	-1.230204	1.231517
*Pre-test * Oscillating Condition * Action Requirement*	-0.59195	0.6044	-0.979	0.328	-1.778081	0.594181
*Pre-test * Constant Increase Condition * Action Requirement*	0.73619	0.628301	1.172	0.242	-0.496839	1.96922
*Pre-test * Oscillating Condition * Directionality*	0.549714	0.622203	0.883	0.377	-0.671305	1.770734
*Pre-test * Constant Increase Condition * Directionality*	1.404308	0.638604	2.199	0.028	0.151096	2.65752
*Oscillating Condition * Location * Block Trial*	-0.016996	0.088969	-0.191	0.849	-0.191593	0.157602
*Constant Increase Condition * Location * Block Trial*	-0.089752	0.092322	-0.972	0.331	-0.270929	0.091426
*Oscillating Condition * Action Requirement * Block Trial*	0.141827	0.089107	1.592	0.112	-0.03304	0.316695
*Constant Increase Condition * Action Requirement * Block Trial*	0.10237	0.093096	1.1	0.272	-0.080325	0.285065
*Oscillating Condition * Directionality * Block Trial*	-0.037742	0.063107	-0.598	0.55	-0.161586	0.086102
*Constant Increase Condition * Directionality * Block Trial*	0.124289	0.069032	1.8	0.072	-0.011176	0.259755
*Control Condition * Directionality * Block Trial*	0.01959	0.066853	0.293	0.77	-0.111601	0.150782
*Oscillating Condition * Location * Action Requirement*	0.159019	0.606682	0.262	0.793	-1.031582	1.34962
*Constant Increase Condition * Location * Action Requirement*	0.231282	0.629257	0.368	0.713	-1.003627	1.466191
*Oscillating Condition * Location * Directionality*	0.113377	0.620773	0.183	0.855	-1.104847	1.331601
*Constant Increase Condition * Location * Directionality*	-0.458526	0.638669	-0.718	0.473	-1.711875	0.794823
*Oscillating Condition * Directionality * Action Requirement*	0.106863	0.697666	0.153	0.878	-1.262261	1.475986
*Constant Increase Condition * Directionality * Action Requirement*	-1.41759	0.731175	-1.939	0.053	-2.852572	0.017392
*Pre-test * Location * Directionality * Action Requirement*	0.905153	1.052562	0.86	0.39	-1.160434	2.97074
*Location * Directionality * Action Requirement * Block Trial*	0.158362	0.154212	1.027	0.305	-0.144268	0.460992
*Pre-test * Location * Action Requirement * Block Trial*	0.042277	0.149618	0.283	0.778	-0.25134	0.335895
*Pre-test * Location * Directionality * Block Trial*	-0.108693	0.149598	-0.727	0.468	-0.402267	0.184881
*Pre-test * Directionality * Action Requirement * Block Trial*	0.06519	0.15406	0.423	0.672	-0.237137	0.367517

Pre-test * Oscillating Condition * Location * Block Trial	-0.120246	0.177547	-0.677	0.498	-0.468675	0.228183
Pre-test * Constant Increase Condition * Location * Block Trial	-0.294143	0.185347	-1.587	0.113	-0.657877	0.069592
Pre-test * Oscillating Condition * Action Requirement * Block Trial	-0.110363	0.177762	-0.621	0.535	-0.459216	0.238489
Pre-test * Constant Increase Condition * Action Requirement * Block Trial	0.073172	0.185999	0.393	0.694	-0.291845	0.43819
Pre-test * Oscillating Condition * Directionality * Block Trial	0.390596	0.185605	2.104	0.036	0.026357	0.754836
Pre-test * Constant Increase Condition * Directionality * Block Trial	0.144205	0.188096	0.767	0.443	-0.224922	0.513333
Pre-test * Oscillating Condition * Location * Action Requirement	1.796567	1.212596	1.482	0.139	-0.583145	4.176279
Pre-test * Constant Increase Condition * Location * Action Requirement	2.330318	1.25797	1.852	0.064	-0.138435	4.799071
Pre-test * Oscillating Condition * Location * Directionality	-0.775895	1.238802	-0.626	0.531	-3.206992	1.655202
Pre-test * Constant Increase Condition * Location * Directionality	1.654899	1.269884	1.303	0.193	-0.837192	4.146989
Pre-test * Oscillating Condition * Directionality * Action Requirement	-2.362422	1.286287	-1.837	0.067	-4.886654	0.161809
Pre-test * Constant Increase Condition * Directionality * Action Requirement	0.704837	1.348469	0.523	0.601	-1.941402	3.351077
Constant Increase Condition * Location * Action Requirement * Block Trial	0.04991	0.186086	0.268	0.789	-0.315281	0.415101
Oscillating Condition * Location * Directionality * Block Trial	0.115994	0.185254	0.626	0.531	-0.247558	0.479547
Constant Increase Condition * Location * Directionality * Block Trial	0.165476	0.189663	0.872	0.383	-0.206725	0.537677
Oscillating Condition * Directionality * Action Requirement * Block Trial	-0.203384	0.192394	-1.057	0.291	-0.58098	0.174212
Constant Increase Condition * Directionality * Action Requirement * Block Trial	-0.318511	0.199568	-1.596	0.111	-0.710204	0.073183
Oscillating Condition * Location * Directionality * Action Requirement	0.518915	1.278107	0.406	0.685	-1.98932	3.02715
Constant Increase Condition * Location * Directionality * Action Requirement	-1.455271	1.327191	-1.097	0.273	-4.059836	1.149294
Pre-test * Location * Directionality * Action Requirement * Block Trial	-0.275149	0.310752	-0.885	0.376	-0.884985	0.334688
Pre-test * Oscillating Condition * Location * Directionality * Action Requirement	-0.259708	2.583609	-0.101	0.92	-5.330004	4.810588
Pre-test * Constant Increase Condition * Location * Directionality * Action Requirement	-1.322476	2.657935	-0.498	0.619	-6.538685	3.893734
Oscillating Condition * Location * Directionality * Action Requirement * Block Trial	-0.957175	0.385896	-2.48	0.013	-1.714501	-0.199848
Constant Increase Condition * Location * Directionality * Action Requirement * Block Trial	-0.416334	0.393572	-1.058	0.29	-1.188723	0.356056
Pre-test * Oscillating Condition * Location * Action Requirement * Block Trial	-0.244695	0.367481	-0.666	0.506	-0.965876	0.476485
Post-Test * Constant Increase Condition * Location * Action Requirement * Block Trial	-0.204764	0.388762	-0.527	0.599	-0.967707	0.558178
Post-Test * Oscillating Condition * Location * Directionality * Block Trial	0.103199	0.380302	0.271	0.786	-0.643147	0.849544
Post-Test * Constant Increase Condition * Location * Directionality * Block Trial	0.28488	0.3871	0.736	0.462	-0.474801	1.044561
Pre-test * Oscillating Condition * Directionality * Action Requirement * Block Trial	0.332067	0.375599	0.884	0.377	-0.405047	1.06918
Pre-test * Constant Increase Condition * Directionality * Action Requirement * Block Trial	0.50502	0.384704	1.313	0.19	-0.249969	1.26001
Post-Test * Constant Increase Condition * Location * Directionality * Action Requirement * Block Trial	0.600952	0.80657	0.745	0.456	-0.982056	2.18396

APPENDIX Q.

Experiment 2: Pre-/ Post-Test Secondary Analysis Coefficients for the Outcome Variable of Absolute Error

Estimates of Fixed Effects

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	3.284676	0.323858	212.586	10.142	0	2.646291	3.923062
Post-Test	-0.744971	0.13084	971.529	-5.694	0	-1.001733	-0.488209
Block Trial	0.087375	0.024614	68.058	3.55	0.001	0.03826	0.136491
Location	-2.632366	0.536935	992.059	-4.903	0	-3.686025	-1.578708
Action Requirement	0.421691	0.133351	979.182	3.162	0.002	0.160004	0.683377
Directionality	0.876291	0.152004	972.775	5.765	0	0.577998	1.174583
Total Rotation	0.011651	0.006292	978.434	1.852	0.064	-0.000697	0.023998
Total Rotation	0.100164	0.019136	984.712	5.234	0	0.062612	0.137715
Rotational Difference	0.167429	0.021145	977.661	7.918	0	0.125934	0.208924
SampEn-X	-0.900152	4.59621	217.825	-0.196	0.845	-9.958888	8.158585
SampEn-Y	6.014723	4.501405	139.878	1.336	0.184	-2.884865	14.914311
MSAQ	0.023474	0.020171	279.788	1.164	0.246	-0.016233	0.063181
Oscillating Condition	-0.00968	0.285555	41.042	-0.034	0.973	-0.586352	0.566992
Constant Increase Condition	0.10232	0.291446	40.183	0.351	0.727	-0.486632	0.691271
*Post-Test * Total Rotation*	-0.006985	0.0074	920.287	-0.944	0.346	-0.021508	0.007539
*Post-Test * Total Rotation*	-0.009313	0.00862	912.059	-1.08	0.28	-0.026231	0.007605
*Post-Test * Rotational Difference*	-0.048322	0.023015	973.849	-2.1	0.036	-0.093486	-0.003158
*Oscillating Condition * MSAQ*	-0.065617	0.053944	128.91	-1.216	0.226	-0.172347	0.041114
*Constant Increase Condition * MSAQ*	-0.056615	0.048467	391.906	-1.168	0.243	-0.151903	0.038672
*Oscillating Condition * Total Rotation*	-0.004257	0.009543	972.859	-0.446	0.656	-0.022985	0.01447
*Constant Increase Condition * Total Rotation*	0.017369	0.009719	965.003	1.787	0.074	-0.001704	0.036442
*Oscillating Condition * Total Rotation*	-0.019848	0.011066	971.049	-1.794	0.073	-0.041563	0.001868
*Constant Increase Condition * Total Rotation*	0.004655	0.011516	975.575	0.404	0.686	-0.017945	0.027254
*Oscillating Condition * Rotational Difference*	-0.109356	0.030928	900.255	-3.536	0	-0.170055	-0.048657
*Constant Increase Condition * Rotational Difference*	-0.043421	0.030303	805.201	-1.433	0.152	-0.102903	0.016061
*Post-Test * Oscillating Condition*	0.632098	0.301529	959.56	2.096	0.036	0.040366	1.22383
*Post-Test * Constant Increase Condition*	0.195479	0.317004	967.298	0.617	0.538	-0.426615	0.817573
*Oscillating Condition * Block Trial*	-0.054487	0.059581	66.099	-0.914	0.364	-0.173441	0.064468
*Constant Increase Condition * Block Trial*	0.008031	0.06192	66.625	0.13	0.897	-0.115575	0.131637
*Post-Test * Oscillating Condition * Total Rotation*	-0.010616	0.018825	960.486	-0.564	0.573	-0.047559	0.026327

*Post-Test * Constant Increase Condition * Total Rotation*	-0.011925	0.020058	961.924	-0.595	0.552	-0.051287	0.027437
*Post-Test * Oscillating Condition * Total Rotation*	0.000166	0.021715	951.257	0.008	0.994	-0.042448	0.04278
*Post-Test * Constant Increase Condition * Total Rotation*	0.009047	0.022373	956.596	0.404	0.686	-0.03486	0.052953
*Post-Test * Oscillating Condition * Rotational Difference*	0.115912	0.057159	968.663	2.028	0.043	0.003743	0.228081
*Post-Test * Constant Increase Condition * Rotational Difference*	-0.001139	0.05516	971.791	-0.021	0.984	-0.109386	0.107107
*Post-Test * Oscillating Condition * MSAQ*	0.30493	0.161487	522.71	1.888	0.06	-0.012312	0.622173
*Post-Test * Constant Increase Condition * MSAQ*	0.256963	0.16197	500.974	1.586	0.113	-0.061261	0.575187

APPENDIX R.

LSD Post Hoc Analysis of Block for Pre-/ Post-Test Blocks for SampEn-X in Experiment 2.

Pairwise Comparisons

(I) Block	(J) Block	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Block1	Block2	-.007*	0.001	0	-0.009	-0.006
	Block3	-.006*	0.001	0	-0.008	-0.005
	Block4	-.010*	0.001	0	-0.012	-0.009
	Block5	-.008*	0.001	0	-0.009	-0.007
	Block6	-.017*	0.001	0	-0.018	-0.015
Block2	Block1	.007*	0.001	0	0.006	0.009
	Block3	0.001	0.001	0.167	0	0.003
	Block4	-.003*	0.001	0	-0.005	-0.002
	Block5	-0.001	0.001	0.283	-0.002	0.001
	Block6	-.009*	0.001	0	-0.011	-0.008
Block3	Block1	.006*	0.001	0	0.005	0.008
	Block2	-0.001	0.001	0.167	-0.003	0
	Block4	-.004*	0.001	0	-0.006	-0.003
	Block5	-.002*	0.001	0.014	-0.003	0
	Block6	-.011*	0.001	0	-0.012	-0.009
Block4	Block1	.010*	0.001	0	0.009	0.012
	Block2	.003*	0.001	0	0.002	0.005
	Block3	.004*	0.001	0	0.003	0.006
	Block5	.002*	0.001	0.001	0.001	0.004
	Block6	-.006*	0.001	0	-0.008	-0.005
Block5	Block1	.008*	0.001	0	0.007	0.009
	Block2	0.001	0.001	0.283	-0.001	0.002
	Block3	.002*	0.001	0.014	0	0.003
	Block4	-.002*	0.001	0.001	-0.004	-0.001
	Block6	-.009*	0.001	0	-0.01	-0.007
Block6	Block1	.017*	0.001	0	0.015	0.018
	Block2	.009*	0.001	0	0.008	0.011
	Block3	.011*	0.001	0	0.009	0.012
	Block4	.006*	0.001	0	0.005	0.008
	Block5	.009*	0.001	0	0.007	0.01

Based on estimated marginal means

** The mean difference is significant at the .05 level.*

APPENDIX S.

LSD Post Hoc Analysis of Block for Pre-/ Post-Test Blocks for SampEn-Y in Experiment 2.

Pairwise Comparisons

(I) Block	(J) Block	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Block1	Block2	0.001	0.001	0.094	0	0.002
	Block3	-0.001	0.001	0.088	-0.002	0
	Block4	-0.001	0.001	0.267	-0.002	0.001
	Block5	.004*	0.001	0	0.003	0.005
	Block6	.002*	0.001	0	0.001	0.004
Block2	Block1	-0.001	0.001	0.094	-0.002	0
	Block3	-.002*	0.001	0.001	-0.003	-0.001
	Block4	-.002*	0.001	0.005	-0.003	-0.001
	Block5	.003*	0.001	0	0.002	0.004
	Block6	.001*	0.001	0.043	4.16E-05	0.002
Block3	Block1	0.001	0.001	0.088	0	0.002
	Block2	.002*	0.001	0.001	0.001	0.003
	Block4	0	0.001	0.55	-0.001	0.002
	Block5	.005*	0.001	0	0.004	0.006
	Block6	.003*	0.001	0	0.002	0.005
Block4	Block1	0.001	0.001	0.267	-0.001	0.002
	Block2	.002*	0.001	0.005	0.001	0.003
	Block3	0	0.001	0.55	-0.002	0.001
	Block5	.005*	0.001	0	0.003	0.006
	Block6	.003*	0.001	0	0.002	0.004
Block5	Block1	-.004*	0.001	0	-0.005	-0.003
	Block2	-.003*	0.001	0	-0.004	-0.002
	Block3	-.005*	0.001	0	-0.006	-0.004
	Block4	-.005*	0.001	0	-0.006	-0.003
	Block6	-.002*	0.001	0.014	-0.003	0
Block6	Block1	-.002*	0.001	0	-0.004	-0.001
	Block2	-.001*	0.001	0.043	-0.002	-4.16E-05
	Block3	-.003*	0.001	0	-0.005	-0.002
	Block4	-.003*	0.001	0	-0.004	-0.002
	Block5	.002*	0.001	0.014	0	0.003