12-2018

The Influence of Time Spent in Beginning and End-State Postures on Grasp Choice

Rachel Modersitzki
Utah State University

THE INFLUENCE OF TIME SPENT IN BEGINNING AND END-STATE POSTURES ON GRASP CHOICE

by

Rachel Modersitzki

**Capstone submitted in partial fulfillment of
the requirements for graduation with**

UNIVERSITY HONORS

**with a major in
Pre-Physical Therapy in the Department of Kinesiology and Health Science**

Approved:

**UTAH STATE UNIVERSITY
Logan, UT**

Fall 2018

The influence of time spent in beginning and end-state postures on grasp choice

By

Rachel Modersitzki, Principal Investigator

Dr. Breanna Studenka, Faculty Mentor

Abstract

The choice to end comfortably often requires adoption of uncomfortable beginning states, demonstrating that a sequence of movement is planned in advance of movement onset. Many factors may influence the choice of comfortable end-state postures including the greater precision and speed afforded by postures at joint angle mid-ranges (Short & Cauraugh, 1999). There has been no evaluation of the hypothesis that postures are chosen based on minimizing time spent in postures. Typically, the time spent in beginning and end- states are not explicitly constrained, but the end-state posture is likely held for the longer amount of time due to greater precision or task demands (Fitts, 1954). The aim of this experiment was to examine how the relative time required to hold a beginning and end-state posture influenced the choice of posture. We predicted that we would see more thumb-up postures for positions held longer regardless of the end or beginning state of grasp. Participants completed four conditions: unconstrained beginning and end state, constrained beginning state, constrained end state, and constrained beginning and end state. Within each condition, participants moved a wooden dowel rod from one location to another with the requirement to grasp the object with either a thumb up or thumb down posture and to place a specified color of the object down. In addition, by using a conductive object and surface, we were able to measure reaction time movement times, and grasp times. Two strategies for planning emerged. The majority of participants chose to end comfortably regardless of the time required for the beginning state grasp. A smaller group of participants appeared to minimize the effort of motor planning by choosing beginning state comfort on trials that required the beginning state to be held longer.

Acknowledgments

I would like to thank my faculty mentor, Dr. Breanna Studenka for her tireless efforts to help me succeed. I would like to thank the Undergraduate Research Creative Opportunity Grant for funding my project as well as the Honors department and my home department of Kinesiology and Health Science for funding my trips to research. I am grateful for everyone else who has encouraged me and believed in me throughout my researching career.

Introduction

When performing an action involving objects, individuals undergo many rapid, cognitive decisions to determine biomechanical factors underpinning the movement of said object, such as hand placement or type of grasp. For instance, individuals who are reaching for a drinking glass consider both the shape of the glass and the desired outcome to determine the proper grasp choice. Moreover, if a person intends to drink out of an initially overturned glass, they may grasp the glass with an uncomfortable thumb-down position in anticipation of being in a more comfortable posture to facilitate pouring water into the glass. Several factors influence which grasp is chosen including the comfort of the grasp (Rosenbaum & Jorgensen, 1992), the precision requirements of the task (Short & Cauraugh, 1999), and which tasks are performed both prior to and following the grasp (Studenka, Seegelke, Schütz, & Schack, 2012).

When conducting movements, individuals value comfort at the end of a motor action, even if that places them in an unnatural posture to begin the action. This phenomenon has been termed end-state comfort (Rosenbaum et al., 1993). The best predictor for choice of grasp was the comfort rating of the final position (Rosenbaum et al., 1996). This perceived comfort in a particular position is action-specific and depends on a joint's range of motion. Grasps that

required participants to hold positions at the extremes of their joint angles were rated as less comfortable and made their movements less precise (Rosenbaum et al., 1996). Prior research investigating individuals grabbing objects with their hands in different positions (e.g. grabbing a cup thumb-up or thumb-down), shows that people rate thumb-down postures as more uncomfortable than thumb-up postures (Coelho, Studenka, & Rosenbaum, 2014). Moreover, people describe a palm-up position as less comfortable than the alternative, palm-down posture (Rosenbaum & Jorgensen, 1992). From these investigations the palm up, thumb up end state comfort grasp was recognized.

Additionally, one's choice of grasp is representative of the amount of control an individual would need throughout a task's completion. Past investigations have noted that grasps between a joint's range of motion (ROM) extremes allow for more precise and accurate actions (Short & Cauraugh, 1999). The precision hypothesis states that being midway between the joint's range of movement allows for the next movement to be efficient and effective. When participants' chose a grasp, they motor plan based on the precision requirement of the task and what they plan to do with the object next. This is called first order planning. By knowing what the task will entail the participant can plan their movements accordingly. The step of their movement that requires the most accuracy then can be performed at the midrange of their joints ROM and ultimately end in an end state comfort grasp (Rosenbaum et al., 2012). Research examining the precision hypothesis and end-state comfort confirmed that participants' movements are quicker when in the middle of the joints range of motion, as opposed to the joints' movement extremes of the joints range of motion. This produced the middle is faster explanation for why people chose to adopt a comfortable end state (Rosenbaum et al., 1996).

To date, there is no research on how long people spend in certain postures, and furthermore, on how the time spent in certain postures influences choice of posture (e.g., comfortable vs. uncomfortable grasp choice). Typically, the time spent in certain postures is not constrained, whereas the time spent in the end-state posture might be constrained by the precision requirements of the task. If there are no precision requirements then there should be no end state grasp that is necessary to perform the task (Rosenbaum et al., 1996). In end-state comfort experiments, the end-state posture is likely held for the longest amount of time, when compared to the beginning-state posture. For instance, in the seminal work by Rosenbaum (1992), participants were instructed to grasp a wooden dowel and place it into a target (Rosenbaum & Jorgensen, 1992). Although the time spent in each posture was not recorded, the initial grasp was likely performed quicker, while the final grasp took longer because it required greater precision to place it into the target than to lift it up (Fitts & Posner, 1954). However, if a participant were asked to hold the initial grasp for longer than the end-state, it is possible that a more comfortable grasp would be chosen for the beginning rather than the end-state.

This experiment examined how different intervals of time spent in particular postures affects movement planning. More specifically, grasp choice was examined based on predetermined positions in which participants will have to hold beginning grasps longer than end-state grasps. The purpose of this experiment was to determine if time spent in the grasp would affect the order in which the participant would chose an end state comfort grasp. We hypothesized that a greater duration spent in a posture leads to greater choice of comfort. We should see more thumb-up postures for positions held longer regardless of the end or beginning state of grasp. In addition, we aim to replicate other end-state comfort findings of greater choice of comfort at the end-state as well as documenting, for the first time, the actual durations of grasps at the beginning and end-state.

Method

Participants

We recruited 30 participants for this study through the undergraduate research participant pool (SONA). One participant was left handed. We analyzed the data from the 29 right handed participants. Participants were between 18 and 33 years (M = *21.36666667*, SD = 2.85854235) of age with no known neurologic or motor impairment. There were 12 females and 17 males. We excluded left hand participants.

Apparatus and tasks

Participants were seated in front of two targets that were spaced 29 cm apart on a surface of aluminum foil. A wooden dowel rod (half white and half black) with a length of 13 cm and a diameter of 5 cm was being positioned in one of the targets. The dowel was painted with conductive paint that allowed for the recording of the initial grasp time, movement time and the end state grasp time. The task involved grasping the dowel, lifting it from one target, and placing it on the other target. The distance between the start location and the targets was 22 cm. There was little precision requirement or time requirement due to the size of the target in which the dowel was to be placed. Had there been none, we would not have expected individuals to choose end-state comfort as often (based on Rosenbaum 1996 and Short and Caraugh). The time spent grasping the rod in the initial location and in the final location will be manipulated. However, this was not a timed task. Participants were asked to move comfortably and efficiently, not as fast as possible.

Procedure and Design

Prior to movement, participants were informed as to which end of the dowel (i.e. black or white) was to be placed on the target through the use of a circular laminated cue *(Figure 1)* that was black on one side and white on the other. The cue had a diameter of 5 cm and indicated to the participant the color to be placed down *(Figure 2,3)*.

Figure 1. Cue card diameter

Figure 2. No rotation is required setup

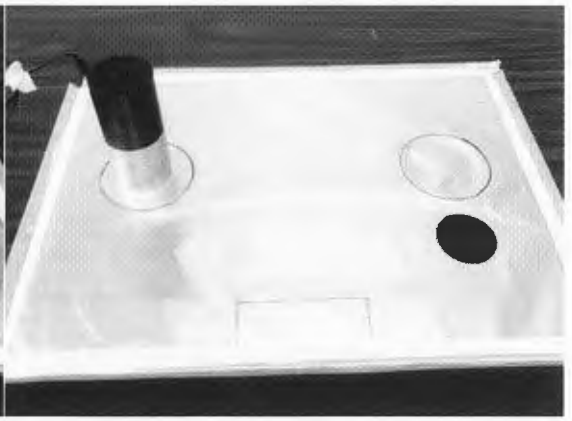


Figure 3. Rotation required setup

The order of both color displayed and color to be placed was counterbalanced and randomized for all trials. The initial trials were unconstrained by time and the participant was free to move the dowel after they heard the start tone. The participant moved the wooden dowel from one location to the other based on where the cue was placed. The start tone indicated to the participant that they could begin the motion (i.e. lift his/her hand off of the sensor and grasp the object). Other conditions included hold-first, hold-last and hold-both. The Hold-First condition consisted of an initial tone indicating that a participant should lift his/her hand from the table and grasp the rod. The participant continued to grasp the rod with his/her beginning-state grasp until a second tone sounded, indicating that the participant should place the specified end of the rod into the target. The opposite of this task was also being performed. The participant grasped the object and moved it to the other target position unconstrained by time and held the end state posture until a second tone sounded signaling the participant to release. The delay between the two tones was 5 seconds. The participant also performed a condition where they he/she grasped the object and hold the beginning state until a second tone sounds and then hold the second posture until a third tone sounds for the participant to release. Two conditions were performed, one where the time spent in each condition is unconstrained, and one where participants were aware of how much time they will have to wait in each position. Four trials were performed for each rod initial orientation, final placement, and duration constraint (64 total trials).

For the first condition, where time spent in each posture is unconstrained, the participant was instructed to move upon the first tone, grasp the rod and place the specified end into the target. For the second condition, where time is constrained and participants were aware of the intended grasp durations, the duration constraint were blocked and participants were informed that all durations will be the same for the beginning state grasp and end state grasp within the current block (n trials). The first condition was always performed first in order to get a sense of how behavior unfolds without time constraints. In addition, this allowed us to replicate other studies on end-state comfort in our sample, verifying that participants typically choose end-state postures that are comfortable. The following conditions with known and unknown time constraints were counterbalanced between participants. A total of 64 trials were performed. The total experiment time was about 45 minutes with instruction and set up.

Data collection and reduction

The set up for the experiment consisted of a MakeyMakey ™ circuit board, two alligator clips, a conductive surface made from aluminum foil, and a wooden dowel painted with conductive paint. For the experiment, one alligator clip was placed on an aluminum foil cap which is then placed on the participant's finger, the other on the conductive surface. A circuit

was completed when the participant grasps the wooden dowel (resting on the surface) and when they lay their hand on the start position to set off the beginning tone. The MakeyMakey fed data into a computer, where a custom written Matlab program detected when the circuit was complete and when it was not. This will allow us to control the time spent in certain postures. Videos were collected of each of the testing sessions and were analyzed to determine the beginning grasp, the end grasp and the direction of rotation. This data was then checked by multiple reviewers to verify the data.

Results

When the grasp is unconstrained, participants should exhibit end state grasps 100% of the time when there is no rotation involved. This was shown to be true. Participants chose end state comfort nearly every trial with no rotation requirements. The trials in which this wasn't the case were preceded by three prior conditions that required a thumb down beginning state *(Table 1)*.

	No Rotation Required			
SUBJECT	U - U	U - HOLD	HOLD - U	HOLD - HOLD
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	1	1	1	1
6	1	1	1	1
8	1	1	1	1
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12	1	1	1	1
13	1	1	1	1
14	1	1	0.88	1
15	1	1	1	1
16	1	1	1	1
17	1	1	1	1
18	1	1	1	1
19	1	0.88	1	1
20	1	1	1	1
21	1	1	1	1
22	1	1	1	1
23	1	1	1	1
24	1	1	1	1
25	1	1	1	1
26	1	1	1	1
27	1	1	1	1
28	1	1	1	1
29	1	1	1	1
30	1	1	1	1

Table 1. End-State comfort is 100% when there was no rotation requirement

When rotation was a requirement, we expected that we would see end-state comfort effect 100% of the time (Rosenbaum et al., 1996). However, our results showed that participants chose end-state comfort only about half of the time. Surprisingly, only 14 participants out of 29 adopted 100% end-state comfort on unconstrained trials. 4 participants had only one trial that didn't adopt end state comfort one participant had three trials that did not end in comfort, three participants had 4 trials that did not end in comfort, 4 participants had 4 of 8 trials not end in end-state comfort, one participant had only 3 trials end in end-state comfort, and 2 participants had no trials end in end-state comfort for the unconstrained task *(Table 2)*.

SUBJECT	U · U	U · HOLD	HOLD · U	HOLD · HOLD
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	0.62	0.62	0.38	0.38
6	1	1	1	0.75
8	0	0	0	0
9	1	1	1	1
10	0.5	0.62	1	1
11	0.62	0.5	0	0.25
12	0.62	0.38	0	0.5
13	0.5	0.5	0.5	0.75
14	1	1	1	0.88
15	0.88	0.88	0.12	0.38
16	1	1	1	1
17	1	0.75	0.12	0.12
18	0.5	0.5	0.5	0.5
19	1	1	1	1
20	1	1	0.25	0.88
21	1	1	1	0.88
22	0.88	0	0	0
23	1	0.5	0.25	0.38
24	0	0	0	0
25	1	1	0.25	0.25
26	0.88	1	0.88	0.88
27	0.5	0.5	0	0
28	0.38	0.5	0.5	0.5
29	0.88	0	0	0
30	0.75	1	1	0.75

Table 2. End-State comfort ratios for each condition where rotation was required showing that the end-state comfort in being chosen only half of the time (highlighted portion)

The fact that when rotation was required and the time was unconstrained, participants did not choose end state comfort was perplexing because the unconstrained grasp task was performed first, and was very similar to other research on end-state comfort. We tested the experimental manipulations that we did not intend to influence such as grasp choice, color and direction, to make sure they didn't have an influence on grasp choice. We ran the full model on trials that required manipulation to test for the influences of direction, color and condition.

An ANOVA was run looking at the independent variables of the direction of the rotation (either left or right) and the color (BW or WB) with the dependent variable as the end-state comfort ratio for trials that required a rotation. We tested only trials that required manipulation using variables direction (to the right or to the left), color (black to white, or white to black), and condition (Unconstrained, Hold-Beginning, Hold-End, and Hold-Both).

Significant main effects of condition, $F(3,112) = 7.68$, $p = .0001$ and direction $F(1,28) = 11.93$, $p = .002$ were seen, indicating that time constraint condition as well as the direction the object was being moved had an influence on how often participants chose end-state comfort as their final posture. The significant main effect of direction indicated that some participants had greater likelihood to end in an uncomfortable position when moving to the left ($M = .54$, $SD = .47$) vs. to the right ($M = .76$, $SD = .40$). Within the first condition, where grasps were unconstrained, a contrast revealed that participants also had greater tendency to end with a

thumb-up posture when moving to the right (M = .91, SD = .27) versus left (M = .64, SD = .46), F (1, 28) = 42.78, p < .0001.

Post hoc contrasts revealed that thumb-up ratio for the unconstrained condition was significantly different from the ratio for the Hold-Beginning condition, F (1, 112) = 18.23, p <.0001, the Unconstrained condition was significantly different from the Hold-Both, F (1, 112) = 12.66, p =.0006, the Hold-End condition was significantly different from the Hold-Beginning condition, F (1, 112) = 8.10, p =.006, and the Hold-End condition was significantly different from the Hold-Both condition, F (1, 112) = 4.56, p =.04.

The results showed that color had no effect, but interestingly enough direction of the movement did matter. We the further analyzed the data in two groups: movement left and movement right. When moving to the right, end-state comfort followed the hypothesis of nearly 100%. When moving to the left, our end-state comfort ratio was about half. When the object was rotated to the right, and grasps were unconstrained, 25 of 29 subjects ended in a thumb-up posture 100% of the time, two subjects ended in a thumb-up posture on 3 of 4 trials, and two participants ended in a thumb down posture 100% of the time *(Table 3)*.

	U - U	U - U
	LEFT	RIGHT
1	1	1
2	1	1
3	1	1
4	1	1
5	0.25	1
6	1	1
8	0	0
9	1	1
10	0	1
11	0.25	1
12	0.25	1
13	0	1
14	1	1
15	0.75	1
16	1	1
17	1	1
18	0	1
19	1	1
20	1	1
21	1	1
22	0.75	1
23	1	1
24	0	0
25	1	1
26	0.75	1
27	0	1
28	0	0.75
29	1	0.75
30	0.5	1

Table 3. The difference between End-State comfort ratios when moving left and right

Two groups emerged on why participants chose beginning state comfort in the unconstrained condition when moving to the left. Participants could be choosing the thumb up

position because it is simply more comfortable in relation relative to the positioning of their arm in relation to their body. The second group is most likely adopting a compatibility method. We had ten participants make their direction of movement compatible with their direction of rotation. In efforts to have compatible movement and direction of rotation, participants are opting to adopt a comfortable beginning state over the more typically accepted end state comfort *(Figure 4)*. Twelve participants rotated right and moved left to end in the end state comfort grasp *(Figure 5)*. Six participants rotated left and moved left and still adopted end state comfort thumb up grasp *(Figure 6)*.

Figure 4. Thumb up grasp

Figure 5. Thumb down grasp

Figure 6. Thumb down grasp

We then looked at participants who exhibited end state comfort in the unconstrained condition to see if requiring a time constraint on the first grasp would change end state comfort. Typically, we hold final grasps longer regardless of moving to the right *(Figure 7)* or to the left *(Figure 8)*. For individuals who chose to end with thumb-up, when moving to the right, end-state grasps were held significantly longer than beginning-state grasps, t (24) = -7.4, $p < .0001$ (see Figure 7). Interestingly, end-state grasps were also held longer than beginning-state grasps for individuals who chose to end with thumb-down postures, t (1) = -24.8, $p = .03$ (note that there were only two individuals in this group). For both groups, the beginning-state grasps were not different between the Unconstrained and the Hold-End conditions, t (24) = .16, $p = .88$, t (1) = 1, $p = .5$, nor were the end-state grasps different between the Unconstrained and the Hold-Beginning conditions, t (24) = .06, $p = .95$, t (1) = 1.9, $p = .31$. These results indicate that grasp times depended more on the constraints of picking up the object and placing it down than on the relative timing of sub-movements.

When moving to the left, the same pattern was seen (see Figure 8). For both individuals who chose to end with thumb-up or thumb-down, end-state grasps were held significantly longer than beginning-state grasps, t (14) = -9.5, $p < .0001$, t (6) = -4.95, $p = .003$. For both of these groups, the beginning-state grasps were not different between the Unconstrained and the Hold-Last conditions, t (14) = -0.1, $p = .91$, t (6) = -1.1, $p = .3$, nor were they different between the Unconstrained and the Hold-Last conditions, t (14) = -0.5, $p = .63$, t (6) = .28, $p = .79$.

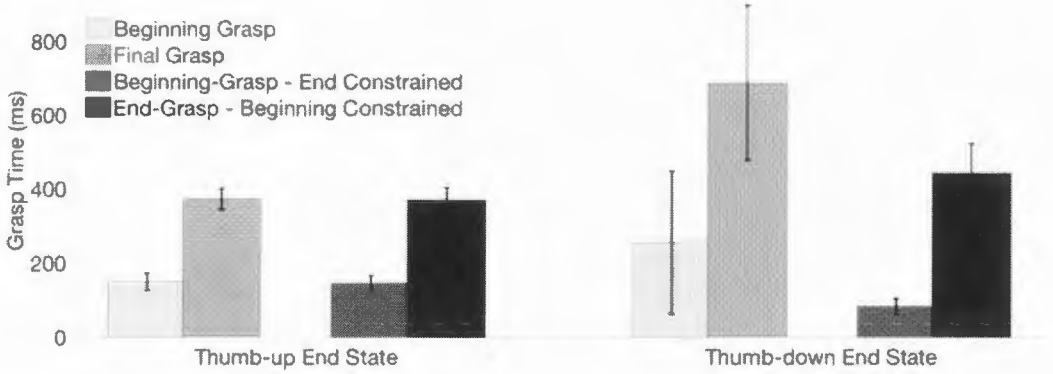


Figure 7. Movement to the right

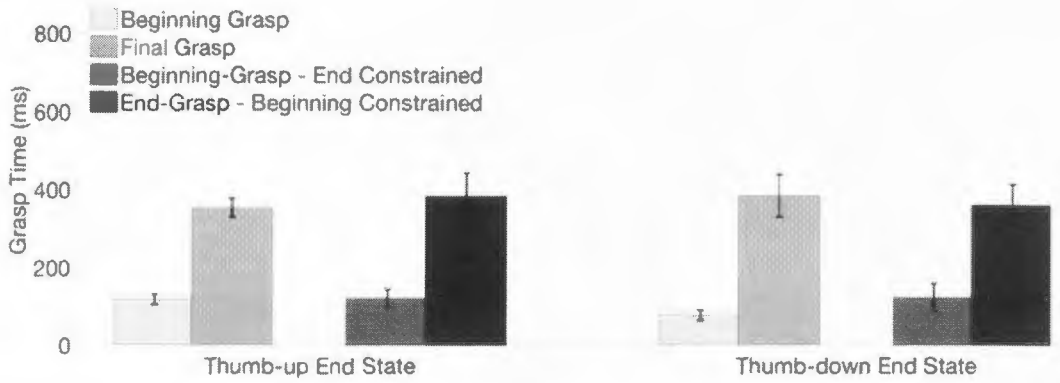
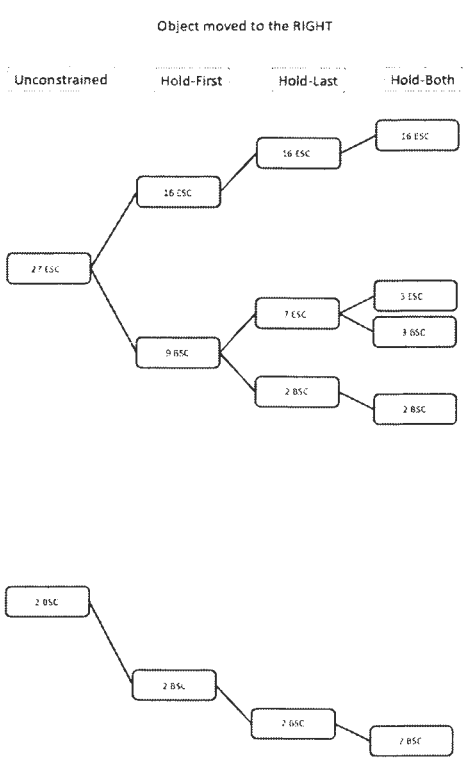


Figure 8. Movement to the left

Participants were split into groups depending on their grasp choices under each condition. We can immediately separate out two participants who chose to adopt a uncomfortable end-state grasp 100% of the time. We would expect that those who chose to change their strategy in the hold-first condition to beginning state comfort would change their strategy back to end state comfort in the hold-last condition when the hold last condition in performed after the hold first condition. However, this was not necessarily true. Some chose to re-adopt their initial end-state comfort grasp and some chose to continue using the beginning state comfort grasp choice *(Figure 7 and 8)*. This made us believe that through the analysis of the reaction time and movement time we could determine if these groups were using different planning strategies when moving the object.



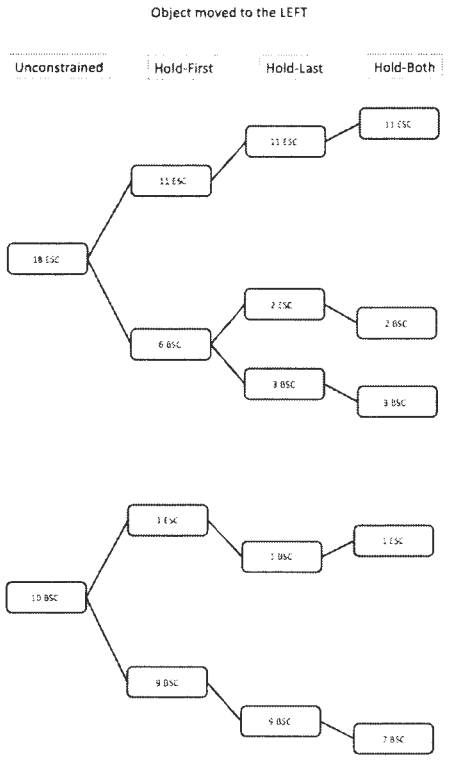


Figure 7. Strategies chosen when moving right

Figure 8. Strategies chosen when moving left

The participants that are choosing beginning state comfort in the hold first condition could be a result of total discomfort minimization, where the cost of an uncomfortable end grasp is less than holding the uncomfortable grasp at the beginning for a longer length of time. Another group of participants fall into the pre-crastination (RTMT of the condition hold first is less than in the unconstrained condition). Pre-crastination is the effect when the participant chooses to grasp the object immediately knowing that once the initial grasp is done they have time during the prescribed holding time to plan the rest of their actions *(Table 6 and Table 7)*.

Discussion

Participants in this study can be split into three groups: those who, regardless of time constraints, chose the end-state comfort grasp, those who plan at the beginning of their movements to reduce total discomfort (Rosenbaum et al., 1990), and those that grasp the dowel immediately and then plan their movements (Rosenbaum et al., 2014). We expected color and direction of movement to be negligible, however as we examined the data we determined that direction of movement indeed played a role in the way participants planned movement. When moving to the left, we saw an increase in types of movement strategies. Participants chose to make their direction and rotation movements compatible, or chose to adopt a beginning state comfort grasp of thumb up and those who chose the end state comfort grasp regardless. This was not what we had originally hypothesized would occur.

We supposed that, due to the precision requirement and passed studies performed by other researchers that the end-state comfort grasp would occur in every condition except the hold-first condition (Rosenbaum et al., 1990). In the hold-first condition, due to timing we

hypothesized that there would be a beginning state comfort grasp that mirrored the end-state comfort grasp. This was due to the supposition that the end-state comfort grasp adoption was partially due to the fact that it was typically held longer than the beginning state grasp. Dr. Rosenbaum studied the effects of the end-state comfort grasp and found that the value of comfort was important to individuals when performing motor tasks (Rosenbaum et al., 1993). However, we found that participants seemed to value other variables as well. These included a less costly planning strategy, movement compatibility and total discomfort reduction.

Participants that chose this less costly planning strategy adopted a pre-crastination mindset. Pre-crastination was defined by Dr. Rosenbaum as a tendency to complete or begin tasks as soon as possible, even at the expense of extra effort (Rosenbaum et al., 2014). In our case we saw participants chose to grasp the dowel as quickly as possible, in a beginning state comfort grasp, and then planning the rest of their movement in the time that they were prescribed to hold the beginning grasp. This aligns with Dr. Rosenbaum's previous study. Even though Dr. Rosenbaum's study focused on the order in which participants chose to move a mixture of light and heavy weighted buckets, much of his findings apply to the movement of our dowel from one location to the other. Completing a sub goal hastily has been described as a rule among experiments such as this (Rosenbaum et al., 2014). We can suppose, that a sub goal of the experiment was seen to be a hasty completion of the task, even though each participant was assured that this was not a timed task. Another aspect of this movement strategy entails looking into mind loads of our working memory. For some participants, it is costlier to remember and plan their movements out in the beginning than to expend extra physical effort. This explains the selection of a fast beginning state and planning after the task has already begun. This implies that participants are choosing their actions as fast as they can have based on grasps that they have chosen previously, rather that creating new motor plans that are costlier on the working memory load (Rosenbaum et al., 1992).

Another group of participants made an effort to have a compatible direction of movement and rotation. This could be due to the comfort of the joint angles as the participant rotates the dowel through their wrist range of motion. Extreme joint angles have been rated in previous studies as less comfortable then the subsequent position that allows the joint to be in the mid-range of motion (Rosenbaum et al,. 1993). When moving to the left in particular, participants chose to also rotate left to minimize discomfort. This entailed participants adopting a comfortable, thumb up beginning state grasp and ending in a more uncomfortable thumb down grasp. This could also be explained through the pre-crastination hypothesis potentially as well as the adoption of the beginning state comfort happened initially and then planning was performed from that point on.

Our final hypothesis aligns most with the most commonly accepted phenomenon of end state comfort grasp. This is the theory of total discomfort minimization. A study was performed in which every ten seconds two patients who were receiving a colonoscopy rated their discomfort levels. One patient's colonoscopy was significantly shorter, however he ended his procedure in high discomfort ratings. The second patient, though his colonoscopy was longer, ended in a low discomfort state. When asked subsequently to rate their total discomfort, shockingly the patient who had the shorter colonoscopy rated total discomfort as much higher than the second patient (Kahneman, 1999). This study suggests that the way we end influences our perception of the total discomfort for the task. Therefore, our participants, by ending in the end-state comfort grasp were minimizing their total discomfort.

We hypothesized that, participants, when asked to hold the beginning posture longer, would exhibit beginning vs. end-state comfort. When moving to the right, 9 participants chose comfort at the beginning state in the hold-first condition, suggesting they wanted to minimize overall comfort rather than comfort at the end-state. When moving to left, of the 14 participants that chose end state comfort, 6 chose to adopt a beginning state comfort. However, 11 chose to continue their adoption of end state comfort the majority of participants chose end-state comfort regardless of time-constraints, suggesting that there's something important about the end-state of movement aside from typically being held longer held longer. Several factors influence which grasp is chosen including the comfort of the grasp (Rosenbaum & Jorgensen, 1992), the precision requirements of the task (Short & Cauraugh, 1999), and which tasks are performed both prior to and following the grasp (Studenka, Seegelke, Schütz, & Schack, 2012).

Even though our findings did not completely reflect our original hypothesis we were able to deduct new insights into motor planning strategies and the effect that time has on choice of grasp. Hopefully, the more this topic is researched the better understanding we can have in fields such as psychology, teaching and health care. As we better understand why people choose to motor strategies they chose the better we can be about predicting states of mind, teaching new skills and giving specific instructions in tasks that require specificity.

Reflection

I began my capstone project with a simple question that I was passionate about. I had attended the weekly lab meetings and read literature about motor planning. The more I read the more I saw room to grow and learn through hypothesis. Being interested in the human body, I immediately set to work to uncover why we chose the actions we chose and if by discovering the reasons behind our actions, we could manipulate variables to control the way someone else acts. As I devoured article after article and was encouraged by my mentor to critically analyze each tantalizing page, I began to become proficient in reading and writing in a scientific manner. This was a completely new form for me and at first it was comparable to a foreign language, but with practice I became fluent. I felt as though I had developed enough base knowledge on the subject to set out on my own research project.

My mentor, Dr. Breanna Studenka, took me under her wing as a freshman and helped me navigate the complex world of discovering my passions. She believed in me and encouraged me that if I was passionate about something, there was nothing that I could not do. She encouraged me to apply for the Undergraduate Research Creative Opportunity Grant and to present my research at the National Conference of Undergraduate Research, the Undergraduate Research Symposium, the Kinesiology and Health Science Seminar and the North American Society for Psychology of Sport and Physical Activity. As I have been studying for the MCAT, I have come across a great need to be able to critically analyze complex passages and draw conclusions from them. However, I have had an easier time than most because Dr. Studenka has pushed me to be my best. She has been having me read many research articles and then provided an environment for open discussion that has made me better at my reading comprehension skills. Dr. Studenka encouraged me to follow my dreams, even when they were not related to my research. She supported me in my decision to run for Miss Science 2018 and consequently Miss USU 2018. She has given me constructive criticism on many assignments that were unrelated to research and has helped me solve scheduling issues so that I could graduate with the best possible educational experience. Honestly, more important than being a mentor to me, Dr. Studenka has been my

advocate from the moment that I stepped into her office as a young eighteen-year-old. I hope that one day I will be able to return the favor and mentor a student in the same way that Dr. Studenka has helped me. I am grateful for the influence she has had on me. Dr. Studenka has written me a letter of recommendation for medical school and because of her influence I will be applying for the MD/PHD programs so that I can continue research for the years to come.

My major is very centralized on human movement. In my degree classes, we have delved into topics that have deepened my understanding of the "how" of movement, but my research experience has put a "why" to that "how". As I have paralleled my studies I have been able to ask deeper questions in my classes and apply my knowledge to my projects. This has given me a more well-rounded experience in my major. Another pertinent moment in my studies was when I presented at the Kinesiology and Health Science Seminar. Many of my professors from my classes were in attendance and able to help me tie many concepts together and helped me understand my research on a deeper level. They offered me years of experience in the field and unique prospective about my research. When explaining that I found that the research showed that indeed the direction of movement effected the data and my proposed hypothesis as to why, my professors were able to supplement my ideas. They tied together the mechanics of the body and the results that I had discovered. Through the coupling of these two things, I was able to draw a greater and more complete conclusion to my project.

Even though this project focused on Kinesiology and Health Science, I truly believe that this could be expanded into an interdisciplinary study because comfort ratings are subjective and strategies could have blossomed from differing experiences that specific individuals could have had. By more closely looking at the relation of strategies and IQ scores I believe that we could look into a different side of movement planning. This broadened my understanding of psychology as it became apparent that a broader perspective would be necessary if I was to truly understand the purpose of the research. My research also helped me dive deeper into my love of anatomy. As we studied the effects of uncomfortable grasps and why some grasps at extremes of joint angles were rated more uncomfortable than other grasp, I was able to apply my knowledge of the structure of joints in supporting proposed conclusions. This project could also be useful in a clinical setting because autistic children do not motor plan because for them, the cost of forming a new motor plan is higher than that of a typical child. The hope is that the more that we research and learn about motor planning the better we can understand why autistic children chose the actions that they chose to and hopefully we can take this knowledge and use it to teach them to motor plan. I hope to take this project to the next step in the fall and continue my pursuit of understanding with a newfound awareness of process. Now that I understand the steps to be taken to study a new question, I believe that I have the skills to follow through until I have developed a greater understanding of what I am researching. I hope to continue using the skills I have learned in working for Dr. Studenka as I graduate and embrace new schooling and educational opportunities.

References

Coellho, C. J., Studenka, B. E., & Rosenbaum, D. A. (2014). End-state comfort trumps handedness in object manipulation. *Journal of Experimental Psychology: Human Perception and Performance*, *40*(2), 718.

Fitts,P.M.(1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, 47, 381-391.
Kahneman, D. (1999). Objective happiness. *Well-being: The foundations of hedonic psychology*, *3*, 25.
Short, M. W., & Cauraugh, J. H. (1999). Precision hypothesis and the end-state comfort effect. *Acta psychologica*, *100*(3), 243-252.
Studenka, B. E., Seegelke, C., Schütz, C., & Schack, T. (2012). Posture based motor planning in a sequential grasping task. *Journal of Applied Research in Memory and Cognition*, *1*(2), 89-95.
Redelmeier, D. A., & Kahneman, D. (1996). Patients' memories of painful medical treatments: Real-time and retrospective evaluations of two minimally invasive procedures. *Pain*, *66*(1), 3-8.
Rosenbaum, D. A., Chapman, K. M., Coelho, C. J., Gong, L., & Studenka, B. E. (2013). Choosing actions.
Rosenbaum, D. A., Chapman, K. M., Weigelt, M., Weiss, D. J., & van der Wel, R. (2012). Cognition, action, and object manipulation. *Psychological bulletin*, *138*(5), 924.
Rosenbaum, D. A., Gong, L., & Potts, C. A. (2014). Pre-crastination: Hastening subgoal completion at the expense of extra physical effort. *Psychological science*, *25*(7), 1487-1496.
Rosenbaum, D. A., Herbort, O., Van der Wel, R., & Weiss, D. J. (2014). What's in a Grasp?. *American Scientist*, *102*(5), 366.
Rosenbaum, D. A., & Jorgensen, M. J. (1992). Planning macroscopic aspects of manual control. *Human Movement Science*, *11*(1), 61-69
Rosenbaum, D. A., van Heugten, C. M., & Caldwell, G. E. (1996). From cognition to biomechanics and back: The end-state comfort effect and the middle-is-faster effect. *Acta psychologica*, *94*(1), 59-85.
Witt, J. K., Linkenauger, S. A., & Wickens, C. (2016). Action-specific effects in perception and their potential applications. *Journal of Applied Research in Memory and Cognition*, *5*(1), 69-76.

Biography

Rachel Modersitzki graduating with her B.S. Human Movement Science degree with an emphasis in Pre-Physical Therapy and a minor in Chemistry. Rachel has been named Miss Science 2018 and was Miss Congeniality in the Miss USU 2018 pageant. Rachel has received the Dean Scholarship, Legacy Dean Scholarship and the Adler Service Scholarship and an URCO grant throughout her three years at Utah State. She has maintained a GPA of 3.93. Rachel Modersitzki is finishing her third year at Utah State and will be taking the MCAT this summer to apply to medical school in hopes of becoming a pediatrician. She has been doing undergraduate research since her freshman year in the Sensory Motor Learning and Behavior Lab and has just returned from presenting her work at the National Conference of Undergraduate Research. She will also be submitting her research manuscript for publication at the end of the semester. She is an active participant in the Utah State Honors program and loves her jobs of being a teaching assistant for Human Anatomy and Human Physiology, a coach for gymnastics and a trainer of therapy horses to work with underprivileged young girls. She has been an active volunteer in the community and enjoys volunteering at the Pediatric Rehabilitation Center, TeamWorks Physical therapy, Eastridge Track team for refugee children and at the USU Health and Wellness center

Word Count for the written product: 5,218
Word Count for Reflection Essay: 1,009