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HOW PHYSICAL PROBLEM SOLVING CAN BENEFIT INTELLECTUAL PROBLEM SOLVING

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ABSTRACT

The systems of cognition and motor planning have been shown to be heavily intertwined within one another. After coming to the realization that individuals who utilize wheelchairs have to constantly maneuver their world using creative cognitions and motor planning strategies, it was predicted that there might be a relationship between creativity in cognition and action. The purpose of this study was to investigate the priming effects that creative motor planning could have on creative cognitive problem solving. Participants were asked to tie two knots with either both hands, only their right hand or only their left hand. After completing the creative motor planning task, the participants were then asked to participate in two cognitive problem solving questions. It was predicted that individuals who used only one hand to tie knots would be better primed with creativity, therefore making these participants more effective in answering the cognitive problem solving questions. Although there were no significant differences found, there were small effects showing a difference in the effectiveness in answering the cognitive problem solving questions for participants who tied knots with one hand compared to participants who tied knots with both hands.

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Chapter 1 Introduction

Personal Interest

Throughout my life I have had the opportunity to work with many different types of individuals. During some of these experiences I have noticed that individuals who utilize wheelchairs have a unique way of interacting with the world around them. After having this realization, the connection between physical and cognitive problem solving became evident. People who use wheelchairs live their lives problem solving through creative cognition and motor control. Squeezing your wheelchair through tight spaces, maneuvering a world that seems to be for much taller people, or performing your daily living tasks using tools created with only an able body in mind all require problem solving. It seems as if these individuals are living their lives relying on the most creative ways to solve daily problems that arise within their lives. After gaining this new perspective, I started to realize that most individuals with disabilities are living their lives with an increased level of creativity. People with disabilities have to learn to maneuver a world that was created for an able-bodied person. This new perspective leads me to wonder if this sort of creative problem solving can be primed in individuals. I am choosing to dive into this research in hopes of gaining a new point of view about how the body and mind interact with one another. As an aspiring occupational therapist, I am looking forward to utilizing the research skills and gaining knowledge in order to help my future patients.

Cognition and Action

The human body consists of different systems, both biological and psychological. Most of these unique systems regularly communicate with one another in order to maintain a sense of homeostasis. The cognitive system is responsible for learning, knowledge, communication, and memory (Myers, 2013). The associational cortex is the area of the brain that contains these cognitive functions of thinking, memory, and processing (Falvo, 2014). The motor system controls the way our body uses its muscles and is a stabilization system to help move about the world (Rosenbaum, 1991). The motor cortex is the area of the brain, which is responsible for most motor planning tasks like walking, writing or tying a knot (Falvo, 2014). In the past, the cognitive and motor systems were believed to lack significant interaction. This separation perspective is evident today, especially in science books where each body system is explained separately. These texts, based on medical perspective, often overlook the influence that our body has on shaping our mind and its perspectives (Beilock, 2015). However, cognition and motor planning do not simply work independently. Rather, the motor and cognitive systems are both heavily integrated. In order to help or understand one system, you must take the other into consideration. The goal of this literature review is to provide evidence of the interconnectedness between mind and body. Only within the last 10 to 15 years have scientists and psychologists started to focus on the relationship between the cognitive and motor system. Knowledge about the way we work as human beings can be beneficial, but understanding the connection between these systems could enlighten many psychology and rehabilitation studies in the future.

Embodied Cognition

When first theorizing about cognition, pre-evolution western philosophers thought the body to be tangential to cognitive processing. Cartesian dualism, or the belief that the mind and body are made of different substances, has informed many perspectives of cognitive psychology (Foglia & Wilson, 2013). From Cartesian dualism, theorists created the idea of computationalism. Computationalism sees cognition as a mind that contains specific ideas and rules in which it processes abstract ideas (Foglia & Wilson, 2013). These theorized processing techniques are similar to that of a computer or calculator. In this computational perspective, the mind creates certain archetypes that inform the cognition of individuals. These archetypes provide an living manual by which an individual can live and learn.

Only within the past 10 to 15 years, have theorists and psychologists started to focus on the roots of the interconnectedness between action and cognition. Theorists are now starting to look at the sensory-motor system as a part of these ideas and rules of which cognition is based. In other words, these intellectuals are beginning to consider how the body and its interaction with the world play into the brain's creation of this cognitive rulebook. This link between mind and body stems from a focus within psychology termed "embodied cognition." Embodied cognition looks into the way individuals interact with the world around them and how these interactions shape us (Beilock, 2015). Interactions with the environment help mold a person's cognitive manual by influencing their cognitive perspectives and motor planning strategies. Each time an individual has a new experience their personal cognitive manual is molded based on that new perspective. A cognition can become embodied when it is conditional on the physical body and when the body and its neuromuscular structures are needed to understand the cognition (Wilson & Foglia, 2011).

Embodied cognition helps inform many different realms. One of the biggest benefactors of embodied cognition is artificial intelligence (Beilock, 2015). The research done to understand the connection between the mind and body helps educate these scientists on intelligent action. Understanding how a human might reach for an object may assist the programming of a robot to perform in the most efficient way. This perspective also helps inform research combining kinesiology and psychology.

This psychological theory of embodied cognition goes beyond the brain and into the relationship between the body and mind. Our movements through the world help people understand how the world works. As human beings, we learn from doing. Every time our body interacts with the world, our cognitive manual becomes more informed. This embodied cognition perspective helps inform the research that will be provided in this thesis.

The Cognition and Action Relationship

From an evolutionary perspective, the cognitive and motor systems have even been hypothesized to have developed together (Leisman, Moustafa & Shafir, 2016). Jean Piaget, an innovator in child developmental psychology, argued that children's bodily interaction with the world influences their "sensorimotor intelligence" (Helmore, 1969). These kids create their perspectives about the world based on these experiences. Research conducted by Herbert, Gross and Hayne provides evidence to Piaget's "sensorimotor intelligence" theory through infant memory retrieval. This study was performed with nine-month-old infants (n = 96). Half of the infants were crawling during the time of the experiment, and half were not (Herbert, Gross & Hayne, 2007). The infants were presented with a toy that looked like a cow or a duck. When the button on the stimulus was pressed, it either mooed or quacked. In the first session, the infant was given a demonstration on how to get the sound from the toys. After 24 hours, only the infants who were crawling at nine months were able to show retention of the task when presented with a different stimulus in a different situation (Herbert et al., 2007). For example, if an infant was given the demonstration with the cow, they were able to show the same button-pushing task with the duck if they were crawling at nine months. This study is a great example to show how, as an infant, maneuvering objects in the world gives opportunities to practice using cognitive skills such as long-term memory.

This intertwining of the systems can even be seen with disruptions of the system. For example, individuals with developmental disabilities often also see impairments in their motor system (Leisman, Moustafa & Shafir, 2016). In 1997, Owen and McKinlay found a relationship in motor task speed in children diagnosed with speech and language disorders compared to a group of children who have not been diagnosed with a speech or language impairment. Before this article was published, there had been numerous studies showing the relationship between language impairments and motor impairments in children. Though, this study was the first to make the relationship between language and motor impairments the central piece of the design. Owen and McKinlay (1997) compiled two groups of children aged four to seven. The first group consisted of 16 children who had been diagnosed with severe developmental speech and language disorders. This study found that children diagnosed with developmental speech and language disorders were significantly slower in three of the four motor tests compared to the control group. The four tasks were The Wallin Pegboard, threading beads on a string, fastening buttons and placing crosses in boxes (Owen & McKinlay, 1997). The hypothesis of this study highlights the deeply embedded connection between action and cognition.

Although motor planning delays is not a diagnostic criterion for autism, numerous studies have shown that individuals who have been diagnosed with the neurodevelopmental disorder of autism are also likely to show motor planning impairments. One of the most common motor planning assessments of school-aged children is their handwriting competency. Compared to neuro-typical children, children with autism show a significantly worse quality of handwriting. Specifically in the area of letter forming (Fuentes, Mostofsky & Bastian, 2009). Looking more deeply into motor planning delays of children with autism, Scharoun and Bryden found that individuals who have been diagnosed with autism spectrum disorder also have difficulty planning and coordinating motor movements. This can be seen when assessing these children for end-state comfort (Scharoun & Bryden, 2007).

End- state comfort is a motor planning phenomena that requires individuals to plan their hand grips to complete a motor planning task with the most versatility and comfort level (Zhang & Rosenbaum, 2008). End state comfort can be seen when an individual picks up a coffee cup that is upside down. Typically, this person would pick the coffee cup up in a thumb down position to end up in a thumb up position. The thumb up hand position allows a person to have the most control with their hand in order to complete the intended motor planning action, like filling the cup up with coffee. Individuals with autism have difficulty with anticipatory movements, like end-state comfort, likely because of delays in the cognitive system. This inability to plan for future actions is another example of how the cognitive system can affect the motor planning system.

Research studies that have been done linking dyspraxia and autism help show an even deeper interconnectedness between the two systems. According to the DSM-V, dyspraxia is a neurodevelopmental disorder that can interfere with everyday life and occurs across cultures, socioeconomic status, and races (APA 2013). Dyspraxia is seen in individuals who have typical muscle strength, coordination, and sensation, though they may seem at a loss when planning voluntary motor movements (Falvo, 2014). Children typically have this disability from birth, though the neurologically-based disorder is often discovered during infancy. Dyspraxia can be especially evident when the child is beginning to crawl or walk.

Dziuk and colleagues studied a group of 47 children with high functioning autism spectrum disorder. Based on the results from the Physical and Neurological Assessment of Subtle Signs, a motor control test, the parallel function of brain systems is evident. This lack of motor skill can show markers of motor planning delays, which have been found to be predictors of other autism symptoms, like compromised communication skills (Dziuk, Larson, Apostu, Mahone, Denckla & Mostofsky, 2007). Dyspraxia, or lack of motor planning control, may even become a grounds for diagnostic testing of autism in the future.

From an embodied cognition perspective, the motor planning delays seen within different cognitive impairments might be due to the way these children are interacting with the world. Someone with autism might not have the same capability to model the typical motor planning that adults show because of their cognitive impairments. For example, a child with autism may choose not to interact with adults or other children who show end-state comfort. Therefore, these children might take longer to demonstrate the effect because they are not modeling theses adults interactions. Overall these kids show reduced social interactions, therefore reducing opportunities for modeling. No matter the cause of the relationship between cognitive and motor development, this study provides strong evidence between the complex relationship between cognition and action. It seems likely that the impairment of cognition can cause impairment of motor planning. One might question whether the stimulation of one of the systems can prove beneficial to the development of the other system?

Exercise and Cognition

In a 2008 study by Kwak, Um, Son and Kim, makes a connection between physical activity and delayed cognitive decline in senile dementia. The give and take relationship between exercise and cognition is demonstrated within this study. Like many other neurological processes, the connection between exercise and improved cognitive function was unknown. This experiment looked at individuals with senile dementia who participated in a regular exercise plan. The activity plans included both aerobic and stretching exercises. The cognitive state of the individuals was assessed based on the individual's activities of daily living, also called ADLs, and a caretaker survey. These assessments were taken before, during, and after the physical intervention. Overall, the individuals who participated in the interval exercise routine showed improvement in their daily functioning (Kwak et al., 2008). This article also helps create a strong connection between the benefits of physical activity on cognition. This research showed how an independent variable of motor planning can benefit cognition.

Other studies corroborate the findings that physical activity can benefit cognitive function. In 2016, Groot and colleagues completed a meta-analysis from 18 randomized controlled trials which included 802 participants. The meta-analysis included studies that provided physical exercise as a therapy for individuals diagnosed with dementia (Groot, Hooghiemstra, Raijmakers, Berckel, Schseltens, Scherder, Flier, & Ossenkopple, 2016). Studies that only included physical exercise as the therapy were included. For example, studies that included physical exercise and occupational therapy were excluded. Every study also documented both pre- and post-intervention measures. Overall, the meta analysis found that both high-frequency and low-frequency exercises benefited individuals with dementia (Groot et al., 2016). These advantages included positive effects on cognition as well as being a cost-effective therapy. Based on these studies, there seems to be a likely relationship between a deteriorating cognitive system and the improvements that long-term physical exercise can make. We questioned whether a neuro-typical individual also would benefit from short-term exposure to physical activity.

To help support this argument, a recent literature review of the relationship between children's physical health and cognition has found similar data to show that the cognitive and motor systems are heavily related. So much so that teachers and schools who provide their children with time during the day to be physically active have a higher rate of academic success (Chaddock, Pontifex, Hillman & Kramer, 2011). Another similar report made by the Center for Disease Control saw positive correlations between physical activity in children with more positive attitude, behavior and academic achievement (2010).

Working memory is a facet of short-term memory that deals with processing relevant information, especially with incoming auditory and visual information (Myers, 2013). This cognitive function is something that is used every day, especially in school and for other types of problem-solving. Martins and colleagues found that small bouts of physical exercise using an exercise bike improved an individual's working memory. Compared to a resting group, the participants who were in the exercise group were able to answer verbally presented math problems faster (Martins, Kavussanu, Willoughby, & Ring, 2013). This experiment shows that even short periods of exercise can improve cognitive functioning.

Based on these research studies, there seems to be a biological change in the body with physical exertion. So much so that a study by Van Praag, Kempermann and Gage was able to show that exercise can actually produce new brain cells in mice. The mice that had access to exercise had approximately twice as many brain cells compared to the control group (Praag, Kempermann & Gage, 1999). The neurogenesis that occurs in these mice is one of the strongest scientific pieces that connects the brain and movement. This biological change brought on by exercise seems to be at least one of the reasons why individuals are so positively influenced by physical movement.

Problem Solving and Motor Planning

One of the first places children begin to formally problem solve is in the classroom. Although this is not a highly researched topic, physical motor planning seems to have a positive effect on cognitive skills like comprehension and problem-solving. The study completed by Glenberg, Brown, and Levin is an example of how physical movement can enhance cognition. Specifically, this study looks at how children's reading comprehension can be improved by the use of relevant concrete objects. There were 45 participants aged six to eight. The participants were separated into two different groups. Each child was randomly assigned to one of two groups (Glenberg et al., 2007). The two groups of children were instructed to read a story. The experimental group used object manipulation during sections of the story and the control group was instructed to reread the same sections of the story. During the experiment, the children were broken up into reading groups of three. The children were asked to read a story and manipulate objects given to them that represented the actions happening in the story. For example, the children were asked to hook a tractor up to a cart when the story read that action (Glenberg et al., 2007). In contrast, the control group was simply asked to reread these action sentences.

After the story had been read, the children had a two-minute break followed by a written comprehension test. The comprehension component was a 10 question written test based on the stories that the children read. The test was measured by how many questions were answered correctly (Glenberg et al., 2007). The results found that the children who manipulated the toys while reading the story were able to more accurately answer the reading comprehension questions compared to the control group who just reread the story (Glenberg et al., 2007).

This experiment is yet another example of how physical action can improve cognition. Specifically, in this experiment, the researcher can make the causal relationship that the fine and gross motor task of object manipulation specific to a story can enhance a child's ability to comprehend that story.

The children in this study are embodying the story by playing it out. This example also researches a physical action specifically done with the hands, rather than a physical action involving the entire body. In this case, it seems obvious, that physical movements can benefit cognition. Glenberg and colleagues' 2007 article is one of the few examples showing the connection of problem solving and creativity. This example shows benefits that embodying a topic can provide. Therefore, embodying creativity may help to prime the creative system.

Research Questions

Although the findings within neuroscience have not allowed us to reasonably understand the underlying mechanisms of the relationship of action and cognition, these studies provide the basis to make the assumption that there could be a connection between the priming effects of creativity in action and cognition. It might be possible to enhance creativity between physical and cognitive modalities by participating in a physical, creative task before having to solve another problem creativly. Therefore, based on the existing literature related to cognition and motor planning, the following research questions help guide this experiment.

> Does engaging in a physical problem-solving task influence the performance on subsequent intellectual problem-solving tasks? Specifically, are individuals who are primed for creativity by performing challenging motor tasks better at solving a cognitive problem-solving question?

The creativity priming tasks require participants to rely on one hand to complete a knot-tying task. The experiment reviews those primed by the challenging one-handed motor task to see if they will more efficiently solve the Duncker candle-box question and will also be able to draw more unique figures on the Ruff Figural Fluency task compared to those who tied knots with both hands. If participants who were only able to use one hand during physical task are better primed to answer the set of cognitive problem-solving questions, then there might be a link between physical and cognitive creativity. If participants who use one hand during the physical task are able to answer the cognitive task, then creativity may also prepare participants to better deal with physical challenges in the future.

Looking more specifically into handedness, this hypothesis also predicts that the individuals who use only their right, dominant hand will be best primed to answer the cognitive problem-solving questions compared to participants who use both hands or only their left hand. If the participant uses only their right, dominant hand to tie the knots, than they will be able to most successfully answer the cognitive problem-solving questions. This is because these participants are in the condition that requires the most amount of creativity with only a moderate amount of stress. This level of the experiment would be the ideal priming for creativity. If the participant uses only their left, non-dominant hand to tie the knots, than these participants will be better primed to answer the creative problem-solving question compared to the control group. Though, the left, non- dominant group will not be as well primed at the right, dominant hand group. This might be because this group is required to participate in a creative motor planning task, but using only your non-dominant hand requires a much higher level of stress compared to using both of your hands or only your right, dominant hand.

Participants who use only their right hand or only their left hand to tie knots represents individuals with physical disabilities having to maneuver their world more creatively. Compared to the control group of participants who use both hands, which represents an able-bodied individual. Participating in physical tasks that require creative motor planning while someone is healthy may also prepare that individual for possible disabilities they may deal with in the future.

Chapter 2 Method

Participants

This experiment tested a convenience sample of college students. The participants were recruited from the college student population from an introductory psychology course. The students were obtained through The Pennsylvania State University's online Psychology 100 recruiting website. Each participant was given one credit hour of participation towards his or her introductory psychology class. The participants included 26 females and ten males aged 18 to 22

(M=19). Based on a handedness questionnaire there were 35 self-identified right-handed individuals and one left handed individual. The single left-handed person was assigned to the control group. Each condition tested 12 participants, making 36 the total number of participants. The participants had to be able to speak and understand directions in English as well as have the capability to perform tasks with the use of their whole body.

Design

This experiment is a between subject 3 (Knot tying hand) X 2 (creative, cognitive problem-solving question) design. The independent variable is defined by which hand the participant used during the, creative motor planning, knot tying portion of the experiment. The independent variable is broken up into three different groups, both hands, right/dominant hand only, and left/non-dominant hand only. Whereas, the both hand group used both hands to tie a figure eight and slip knot (see Figure 1 and 2). The both hand group was used as the control group for the experiment, representing the group with the least amount of stress. The right, dominant hand group used only their right, dominant hand to tie a figure eight and slip knot. The right/ dominant hand group was considered the first experimental group. This group requires the most amount of creativity without overstressing the creative system. The left, non-dominant hand group used only their left hand to tie a figure eight and slip knot. The left/non-dominant hand was considered as the second experimental group. This group requires the most amount of creativity while also having the highest level of stress. The participants were randomly assigned to one of the three groups. This task of knot tying was chosen based on multiple beta tests that were run on peers. Knot tying has the benefit of being a difficult task, yet attainable to complete within the given amount of time. The knot presented to the participants and the order in which they tied them were counterbalanced between participants.

The dependent variable for this experiment is creativity. This was operationalized through two different cognitive problem-solving questions. The first measure of creativity was the Dunker candle-box question (please see Figure 3). This question requires the participant to overcome functional fixedness, for example thinking of different ways to use household objects to solve the problem presented. This cognitive problem-solving question was measured in seconds it took the participant to correctly answer the question. The second cognitive problem-solving question was the Ruff Figural Fluency Task (1987). Using the Ruff Figural Fluency task requires a person to be creative while drawing as many unique figures as possible (please refer to Figure 4 or Appendix B). The participants completed both cognitive problem-solving questions to collect more data on the outcome of primed creativity. The cognitive problem-solving questions were presented in a counterbalanced manner.

Participants were excluded from the study if they were not proficient enough in English to understand the directions. Participants were also excluded from the study if they had previously seen either of the cognitive problem-solving questions before. No participants had any obvious physical injury or cognitive impairment. If injury was reveled on intake document, the researcher asked participant if that injury impaired their ability to tie knots. The same materials and environment were used to test each participant.

Materials

For this experiment, an empty room with a single chair and table was used to run the test. Before beginning the experiment, the participant filled out an Edinburgh Handedness Inventory from 1971 (See Appendix C for example). This scale uses simple questions to measure an individual's handedness. For the physical task, the experiment used two 14 inch pieces of one-fourth inch rope. For the knot tying task, there were two, eight by 22-inch printouts of the knot-tying instructions (please see Figures 1 and 2). For the dependent variable, the experiment measured creativity. Creativity is the ability to think about problems from different perspectives. For measuring creativity, I used the Duncker candle box question (Dunker, 1945). This scale forces the participant to overcome functional fixedness to answer the question presented to them correctly. The participant was given an eight by 11 print out of the candle box question (please see figure 3). The participants were also given five different eight by 11 print outs of the Ruff Figural Fluency Task (please see Appendix B) (1987). For this task, the participant was given a ballpoint pen to complete the drawings. The researcher also used a stopwatch to measure the time in seconds that it took the participant to correctly answer the Duncker candle box question (Dunker, 1945). A video recording was made to document each participant's completion of the study.

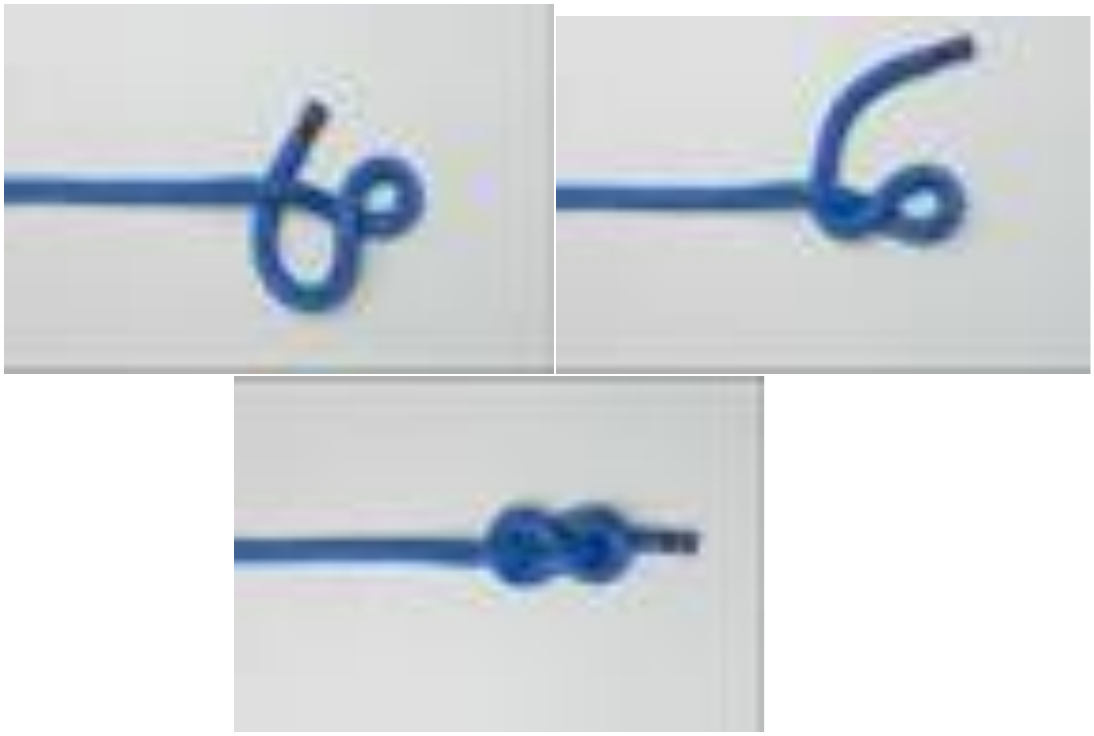


Figure 1. Figure Eight Knot

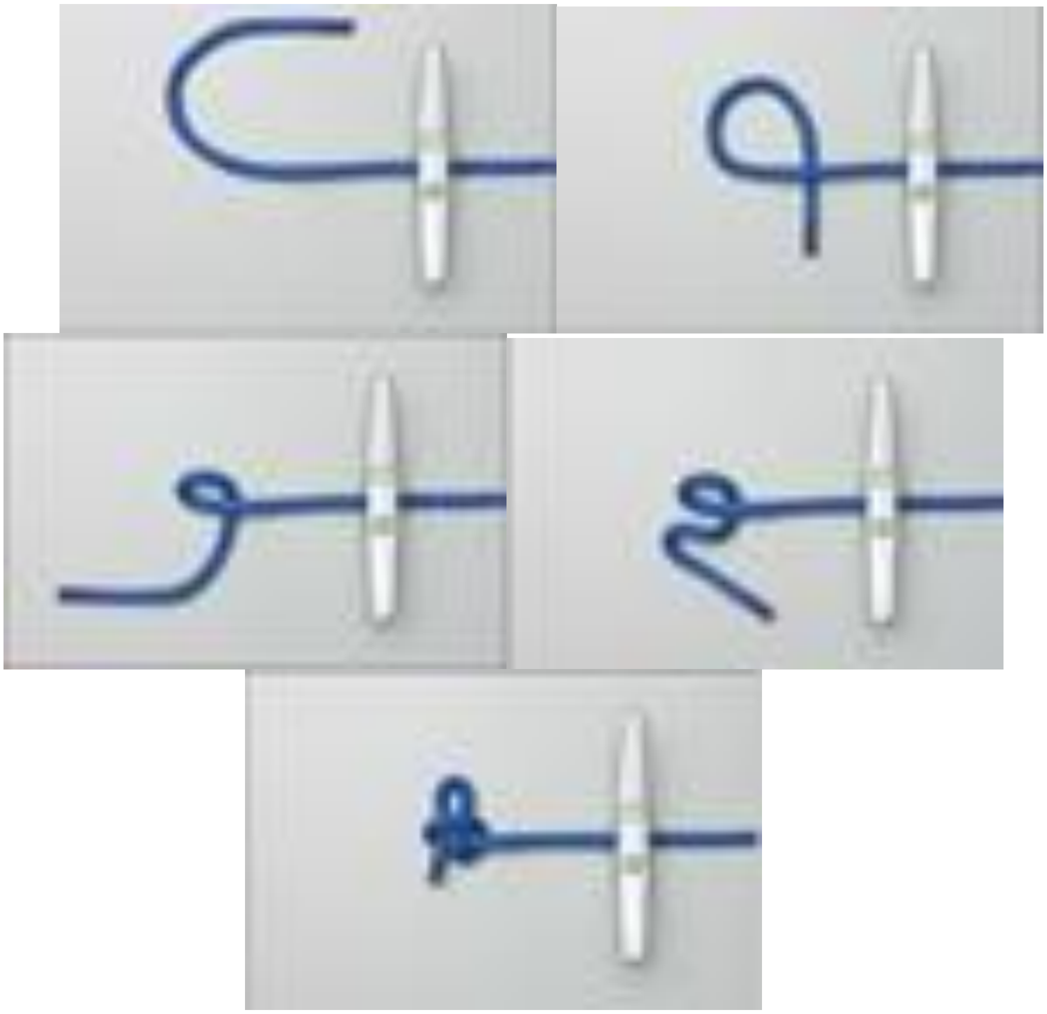


Figure 2. Slip Knot

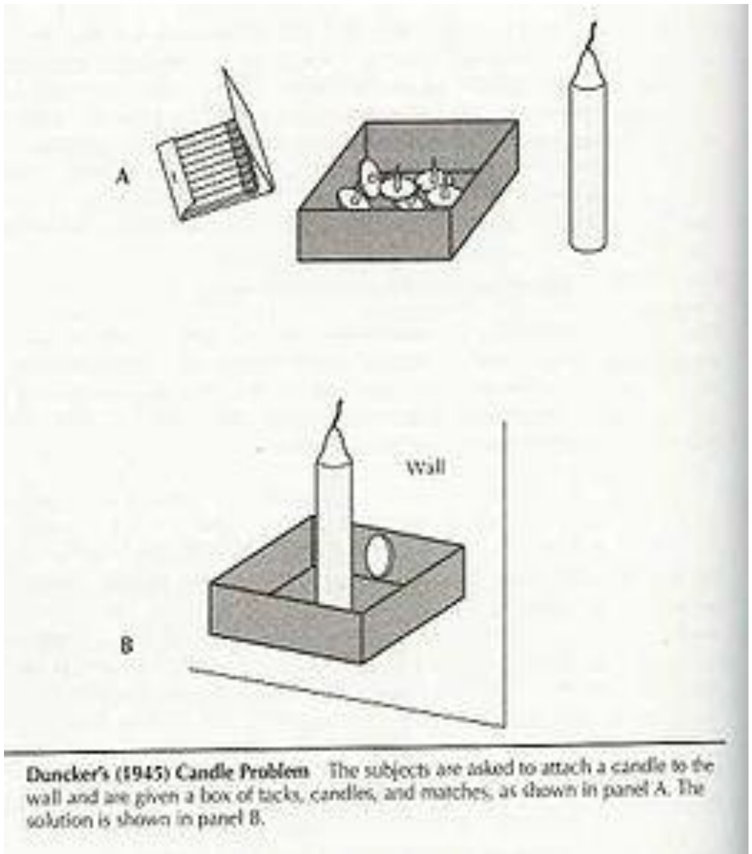


Figure 3. Duncker Candle Box Question

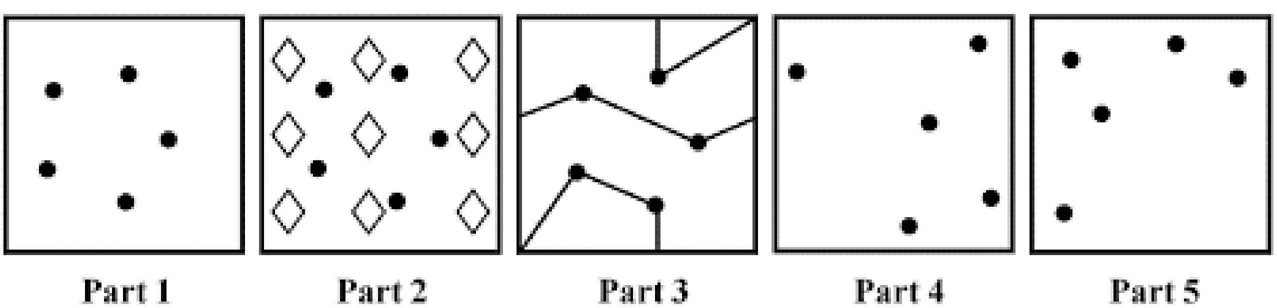


Figure 4. Ruff Figural Fluency Task

Procedure

As soon as the participant entered the laboratory setting, they were asked to review a written consent form. Once the participant gave written consent, they were asked to fill out an intake form. This intake form included basic descriptive information such as gender and age. The form also included a handedness questionnaire, specifically the Edinburgh Handedness Inventory from 1971 (See Appendix C for example). After the intake form had been completed, the participant was randomly assigned to an experimental group.

The participants were asked to tie two different types of knots. One was the figure eight knot and the second was the slip knot. Which knot is being viewed and tied first was also balanced between participants. Each participant was able to have in front of them a set of pictures (please refer to Figure 1 and 2) during the entirety of the first part of the experiment. The participants were directed:

> "For the first part of the experiment, I will need you to successfully tie both of the knots presented in front of you. A knot will be considered successful once it looks the same as the final picture in the series in front of you."

Based on which group the participant has been randomly placed into, the individuals were asked to do the physical task with either both hands, only their right hand or only their left hand. The right hand only group was asked to hold a pillow in between their left hand and their chest. The directions explicitly stated:

> "Please hold this pillow between your left arm and your chest. You will keep this pillow in this position until the first part of the experiment is complete. Please refrain from using the hand that is holding the pillow for the experiment."

The left hand only group heard similar instructions, except “your left arm” was replaced with “your right arm.” The both handed group did not hear any instructions regarding their hand use.

Once the participant believes they have successfully created both knots the researcher recorded whether or not the task had been accurately completed. The participant received no feedback on whether or not the task was completed successfully. After the physical task was completed, the participants moved on to the second half of the experiment. At this time the pillow was to be returned to the experimenter, and the participant had the ability to use both limbs as they please.

During the second half of the experiment, the participants were asked to complete two cognitive problem-solving tasks to test their ability to creatively problem solve. While the participant was sitting at the table, they were presented with the Duncker candle box question (please refer to Figure 3) (Duncker,1945) and the Ruff Figural Fluency Task(1987). Each of these tasks was evenly presented first and second to the participants. For the candle box task the participants received the following instructions before answering the question:

> “Could you please describe to me a way in which you would be able to affix and light this candle on a wall? Please make sure the candle is affixed in a way so the candle wax will not drip onto the table below. To do so you must only use the following items shown in the picture: the box of matches, the box of thumbtacks and a candle.”

The participants were then timed by a stopwatch by the researcher. The time in second in which it took the participant to answer the question sucessfully was recorded. A video camera was used to ensure the researcher had timed the participant’s answer accurately. The instructions for the Ruff Figural Fluency Task was presented as follows:

> “You will be presented with a sheet consisting of 35 squares. Inside each square are five dots, each arranged in a different pattern. In each trial, you will have 60 seconds to draw as many unique figures as possible using these five dots. You will complete five 60 second long trials. Do not worry about drawing similar figures from one sheet to the next. The dots will be arranged so that it will be very difficult to draw the identical figure twice.”

Once one sheet was completed, the researcher removed that sheet from the table and was given the next sheet. The participant was prompted not to start drawing until the investigator said: “go.”

It is important to note that the investigator was also behind the participant at all times. This was important to limit the feedback given to the participant from the investigator. The participant and the investigator were the only individuals in the room. This limited the verbal and nonverbal feedback that was transmitted from the investigator to the participant. Please see Appendix A for full instructions.

Chapter 3 Results

The results were measured using SPSS Statistics Software to complete an analysis of variance (ANOVA). Results of the ANOVA revealed non-significant results, indicating that statistically significant differences were not detected in the measures of problem-solving tasks. There are no significant differences in the number of creative solutions for cognitive tasks between the groups who tied both hands compared to those who tied with one hand. The non-significant differences could be due to small sample size. To further investigate this, effect sizes were computed using the means and standard deviations to determine if meaningful differences existed between the groups.

Table 1. ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Total_Ruff_Sum	Between Groups	447.389	2	223.694	.358	.702
	Within Groups	20618.167	33	624.793		
	Total	21065.556	35			
how long did it take to answer question	Between Groups	13012.056	2	6506.028	.416	.663
	Within Groups	515594.250	33	15624.068		
	Total	528606.306	35			

In Table 2-4, the means and standard deviations were calculated and compared for the seconds it took participants to answer the Duncker candle-box question accurately. The both, or both hands, control group (M= 145.9167, SD= 139.2424), the right, or right hand only, dominant, experimental group (M=102.333, SD=101.1914) and the left, left hand, non-dominant, experimental group (M=138.3333, SD=131.3166) were all compared. In order to determine if there were meaningful differences between means and standard deviations, the Cohen's d was computed. For the both hand, control group to Right hand mean comparison (Cohen's d= 0.3581) showing a small effect. The both hand to the left-hand comparison (Cohen's d= 0.0560) showed trivial effect. The left to right hand comparison (Cohen's d= 0.3071) also showed a small effect.

Table 2. Group Statistics Both v Right Duncker

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
how long did it take to answer question	both	12	145.9167	139.2424	40.19582
	righ hand	12	102.3333	101.1914	29.21144

Table 3. Group Statistics Left v Right Duncker

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
how long did it take to answer question	left hand	12	138.3333	131.3166	37.90785
	righ hand	12	102.3333	101.1914	29.21144

Table 4. Group Statistics Left v Both Duncker

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
how long did it take to answer question	left hand	12	138.3333	131.3166	37.90785
	both	12	145.9167	139.2424	40.19582

In Table 5 and 6, the means and standard deviations were calculated and compared to the number of unique figures drawn during Ruff Figural Fluency Test. The both, or both hands, control group (M= 52.5000, SD= 15.45962), the right, or right hand only, dominant, experimental group (M=60.7500, SD=25.40267) and the left, left hand, non-dominant, experimental group (M=54.4167, SD=15.45926) were all compared. In order to determine if there were meaningful differences between means and standard deviations, the Cohen's d was computed. For the both hand, control group to Right hand mean comparison (Cohen's d= 0.324769) showing a small effect. The both hand to the left-hand comparison (Cohen's d= 0.091153) showed trivial effect. The left to right hand comparison (Cohen's d= 0.301196) also showed a small effect.

Table 5. Group Statistics Right v Both Ruff Figural Fluency

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
Total_Ruff_Sum	righ hand	12	60.7500	25.40267	7.33312
	both	12	52.5000	15.45962	4.46281

Table 6. Group Statistics Left v Both Ruff Figural Fluency

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
Total_Ruff_Sum	left hand	12	54.4167	31.46559	9.08333
	both	12	52.5000	15.45962	4.46281

Table 7. Group Statistics Left v Right Ruff Figural Fluency

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
Total_Ruff_Sum	left hand	12	54.4167	31.46559	9.08333
	righ hand	12	60.7500	25.40267	7.33312

Chapter 4 Discussion

This study aimed to find a relationship between creativity in motor planning and creativity in cognition. The hypothesis researched looked at the following: It was hypothesized that if an individual used one hand during a knot tying task that individual would be better prepared to solve two types of cognitive problem-solving questions, the Duncker candle-box question, and the Ruff Figural Fluency Test. Specifically, when an individual uses their right, dominant hand for a knot tying task, they will be primed with a creative motor planning task that provides a moderate level of stress to the creative system. This provides the particiapnt to be best primed to answer a cognitive problem-solving question, compared to a control group who used both hands. The left hand or non-dominate group will not be as well primed as the right-handed group because of the higher level of stress this motor task requires on the creative system.

Overall the results were not consistent with the hypothesis, and there was no significant relationship between creativity in motor planning and cognition. According to the statistical analysis, this study failed to find any significant data supporting the hypothesis that tying a knot with one hand helps individuals become more successful problem solvers. Although, it is important to point out the small effects seen within the mean comparisons.

Within the Duncker candle-box question, two small effects were seen based on Cohen's d. One small effect was observed in mean seconds for the right hand only group (M=102.333, SD=101.1914) which was slightly less compared to the both hand group (M= 145.9167, SD= 139.2424) in answering the Duncker candle-box question. This comparison showed a small effect size (Cohen's d= 0.3581). Meaning that some people in the right hand only group were able to answer the Duncker candle-box question faster than the both hand group. Also, for the Duncker candle-box measure, the right hand only group (M=102.333, SD=101.1914) had a slightly lower mean than the left-hand group (M=138.3333, SD=131.3166). This comparison showed a small effect size (Cohen's d= 0.3071). This shows that the participants who used only their right, dominant hand to tie knots were able to answer the Duncker candle-box question faster than the participants who used only their left, non-dominant hand.

Two small effects were also seen in the Ruff Figural Fluency Test. The first small effect was seen in the mean of unique figures drawn for participants who used only their right, dominant hand (M=60.7500, SD=25.40267) compared to participants who used both hands (M= 52.5000, SD= 15.45962). This comparison showed a small effect size (Cohen's d= 0.324769). This means, on average, the participants who used their right hand only to tie knots were able to draw more unique figures than the participants who used both hands to tie the knots. The second small effect was seen in the mean of unique figures drawn for participants who used only their right, dominant hand (M=60.7500, SD=25.40267) to tie knots compared to participants who only used their left, non-dominant hand (M=54.4167, SD=15.45926) to tie knots. This comparison showed a small effect size (Cohen's d= 0.301196). On average, the participants who used only their right hand to tie knots were able to draw more unique figures using the given dots than the participants who used only their left hand to tie knots.

Although there were no significant differences found, the small effects seen within the data show that the predicted hypothesis may be pointing in the right direction. Within both measures of creativity, the Dunker candle-box question and the Ruff Figural Fluency Test, the participants who used only one hand to tie the knots were on average able to better answer the cognitive problem-solving questions. Though, the participants who used only their right, dominant hand to tie the knots were most successful at answering both measures of creativity. These small effects show that it might be possible to show that creative motor planning may, prime individuals to answer cognitive problem-solving questions more efficiently.

Limitations and Future Directions

After reviewing the study and data, there were many critical flaws within the study. These flaws were likely to have led to the insignificant findings. One major problem with this study lies in the lack of participants in each group, being that there were only 12 participants in each group. With 12 people in each group, the total participant count is only 36. The lack of participants in this study is likely one of the primary reasons that none of the statistical analysis resulted in significant findings. If it were the case that I ran this exact experiment again with more participants, I would likely double the size of each group. Therefore, the study would be run with 24 participants in each group making the total number of participants 72.

With more participants in the study design, I would predict to find more statistical significance between the test groups. The differences I would expect could suggest that the individual using their right, dominant, hand for the physical tasks will have to implement the most creativity without a overworking the creative system. This allows them to be best primed to answer the cognitive problem-solving task. Similarly, the individuals who use their non-dominant, or left hand only will be overworking their creative system during the first task, making answering the cognitive problem-solving question more difficult.

If this replica study were successful, the next step of the research would be to include another measure of creativity by running a constructive replication. For example, I would use something like the building a large scale Lego structure. This would be another way to replicate physical creativity with more gross motor properties. I would also consider using “The Green Eggs and Ham Hypothesis” to provide another definition of creativity. This particular study measured creativity by having individuals make up creative greeting cards, where the uniqueness of the phrase created inside the card is measured (Haught-Tromp, 2016). Using these different measures of the creativity would allow me to make a stronger claim that there is possibly a priming effect in creative motor planning and creative cognition.

This experiment has taken some precautions to avoid issues with validity. Though, it is also possible that the research may naturally have problems in construct validity, specifically with researcher expectations. Even with a written script for the direction, the researcher may be unintentionally encouraging or discouraging to the participant, making them better or worse at solving the Duncker candle-box question (Dunker, 1945). This flaw could have been seen in the tone of voice of the researcher when talking to the participants or even the quickness at which the researcher read the instructions. In the future, this could be addressed by making the experiment a double-blind study. In this case, both the researcher testing the participants and the participants would not know the actual hypothesis of the experiment. Removing the experimenter from the room as a whole could also present a solution for this issue of validity. In the case of replacing the researcher's voice with a computer, a participant would only hear the prerecorded voice, making the tone of voice and speed the same for all participants. This issue in construct validity could also lead to a problem with internal validity and observer bias. Because the answer to the Duncker candle-box question is free formed, the experimenter might be more likely to mark a correct answer, when in fact, it is not entirely accurate. To address this bias, numerous researchers could code the video data to ensure that the appropriate answer the Duncker candle box question was given (Dunker, 1945).

This experiment also poses issues with design confounds. According to the “Green Eggs and Ham Hypothesis,” creativity can be evoked through constraints (Haught-Tromp, 2016). So, the natural constraints or stress that an experiment could put on an individual could make them more creative, regardless of the fact that the participant was engaged in creative motor planning. This could be addressed by creating a follow-up study that put more stress on the participants. This pressure could be added by making the participants aware of time restraints. If it were the case that this experiment showed faster times to answer the Duncker candle box question, one could make the assumption that stress of the experiment might be the reason the participants are more creative. Alternatively, if this confounding variable were correct, and the hypothesis about overworking the creative system were not true, the left hand only group would complete the Duncker candle box question the quickest (Dunker, 1945).

This study aims to be generalizable to all people. It is possible that because the participant pool selected from college students that the data might change if the study were run for different demographics. Though, this study is trying to understand an underlying connection between cognition and action. This is a link that has been found to be prevalent in different populations. The possibility that this is a mechanism of the human brain should make this study generalizable. Though it is possible that depending on an individual's level of cognition or motor planning abilities the results could change. My prediction would be that the data would not show statistically different times between the groups. For example, a group of younger college aged students might have faster times answering the problem-solving questions compared to a group of older adults. Although, it might still be possible that older adults could also see the benefit of physical problem solving on intellectual problem-solving.

Practical Implications

Learning more about how the body and the brain interact with one another provides implications in many realms. If future studies were to show that there is a relationship between creativity in motor planning and creativity in cognitive problem solving, the research many have substantial implications both on embodied cognition research and the disability world, especially rehabilitative therapies like occupational and physical therapy.

If it is the case that creativity can be primed between action and cognition, there could be a claim to say that practicing either creative cognitions or creative motor planning could prepare you for future injury. For example, if someone who is regularly engaging in creative cognitive problem solving acquires a physical disability, they will be able to better cope with that disability because they will understand how to maneuver their environment the most creatively. There also might be room to claim that individuals who suffer in either an area of cognition or motor planning should participate in activities opposite to their disability. For example, if a child was diagnosed with a speech disorder, it might benefit that child to also engage in challenging motor planning tasks. These challenging motor planning tasks could include things like play therapy using puzzles.

This experiment also might lead to other interesting experiments, specifically having to do with handedness and creativity. For example, there might be a reason to say that individuals who are left-handed may have to maneuver their environments more creativity because most instruments or things to complete daily living tasks are made for right-handed people. Therefore, because individuals who are left handed are having to constantly creatively problem solve around their physical environment, they will tend to be more creative people in general. These left-handed people may be more likely to play music, paint or problem solve because they have significantly more practice being creative

Embodied cognition research also helps to inform robotics programming heavily. When psychological researchers can dig into the underlying functional manual of the brain, robotics programmers can create coded rules that represent the rules in the human brain. Understanding these deeply complex functions of the brain helps inform these coded robots to perform their tasks with more ease.

Overall, having a better understanding of creativity could prove to have more application than once originally thought. Not only could this experiment have implications for future rehabilitation processes, but it might also have a place in everyday life. Individuals may benefit in many ways by practicing both physical and cognitive creativity.

Appendix A

Problem Solving Instructions

February 1, 2016

Today you will be participating in a two-part study about problem-solving.

Part 1 Instructions:

1. Please have a seat at the table in front of you and center yourself between the two sets of pictures placed on top of the table.
2. {Odd participants1,5,9 } Each set of pictures on the table in front of you, one to the left and the other to the right, corresponds to a style of knot that you will be asked to attempt to tie. The pictures on the left correspond to the first knot that you will attempt to tie, which is called a figure-eight knot. The pictures on the right correspond to the second knot you will attempt to tie, which is called a slip knot.
3. {Even participants1,6,10} Each set of pictures on the table in front of you, one to the left and the other to the right, corresponds to a style of knot that you will be asked to attempt to tie. The pictures on the left correspond to the first knot that you will attempt to tie, which is called a slip knot. The pictures on the right correspond to the second knot you will attempt to tie, which is called a figure-eight knot.
4. {Odd participants3,7,11} Each set of pictures on the table in front of you, one to the right and the other to the left, corresponds to a style of knot that you will be asked to attempt to tie. The pictures on the right correspond to the second knot you will attempt to tie, which is called a slip knot. The pictures on the left correspond to the first knot that you will attempt to tie, which is called a figure-eight knot.
5. {Even participants4,8, 12} Each set of pictures on the table in front of you, one to the right and the other to the left, corresponds to a style of knot that you will be asked to attempt to tie. The pictures on the right correspond to the second knot you will attempt to tie, which is called a figure-eight knot. The pictures on the left correspond to the first knot that you will attempt to tie, which is called a slip knot.
6. Your goal in the first part of the experiment will be to try your best to tie each of these knots, one at a time. You may refer back to the pictures as often as necessary to guide you through the steps to tie either knot.
7. Please note that a knot will be considered to be successfully tied once it looks identical to the final image of the set of pictures corresponding to that knot.
8. Please also note that you should not move on to the second knot until you feel that you have successfully tied the first knot, as indicated by the final image of the picture sequence placed in front of you.
9. **For Right hand only**: I do want to add one thing that I didn't say before. That is that before you begin tying the knots shown in the sets of pictures on the table, I would like you to hold this pillow firmly between your left arm and your chest. Please keep the pillow between your left arm and your chest for the remainder of this portion of the experiment. Though you may be tempted, please refrain from using the hand that is holding the pillow for the experiment.
10. **For left hand only:** I do want to add one thing that I didn't say before. That is that before you begin tying the knots shown in the sets of pictures on the table, I would like you to

hold this pillow firmly between your right arm and your chest. Please keep the pillow between your right arm and your chest for the remainder of this portion of the experiment. Though you may be tempted, please refrain from using the hand that is holding the pillow for the experiment.

11. Once you feel you have successfully tied both knots please let the experimenter know and they will check that both of the knots look identical to the final image shown on the set of pictures.
12. Could you please explain to me in your own words what you will be doing in this part of the experiment?

{Done with part one.}

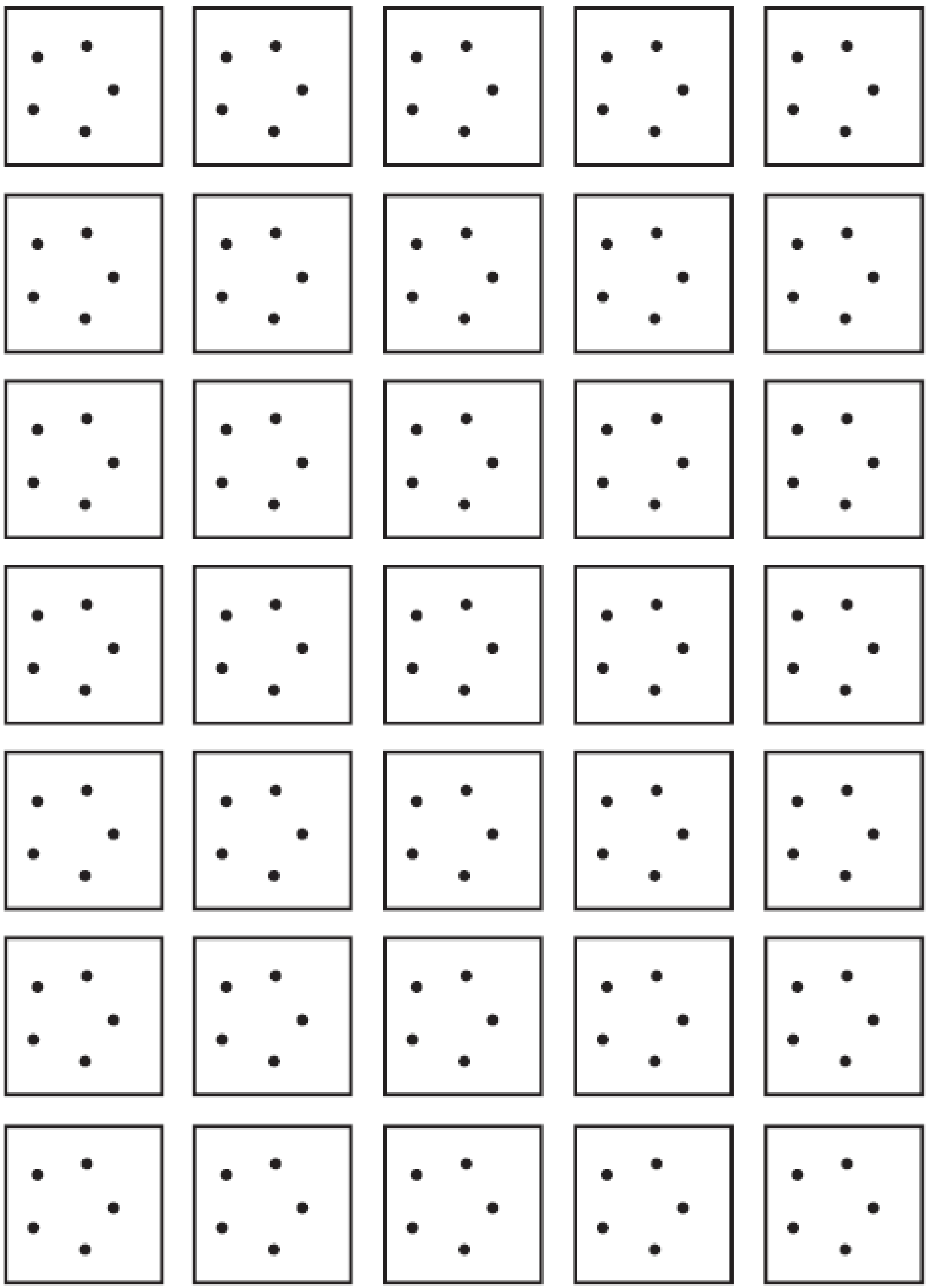
Part 2:1 Instructions:

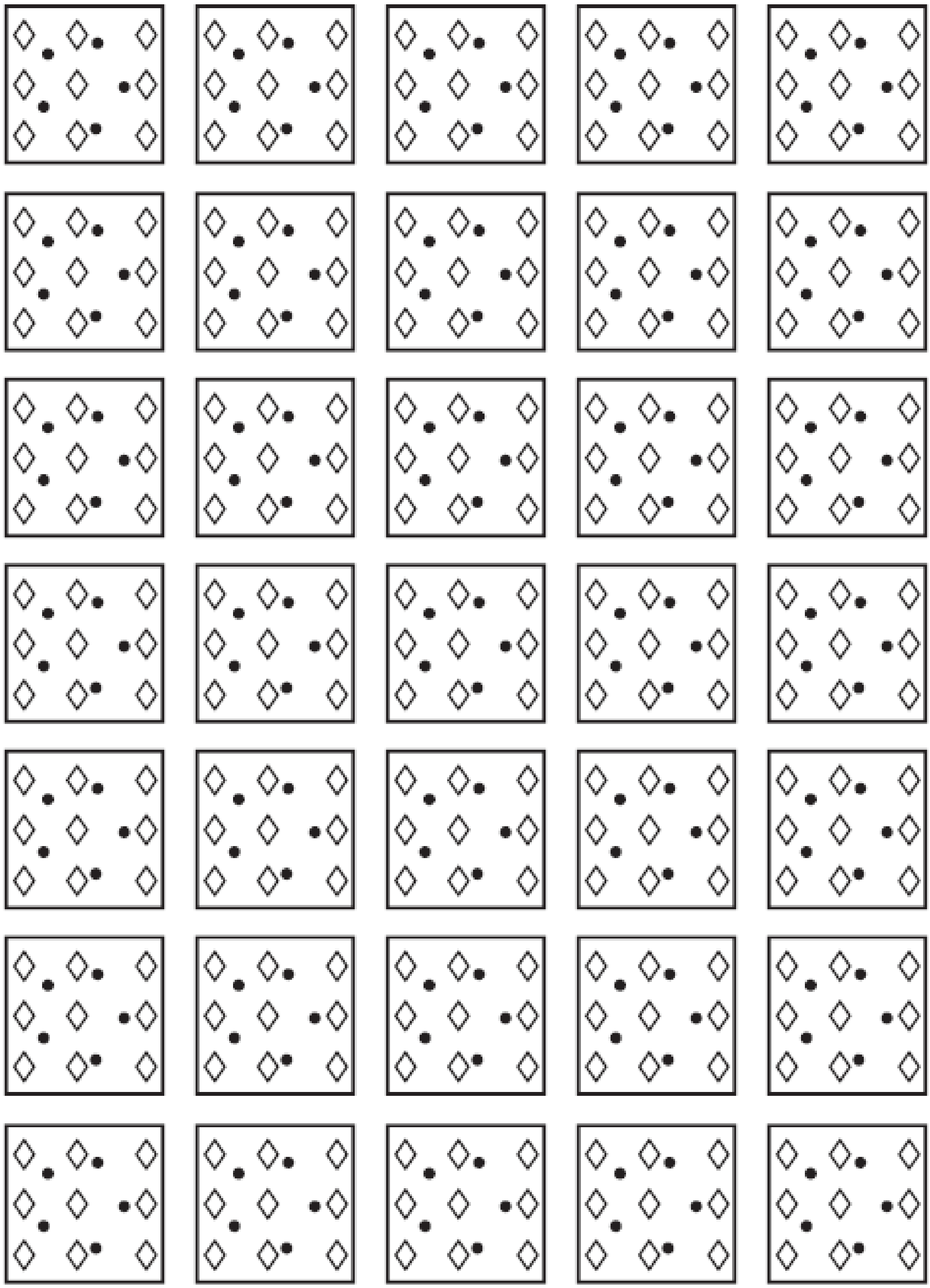
1. For the second part of this experiment, you will be asked to complete two cognitive problem-solving questions.
2. For the first task, please look at the picture presented in front of you.
3. Could you please describe to me a way in which you would be able to attach this candle to a wall and light it? Please make sure the candle is attached in a way so the candle wax will not drip down onto the table below. You must only use the items shown in the picture: the box of matches, the box of thumbtacks, and the candle.
4. You will have five minutes to complete this section. Once you have your answer please clearly describe your answer to the experimenter. If you answer the question incorrectly, you will have another chance to answer the question, as long as you are within the 6-minute time limit if you answer the question incorrectly, the experimenter will say, “Please try again.” If you answer the question correctly, you will move forward to the next task. Alternatively, if you are not able to answer the question correctly, you will move forward to the next task only after the 6-minute time limit has elapsed.

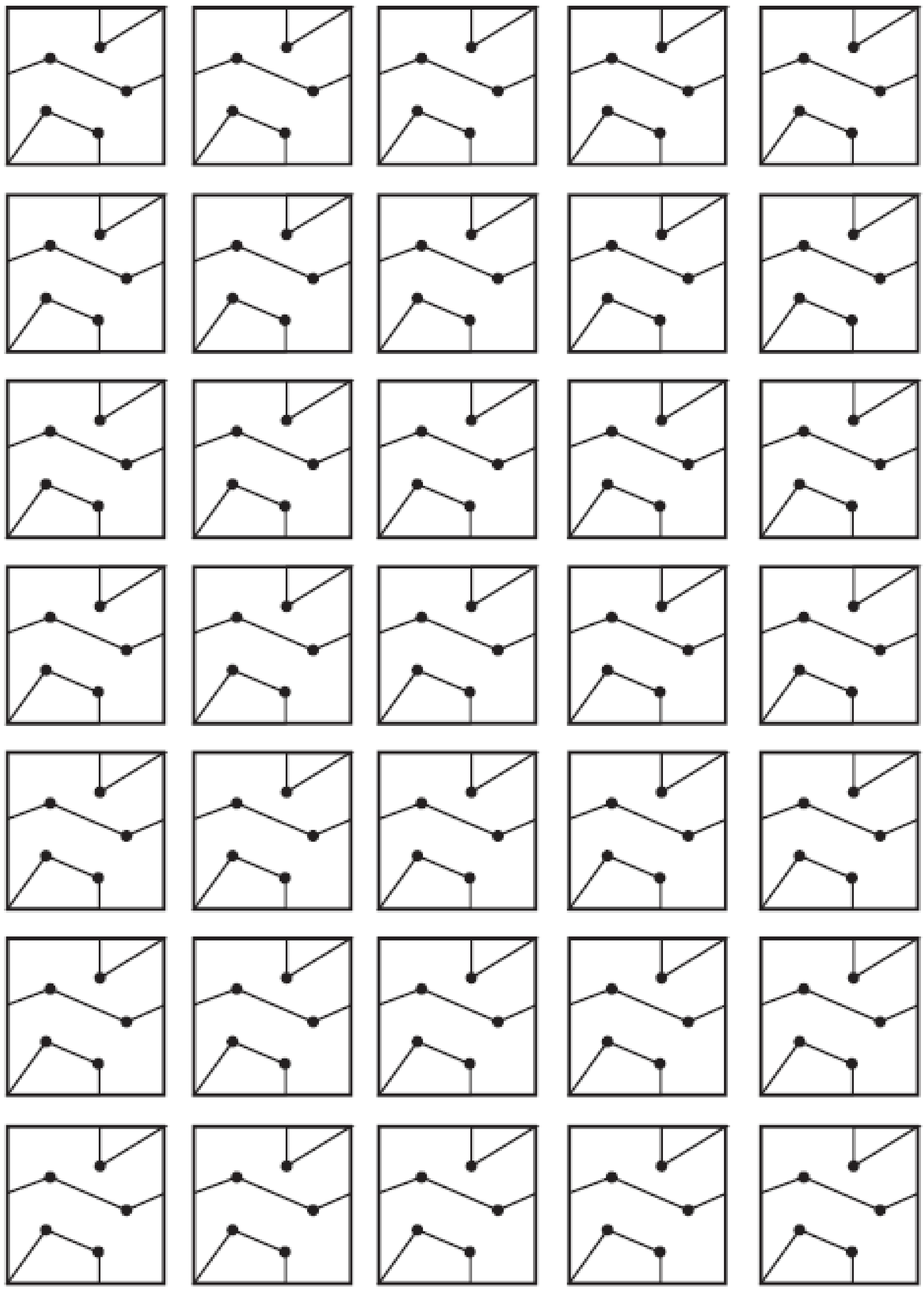
Part 2:2 Instructions:

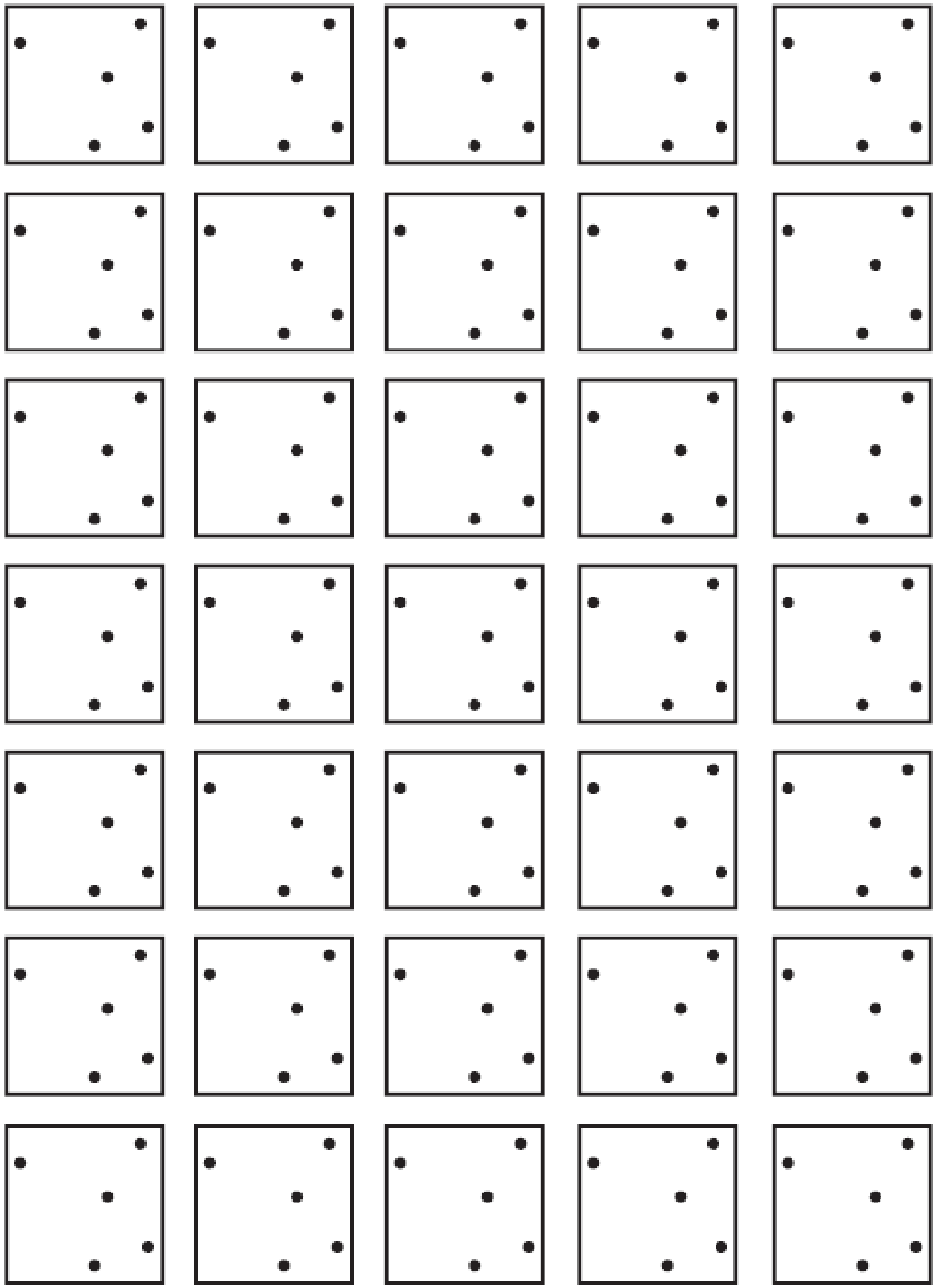
1. For the next problem-solving task, I will ask you to draw some pictures.
2. You will be presented with a sheet consisting of 35 squares. Inside each square are five dots, each arranged in a different pattern. In each trial, you will have 60 seconds to draw as many unique figures as possible using these five dots. You will complete five 60 second long trials. Do not worry about drawing similar figures from one sheet to the next. The dots will be arranged so that it will be very difficult to draw the identical figure twice.
3. Once you have completed a sheet the experimenter will remove that sheet from the table. The experimenter will then give you the next sheet. When the experimenter says “go,” you may begin drawing figures on the next sheet. This will be repeated until you complete all 5 sheets.

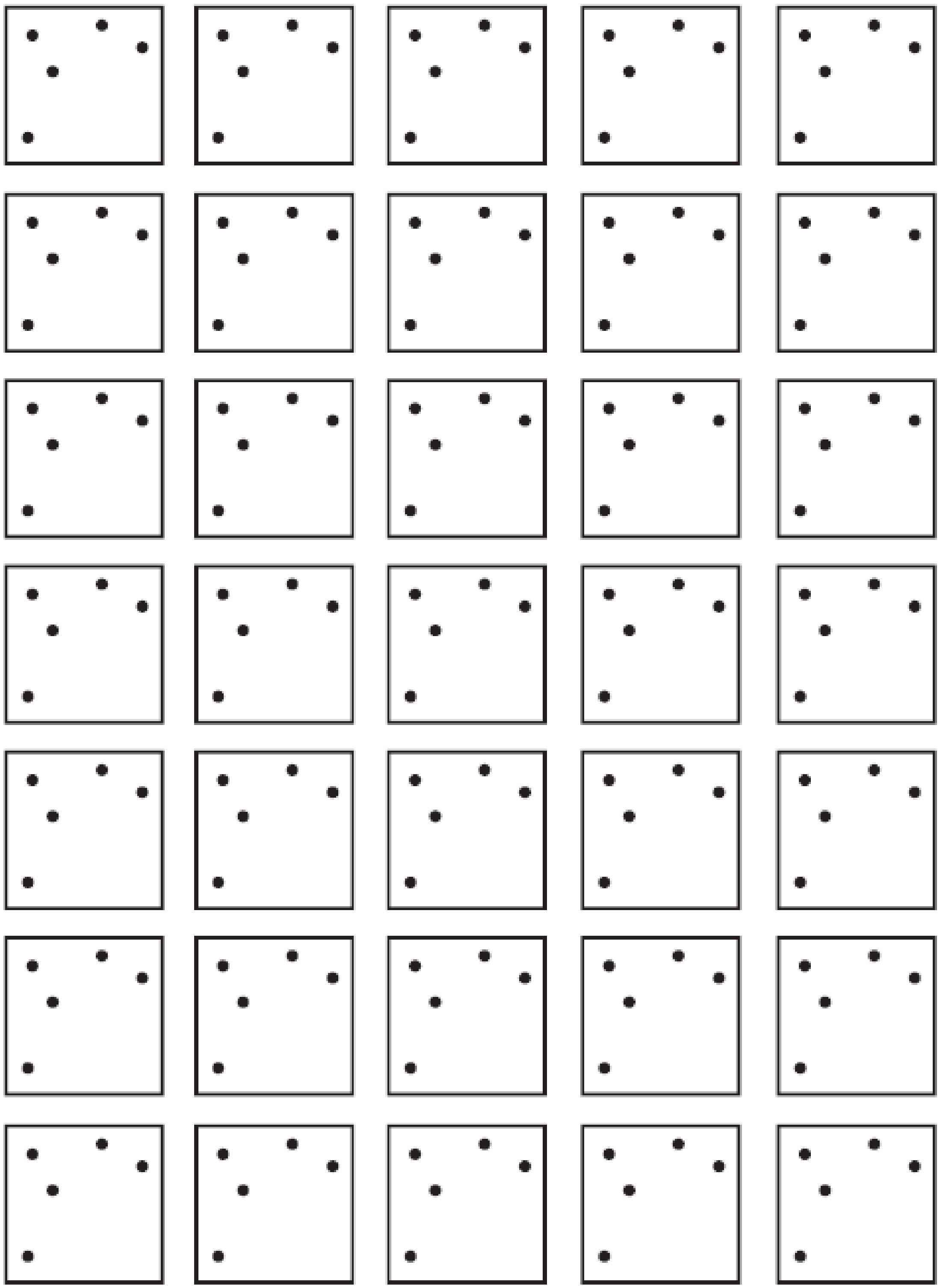
Appendix B
Ruff Figural Fluency Pages











Appendix C

Edinburgh Handedness Inventory

EDINBURGH HANDEDNESS INVENTORY

Surname.. Given Names...

Date of Birth... Sex..........................

Please indicate your preferences in the use of hands in the following activities *by putting + in the appropriate column*. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, *put ++*. If in any case you are really indifferent *put + in both columns*.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

		LEFT	RIGHT
1	Writing		
2	Drawing		
3	Throwing		
4	Scissors		
5	Toothbrush		
6	Knife (without fork)		
7	Spoon		
8	Broom (upper hand)		
9	Striking Match (match)		
10	Opening box (lid)		
i	Which foot do you prefer to kick with?		
ii	Which eye do you use when using only one?		

L.Q.		Leave these spaces blank	DECILE	

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ACADEMIC VITA

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Education
Major(s) and Minor(s): Rehabilitation and Human Services with minors in Psychology and Disability Studies
Honors: Rehabilitation and Human Services

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Research Experience

January 2016- Present
Research Assistant
Worked with graduate students to conduct neurofeedback studies. Learned simple EEG capping techniques.
The Pennsylvania State University
Dr. Carlos Zalaquett

August 2014- May 2016
Research Assistant
Worked with graduate and undergraduate students to create, conduct and analyze studies focusing on physical action.
The Pennsylvania State University
Dr. David Rosenbaum

Work Experience

January 9th, 2017- June 1st, 2017
Administrative Assistant
Worked alongside classroom teacher at Central Counties Youth Center, juvenile delinquency facility. Responsible for contacting children's home school districts in order to complete intake and discharge paperwork. Assisted in classroom instruction. Provided one on one instruction with children if needed.
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Judy Koch

Summer 2014, 2015, 2016
Therapeutic Instructor

Worked with participants aged 7-21 with various physical and intellectual disabilities, implemented impromptu discussions and lessons about public safety and other important life skills in community-based environments. Trained in CPR, first aid, lifts and transfers, signs and symptoms of illness and non-violent intervention
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January 2016- January 2017
Substitute Teacher for Adult Education at Skills of Central PA
Worked with adults with physical and intellectual disabilities, teaching reading, writing, math and life-skills.
Central Intermediate Unit #10
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Patricia Roeber

Presentations:

Psi Chi Undergraduate Research Conference 2016
Presented theoretical research poster on the predicted effects of physical activity on cognitive creativity.

Psi Chi Undergraduate Research Conference 2015
Presented empirical research poster on the effects of metacognition on physical action.

Community Service Involvement:

August 2016 – May 2017
The Pennsylvania State University Equestrian Team Thon Co-Chair
Worked with a counterpart to implement fundraising efforts for the Pennsylvania State University's Dance Marathon benefitting children with pediatric cancer.

December 2015 - Present
Out of the Cold Emergency Winter Shelter, State College, PA
Volunteered as overnight support for a community-based shelter assisting people who are homeless and precariously housed.

October 2015 - Present
Jana Marie Foundation Wellness Forum, State College, PA
Volunteered at the creative expression instructor at a wellness forum for girls in grades 6-8, working towards building personal strength and self-confidence in order to help combat stress.

International Education:

March 2015
Public Health Brigade to Honduras
Volunteered in a program in Buena Vista, Honduras to complete projects to help prevent infections disease. Taught local children about healthy living habits.