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The University of Toledo

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The Influence of Action Observation on Motor Learning for Assistive Device Use in Adults with Arthritis

Alexis N. Misko

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May 2012

This scholarly project reflects individualized, original research conducted in partial fulfillment of the requirements for the Occupational Therapy Doctorate Program, The University of Toledo.
Abstract

OBJECTIVE: This study implemented action observation during a fine motor task with a novel tool to determine whether motor performance improved as a result.

METHOD: The study employed a 2x2 design of two independent variables (action observation and occupational embedment, the former of which is emphasized in this report), with 26 participants with arthritis of the hand. The uses of a novel tool and a challenging task were selected to maximize the potential for observing motor learning. In the action observation condition (AO), participants observed video demonstration, while in the control condition (V), only verbal instructions were given. In the occupationally embedded (OE) condition, participants used the tool to pick up tablets of aspirin and sort them into a weekly pill organizer. In the control, rote condition (R), participants used the tool to pick up pieces of a dowel rod and sort them into a multi-well chamber. To assess whether participants demonstrated motor learning, means across the four conditions (AO/OE, AO/R, V/OE, V/R) mean movement time, displacement, and movement units were compared.

RESULTS: Across conditions, motor performance improved from trial 1 to 10. For the independent variable of action observation, no significant differences were found in motor learning ratios for action observation and verbal conditions. However, results were significant for the variables of velocity and movement units in a manner that suggested that combination of the two teaching methods (action observation and occupational embedment) offers greater advantage than using either one alone.

CONCLUSIONS: To enhance motor learning, rehabilitative tasks such as teaching use of assistive devices can be designed to include both visual demonstration and an occupationally embedded environment.
Introduction

Mirror Neuron System

The mirror neuron system provides a method for the human brain to comprehend the actions of others through observation (Iacoboni & Mazziotta, 2007). When an individual observes an action, neurons corresponding to that action are activated in premotor areas of his or her brain, producing an automatic coding response which help to form an understanding of the action without direct participation (Rizzolatti & Craighero, 2004). First discovered in macaque monkeys (Rizzolatti, Scandolara, Matelli, & Gentilucci, 1981), the mirror neuron system also responds to goal-specific contexts (Elk, Schie, & Bekkering, 2008) and tool use (Iacoboni & Mazziotta, 2007). Because current evidence suggests that the mirror neuron system facilitates neural activity and improved motor performance as a result of observation, occupational therapists might be able to utilize this system to enhance patient rehabilitation (Ertelt, et al., 2007; Mulder, 2007; Ocampo & Kritikos, 2009; Porro, Facchin, Fusi, Dri, & Fadiga, 2007).

The Mirror Neuron System in Monkeys

Stemming from initial research regarding neural activation in the macaque monkey based on visual cues (Rizzolatti, et al., 1981), the mirror neuron system was first discovered through serendipity. In a series of experiments, monkeys reached for and grasped food, bringing it to the mouth. Researchers recorded activity of neurons firing in area F5, the ventral premotor cortex of the macaque brain. Surprisingly, the same neurons fired when monkeys observed researchers performing an action (not part of the original experiment) as did when monkeys themselves performed the action (Rizzolatti, et al., 1988). Ongoing research continues to illustrate deployment of motor neurons in monkeys as a response to mere observation of action, as well as due to comprehension of goals and meaning (Ferrari, Gallese, Rizzolatti, & Fogassi, 2003).
The Mirror Neuron System in Humans

Fadiga, Fogassi, Pavesi, and Rizzolatti (1995) built upon foundational knowledge of the mirror neuron system in monkeys by conducting a transcranial magnetic stimulation study in humans. Motor evoked potentials (MEPs) of the hand muscles were measured in participants as they observed the grasping of objects and the tracing of geometric shapes in air. Increased MEPs were noted when participants observed actions; patterns of muscle contractions were close to those that would occur during actual performance of the same actions, suggesting a neural system responsible for action, observation, and execution.

Subsequent studies have confirmed a role for the mirror neuron system in motor learning, as demonstrated by functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG) during observation followed by motor action (Binkofski & Buccino, 2006; Buccino, Binkofski, & Riggio, 2004; Buccino & Riggio, 2006; Rizzolatti, 2005). During action-observation, the mirror neuron system codes for intentions and goals, as evidenced by numerous studies (Elk, et al., 2008; Gallese, 2009; Iacoboni, et al., 2005; Koski, et al., 2002; Lange, Spronk, Willems, Toni, & Bekkering, 2008). Findings suggest that when participants observe an action, the mirror neuron system responds to the perceived goal of the action, as well as to the motor functions required to complete it (Cattaneo, Caruana, Jezzini, & Rizzolatti, 2009).

Additional studies have also revealed the mirror neuron system’s potential role in coding for other behaviors, including communication (Montgomery & Haxby, 2008) and empathy (Schulte-Ruther, Markowitsch, Fink, & Piefke, 2007). The mirror neuron system responds to auditory cues as well as visual (Keysers, et al., 2003), and can be influenced by cognitive activity (Muthukumaraswamy & Singh, 2008).

Because human mirror neurons cannot be individually recorded in the way that macaque
monkey neurons can, there are conflicting views as to where the mirror neuron system is located in the human brain (Dinstein, 2008). According to Molenberghs, Cunnington, and Mattingley (2009), it is commonly believed that Brodmann area 44, the pars opercularis of the posterior inferior frontal gyrus, is the equivalent of macaque area F5 in the human brain. However, through a quantitative meta-analysis, Molenberghs and colleagues (2009) reveal that the superior and inferior parietal lobules and the dorsal premotor cortex of the frontal lobe are most consistently cited in fMRI studies as housing the human mirror neuron system.

**The Role of Tools.**

Though it was previously thought that the mirror neuron system only activated due to biological stimuli (Binkofski & Buccino, 2006; Mulder, 2007), the use of tools also causes neural responses (Iacoboni & Mazziotta, 2007; Rizzolatti & Craighero, 2004). Studies show that the same areas of the brain are activated during observation of tool use as during observation of hand motion (Peeters, et al., 2009), and improved performance can also result from observation of operation of tools (Massen, 2009). Because occupational performance frequently involves tools, it is necessary that the mirror neuron system respond to non-biological cues. In working with individuals with physical disabilities, occupational therapists often introduce the use of assistive devices, specialized tools that can be used to compensate for physical limitations in accomplishing everyday tasks.

**Assistive Devices and Action Observation.**

Because rehabilitation seeks to improve motor performance, learning correct use of assistive devices is crucial to a beneficial outcome. Occupational therapists have a strong role in educating patients about proper assistive device use, and demonstration is often a key component to their instruction. For example, Schemm and Gitlin (1998) established that demonstration of
devices by occupational therapists for bathing and dressing resulted in adequate understanding and retention by patients. In the same study, some demonstrations were videotaped so that patients could replay them at home. Additionally, research suggests that education about assistive devices is retained more easily when the task is broken down into parts, allowing patients to experience an occupation within a realistic context (Gitlin & Burgh, 1995). The success of these methods suggests a role for the mirror neuron system in learning the use of a novel assistive device through action observation in a naturalistic context.

**Implications for Occupational Therapy.**

Though little research exists concerning the role of the mirror neuron system in the outcomes of occupational therapy, possible benefits can be inferred. Two studies demonstrated performance increases through action observation. Ocampo and Kritikos (2009) found that participant abilities to use the appropriate hand grasp to handle meaningful objects were faster after observation. Participants were shown video clips of hands grasping wine glasses, with either power or precision grasp patterns. They were then given their own wine glasses, with instructions to grasp in either the same or an opposite way than shown in the video clip, allowing the experiment to test the effect of context (i.e. the picture they were shown) on the production of motor actions (their own grasping action). Results showed that carrying out motor actions similar to those of a model improved timing, specifically when participants grasped the wine glass in the same way as shown in the video clip. These results could indicate that action observation can affect how individuals execute manual motor responses to their environments.

Additionally, Porro et al. (2007) demonstrated that observational training increased the force of abduction of the fingers and created improved motor performance. The force of abduction of the right index and middle fingers against elastic resistance, a motion rarely
performed in isolation during daily tasks and therefore a novel movement, was measured using a custom-built force transducer. In the study, volunteers sat in front of participants in the experimental group, demonstrating the desired movement to them while they focused on keeping their muscles relaxed and still. Overall, the average maximum isotonic force of the experimental group surpassed that of the control group, in which participants completed the actions along with the volunteers instead of merely observing. These results indicate that action observation can improve motor performance, and that overt motor practice is not always necessary to achieve motor learning.

More specifically related to rehabilitation, Ertelt et al. (2007) conducted a study of participants with a history of stroke and paresis of an upper extremity, during which the experimental group watched videos of common hand and arm motions. Participants then completed the motions themselves, and results were measured using functional scales and fMRI. The experimental group showed improved motor functioning, as well as increased brain activation in areas containing the mirror neuron system, indicating its neurorehabilitative influence.

Motor Learning

Because learning occurs in phases, therapists should be cognizant of the timing and methods with which they teach assistive device use. Schmidt and Lee (1999) described a three-phase model for motor learning. During the first phase of motor learning, the so-called cognitive phase, instructions, modeling, and demonstration are key; as patients progress through learning, they begin to associate cognitive understanding with motor action (the second phase), and over time skills become automatic (the third phase).

As demonstrated in a classic study by Crossman (1959), women learning to roll cigars in
a factory increased their speed over time through motor learning, as illustrated by a sigmoid curve. The present study explored the potential to maximize performance on the same type of curve through action observation during learning novel tool use, as would occur with assistive device use in a clinical setting.

**Arthritis**

One particular population that can benefit from the use of assistive devices during daily function is adults with arthritis, as arthritis (particularly of the hands) can create fine motor deficits, pain, stiffness, and decreased strength and range of motion for many older adults. Repetitive performance of fine motor tasks can also exacerbate already existing deformities of the wrist, hand, or fingers, and make using joints in a functional way increasingly challenging (Radomski & Latham, 2008). Individuals with arthritis might avoid fine motor occupations altogether to prevent experiencing negative side effects, limiting their sense of meaning and overall participation in occupation throughout daily life. Without proper compensations, individuals may find their sense of independence greatly decreased. For example, picking up and manipulating pills can be a significant challenge for adults with arthritis of the hands, greatly limiting one aspect of self-care. To address this problem, occupational therapists may recommend the use of an assistive device that could make handling the pills less difficult.

Currently, there is an important need within occupational therapy to study motor learning during fine motor tasks, such as the self-care task of picking up pills, in a way that yields information about how individuals with arthritis learn to use assistive devices. Little is known about how this specific population acquires the motor skills to use novel tools, and the present study aimed to implement the use of action observation during motor learning to better understand how assistive device use might be taught and recommended for adults with arthritis.
of the hands.

The Present Study

Because minimal evidence exists in the literature to relate the mirror neuron system to occupational therapy, the present study sought to further identify the benefits of action-observation as they may be used in rehabilitation. In clinical settings, active rehabilitation of patients is not always possible, especially during initial treatment (Iacoboni, 2007). Including an observational component in neurorehabilitation has the potential to enhance the therapy experience, allowing neural activity to occur even in the absence of physical movement. The mirror neuron system is sensitive to both the context and the goal of observed actions (Cattaneo, et al., 2009; Elk, et al., 2008; Ocampo & Kritikos, 2009). Similarly, both research and theory in occupational therapy (Hsieh, Nelson, Smith, & Peterson, 1996; Melchert-McKearnan, Deitz, Engel, & White, 2000; Nagel & Rice, 2001; Nelson, et al., 1996; Trombly, 1995; Zimmerer-Branum & Nelson, 1994) has demonstrated that occupational performance is enhanced in conditions that incorporate naturalistic materials (occupational embedment) as compared to simulated materials (rote), and this remains an area of active investigation within the field. In collaboration with other researchers, the present study explored those parameters within the context of novel tool use that could further inform therapists of methods for producing motor learning using action observation in clinical practice.

Participants engaged in a common task using a novel tool that could be recommended as an assistive device. The tool was a pair of pliers with reverse action grip such that they open when squeezed. These were used to sort small items into a multi-well chamber. The uses of a novel tool and a challenging task were selected to maximize the potential for observing learning, as evidenced by improving motor function, in the course of the study. In the action observation
condition (AO), participants observed videotape of an expert performing the task, while in the control condition (V), only verbal instructions were given. In the occupationally embedded (OE) condition, participants used the pliers to pick up tablets of aspirin and sorted them into a weekly pill organizer. In the rote condition (R), participants used the pliers to pick up pieces of a dowel rod and sorted them into a multi-well chamber.

Methods

Participants

Participants in this study were either male or female, 18 years or older, with any type of arthritis affecting the hand. Participants had either hand dominance, and needed at least 3 pounds of pad-to-pad pinch force, measured by pinch meter. This criterion was chosen as it is 3 times the force needed to operate the pliers. They were also required to have a driver’s license or to demonstrate at least 20/40 vision. Participants also needed to score at least a 23 on the Mini Mental State Exam (MMSE). Data were collected at The University of Toledo, and at two YMCAs in the greater Toledo area. Participants were recruited from senior organizations, hospital arthritis programs targeting the general community, through advertisement, flyers, networking with pertinent organizations in the Toledo area, and through word of mouth. (See Table 1 for a summary of participant demographics.) Twenty-six individuals participated in this study; however, technical difficulties in digitizing movement trajectories resulted in the loss of data from six participants.

Study Design

The study employed a 2x2 design of four conditions. The conditions included action observation-occupationally embedded (AO/OE, n=6), action observation-rote (AO/R, n=5), verbal-occupationally embedded (V/OE, n=4), and the verbal-rote (V/R, n=5) condition.
Participants were randomized to one of the four conditions using permutated blocks.

**Apparatus**

In all conditions, a modified pair of reverse action, mini snap ring pliers were used, 3” long by 11/16” max opening, with tips angled at 45 degrees. After consultation with an expert in ergonomics and arthritis, the pliers were modified, with a rectangular piece of Thermoplast splinting material wrapped over the handles to increase the finger/thumb contact surface. (See Figure 1 for images of the pliers.)

The movement trajectory of participants was collected in two dimensions (X-Y) using a Basler B94 black and white 100 Hz digital video camera (Exton, Pennsylvania) suspended from a wooden frame 28.5 inches above the working surface. MaxTraq motion analysis software (Innovision Systems, Inc., Columbiaville, Michigan) was employed for both data collection and data analysis. The image size was 460 X 344 pixels. A standardized ruler with millimeter marks was placed on the work surface at the onset of each data collection session. To aid in digitizing motion, reflective tape was placed on the tips of the pliers to allow for detection of movement of the tool in the work area. A separate computer was used to show participants instructional videos.

**Procedure**

The University of Toledo’s Biomedical Institutional Review Board approved this study. Participants were screened for eligibility. After obtaining informed consent, participants were given instructions as per their randomly assigned condition. Those assigned to the V condition viewed a video clip of the materials to be used in which the audio track was the voice of a researcher giving verbal instructions for the task. Those assigned to the AO condition viewed a video clip that began with the same viewing angle of the materials and the same verbal
instructions, but also included footage of an individual completing the task proficiently. (See Appendix A for the verbal instructions that were included in the video clip.)

Participants either picked up 81-mg safety-coated aspirin tablets (5/16” in diameter) with the pliers, or pieces of a wooden dowel of the same diameter cut to the same size as the aspirin tablets in the OE and the R condition, respectively. Each item (pill or dowel segment) was placed in a plastic box divided into seven wells. In the OE condition, each box was labeled with a letter denoting each day of the week (a common pill organizer). In the R condition, the box was identical but unlabeled. (See Figure 2 for the OE and R materials.)

In all four conditions, each trial consisted of moving seven items, one into each of seven wells. Participants completed 10 trials, resting for 30 seconds between trials. During the rest, the video segment corresponding to the experimental condition was shown again. Participants were seated at a table and in a chair to complete the task.

**Dependent Variables and Statistical Analysis**

Movement trajectories were digitized in two dimensions, the X-Y plane with X being medial to lateral and Y being anterior to posterior, using MaxTraq’s analyses components with calibration to the ruler. The position of the reflective marker on the tip of the pliers was marked in each frame of the digital video. Dependent variables were calculated from the time participants initially moved past a standardized position on the Y–axis on the way to dropping the first object into the first container to the time participants crossed the same point on the Y-axis on the way back to the starting point after dropping the final object in the container. This standardized point on the Y-axis was at the 250th pixel. This point was chosen after being deemed a reliable point at which all participants performed in a similar fashion, regardless of initial position or ending position, which varied from participant to participant.
Motor performance was assessed through variables of movement time, displacement, velocity of movement, and movement units. Movement time was calculated as the number of seconds from the time the start to the end of each trial.

Displacement was then calculated by summing the absolute position difference from sample to sample from the start to the end points of each trial. Velocity of movement was calculated as the distance (in meters) per second. To calculate movement units, the acceleration of movement (the derivative of velocity) was computed. Movement units were designated as segments bounded by acceleration of zero. Lower movement time, movement units, and displacement indicated more efficient motor performance. Conversely, higher velocity of movement indicated more efficient motor performance.

Data are presented as mean and standard deviation. Statistical tests used to assess motor learning were as follows: to assess whether the experimental paradigm represented sufficient novelty to allow for learning, paired t-tests were used to compare the means of measures of the dependent variables in trial 1 to trial 10; to test the effect of the experimental conditions on motor learning, the ratio of the 10th trial to the 1st trial was utilized as a measure of motor learning (for movement time, movement units and displacement, ratios smaller than one indicated improved motor performance; for velocity, ratios greater than one indicated improved motor performance), and subsequently these ratios were compared across experimental conditions using an unpaired t-test to assess between action observation and verbal instruction and a one-way ANOVA to assess across all experimental conditions. Significance was set at the $\alpha = 0.0125$ to account for testing four variables.

Results

To assess whether participants demonstrated motor learning, regardless of experimental
condition, means across all four conditions (AO/OE, AO/R, V/OE, and V/R) for all dependent variables were compared from trial 1 to trial 10. Mean movement time was 21.3±8.6 seconds in trial 1 and 14.6±5.6 seconds in trial 10 (p <0.015), indicating faster performance. Mean displacement was 1545.3±322 meters in trial 1 and 1321.4±252.1 meters in trial 10 (p =0.049), indicating a trend toward more direct path of movement. Average velocity did increase from 0.53±1.8 X 10^9 meters/second in trial 1 to 1.0±3.7 X 10^9 meters/second in trial 10, though not significantly (p =0.317) indicating no significant difference in speed of movement. Finally, the number of movement units was 125.9±70.2 in trial 1, compared to 78.5±41.9 in trial 10 (p <0.0125), indicating improved quality and efficiency of movement during motor performance. See Table 2 for summary of variable means for each condition. This suggests that the task was sufficiently novel to present a learning opportunity for participants.

In assessing differences in motor learning between the action observation (AO, n=11) and verbal (V, n=9) conditions, using the ratio of the values from the 10th trial to values of the 1st trial as a proxy value for motor learning, there were no significant differences. The motor learning ratio for action observation and verbal conditions, respectively, was as follows: Movement time, 0.78±0.5 and 0.74±0.3, p =0.831; Displacement, 0.88±0.2 and 0.9±0.2, p =0.901; Velocity, 1.6±0.6 and 1.5±0.5, p =0.899; and Movement Units 0.77±0.6 and 0.75±0.5, p =0.952. Therefore, action observation alone did not influence motor learning. (See Figure 3.) The results of the comparison between the occupationally embedded and rote conditions are reported by our colleagues (DeRemer, 2012).

Finally, we compared the motor learning ratio across all experimental conditions. The results were significant for the variables of velocity (p =0.011) and movement units (p =0.011) but not for movement time (p =0.019) or displacement (p =0.128). Visual inspection of the data
(See Figure 4) reveals that motor learning was greatest when both independent variables were present (AO/OE) or neither was present (V/R) and least when only one was present (AO/R and V/OE).

**Discussion**

Across all experimental conditions, analysis of the data demonstrated that participant performance improved in the measures of the dependent variables of movement time, displacement, and movement units. This was shown in comparing from the last trial to the first trial. The improvements included faster performance, a more direct path of movement, and improved quality and efficiency of movement. The dependent variable velocity of movement showed no significant difference, indicating that participant performance did not improve in speed of movement. The significant increases in measures of movement time, displacement, and movement units indicate that motor learning did occur in our experimental protocol. We conclude that the novel tool selected and modified for this study (reverse action pliers, with a tip that opens when the handles are squeezed) was sufficiently novel to allow testing of motor learning hypotheses.

The overall results of our studies suggest that this tool may be an appropriate device to recommend for use amongst a population of individuals with arthritis, where fine motor skill deficits commonly occur.

No significant differences were found in motor learning between action observation and verbal conditions, indicating that participants learned similarly regardless of whether they received verbal instructions or watched a video demonstration by an expert completing the task. Action observation alone, therefore, did not improve participant motor learning or ability to perform the fine motor task with greater skill.
Several potential reasons might, however, explain why motor learning did not result from action observation alone. The video demonstration by an expert was played for participants during rest breaks after each one of ten trials in the AO condition. As participants became more familiar with the task, they tended not to watch the video as closely each time, sometimes beginning the next trial before the video was completed. Though participants were reminded to rest and watch the video clip each time, they did not always comply, creating inconsistency with deliverance of the action observation component of the task and perhaps altering its effect on motor performance.

Additionally, though the materials used in the present study, most specifically the pair of reverse action pliers used across all conditions, were found to be novel enough to elicit motor learning, perhaps they were not challenging or difficult enough to test whether or not participants would benefit from action observation alone. Had the occupational embedment component of the study (e.g. pill box, aspirin tablets) not been present in some conditions, participants might have been even less familiar with the study materials and therefore depended more on the video clips for demonstration and learning.

Furthermore, in prior action observation studies within the literature (Cattaneo, Caruana, Jezzini, & Rizzolatti, 2009; Ertelt et al., 2007; Iacoboni & Mazziotta, 2007; Keysers, et al., 2003; Peeters, et al., 2009; Rizzolatti & Craighero, 2004) participant performance on action observation tasks and confirmation of learning corresponded with changes in neural processing as measured by functional magnetic resonance imaging (fMRI), adding an element of objectivity when suggesting that portions of the brain controlling goal-directed actions were activated during participant exposure to a study’s action observation task. In the current study, however, motor learning could only be assessed through data obtained through measures of dependent variables.
It is highly possible that various forms of learning did occur within the action observation context of the present study, though this claim is unable to be validated because brain-imaging technologies were unavailable.

Future studies might use fMRI technology to assess action observation and learning within the context of an occupational task, or with tasks related to novel tools or fine motor skills as they relate to occupational therapy and rehabilitation. Future studies might also seek to examine the effects of action observation on motor learning within an experimental design where occupational embedment is not a factor, or where no verbal instructions whatsoever are provided, in order to determine the effects of visual demonstration alone as an efficient method of instruction. Other studies might look at the effects of action observation on a motor learning task where human volunteers, as opposed to video clips, provide demonstration, or examine the long-term retention of motor learning skills acquired through action observation.

Considering motor learning ratios across all experimental conditions, however, results were significant for the variables of velocity and movement units in a manner that suggested that a combination of the two teaching methods (action observation and occupational embedment) offers greater advantage than using either one alone. Consistent with the literature previously discussed (Ertelt et al., 2007; Ocampo & Kritikos, 2009; Porro et al., 2007; Schemm & Gitlin, 1998) the method of how an individual is instructed to complete a task, as well as how these instructions are reinforced throughout task performance, influence the skill with which he or she completes the task. In the current study, the combination of video demonstration by an expert and the presence of a meaningful and purposeful environment enhanced motor learning.

Several limitations of the current study can be identified. The sample size was small partly due to losses of data but also because of difficulty in recruiting; therefore, statistical power
was inadequate to detect small effects. Interrater reliability related to assessing inclusion criteria was not established, such as during scoring of the MMSE or reading results of screens for finger force by pinch meter. Due to the nature of the study design, though randomized, the researchers conducting the study were not blind to which condition participants were in once the experiment began. Because data were collected during several sessions in several different locations, the research environment was not exactly identical across data collection sessions. Though every effort was made to ensure consistency, environmental factors such as lighting, presence of noise and/or distractions, and the height of the table and/or chair that participants used when completing the experiment differed by location.

Overall, this approach suggests a role for occupational therapists when designing the most beneficial learning environments for clients to enhance motor learning. Skills frequently taught by occupational therapists, such as learning to use a novel tool such as an assistive device, can increase independence and a client’s sense of meaning and purpose in every day life. As the results of this study suggest, rehabilitative tasks designed to include both visual demonstration and an occupationally embedded environment might help clients achieve maximal motor learning.
Acknowledgements

All support, collaboration, and communication from occupational therapy doctorate student Beth DeRemer during this study is greatly appreciated. All efforts and assistance from faculty advisors Dr. Alexia E. Metz and Dr. Martin Rice during study design, recruitment, and data analysis were invaluable. Advice given by Dr. Alexia E. Metz in regard to manuscript writing and editing is also greatly appreciated, along with advice provided by Dr. Julie Jepsen Thomas related to ergonomic design of the novel tool used in our study. Finally, this study would not have been possible without the generous efforts of the various individuals with arthritis of the hands who participated in our study.
References


3114-3121.


Table 1

Demographic Information for Study Participants

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### Summary of Variable Means for Each Condition

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Figure 1. Reverse Action Pliers

Figure 1. a) A side view of the pliers showing modification using Thermoplast splinting material to build up the gripped surface to improve ergonomics. b) An above view of the pliers in the closed position. c) An above view of the pliers being squeezed into the open position.
Figure 2. Occupationally Embedded (OE) and Rote (R) Materials

a) The aspirin tablets and pill box to be used in the OE condition. b) The OE task near completion. c) The dowel segments and divided plastic box to be used in the R condition. d) The R condition near completion.
Figure 3. Motor Learning Ratios for Action Observation and Verbal Conditions

*Figure 3.* Graphic representation of the motor learning ratios for the action observation and verbal conditions, and their dependent variables. The results of the comparison between the occupationally embedded and rote conditions are reported by our colleagues (DeRemer, 2012).
Figure 4. Ratio of Motor Learning Across All Experimental Condition

![Graphical comparison of motor learning ratios across all experimental conditions, demonstrating that motor learning was greatest when both independent variables were present (AO/OE) or neither was present (V/R), and least when only one was present (AO/R and V/OE).](image)

AO/OE = Action observation/Occupational embedment; AO/R = Action observation/Rote materials; V/OE = Verbal instructions/Occupational embedment; V/R = Verbal instructions/Rote Materials. MT = movement time; Disp = displacement; Vel = velocity; MU = movement units.

**Note.**

Figure 4. Graphical comparison of motor learning ratios across all experimental conditions, demonstrating that motor learning was greatest when both independent variables were present (AO/OE) or neither was present (V/R), and least when only one was present (AO/R and V/OE).
Appendix A

The following script will be read aloud by an unseen person during the video segments to be shown for participant instruction in each of the two conditions.

**Occupationally Embedded instructions**

“On the table in front of you is a pair of pliers, seven aspirin tablets, and a pill organizer. Please use the pliers to move each pill into a section of the box. Put only one pill in each section. Move one pill at a time. Thank you.”

**Rote instructions**

“On the table in front of you is a pair of pliers, seven wooden pellets, and a divided plastic box. Please use the pliers to move each pellet into a section of the box. Put only one pellet in each section. Move only one pellet at a time. Thank you.”