ROLE OF SIMULATION IN REHABILITATION: THE EFFECTIVENESS OF MODEL HANDS WHEN LEARNING TO MAKE OTHOSES

By

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ABSTRACT

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Simulation has not been extensively studied for teaching rehabilitation practitioners technical skills. The purpose of this study is to test the efficacy of an artificial hand as a teaching tool for orthosis-making. Thirty-four participants were randomized into three groups. The first group made five orthoses on a human hand, the second made five orthoses on a model hand, and the third made one orthosis on a human hand. A one-week transfer test consisted of all participants making one orthosis on a human hand. Their performance and orthoses were evaluated using a validated checklist and global rating scale. No differences were found between groups for process-related measures. The model hand group did better on final product measures and had a larger movement time than the other two groups. Practicing on artificial hands is a useful way of learning to make orthoses. Additionally, higher practice volume did not lead to better performance.
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studies ultimately hinges on the generosity of others to volunteer their time, but just know that we are grateful and don’t take it for granted.
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INTRODUCTION

Simulation has a long history of being used for education in a variety of fields such as aviation (Garrison, 1985; Goodman, 1978; Rolfe & Staples, 1986) and the military (McKenzie et al., 2008). Recently, simulation training has gained acceptance within the health professions community as a useful method for preparing trainees for clinical practice. Simulation aims to place trainees in situations that represent a “real world” environment, and promote learning by providing feedback about decisions and actions (Issenberg et al., 1999). This includes the use of actors for improving diagnostic abilities, teamwork exercises, and virtual reality or physical bench-top models to improve technical abilities (Ali, Mowery, Kaplan, & DeMaria, 2002; Henneman, Cunningham, Roche, & Curnin, 2007). The focus of this study was on how the use of simulation can be used to teach rehabilitation students one particular technical skill: making hand orthoses.

In the field of surgery, hands-on clinical skills training has traditionally occurred in the operating room, with trainees being exposed to higher and higher levels of responsibility until proficiency is reached (Kneebone, 2003; Reznick & MacRae, 2006). In the past, the first time a junior surgeon practiced skills such as suturing or intubation was on a real patient, which potentially put the patient at considerable risk of injury. For this reason and several others such as rising teaching costs (Babineau et al., 2004) and increased patient risk (Ziv, Small, & Wolpe, 2000) both scientists and educators have now adopted a new teaching model that uses simulation as a way of training surgeons before they ever perform in an operating room. Although novice surgeons observe actual surgeries as part of their curriculum, technical skills are primarily being taught in surgical skills facilities, which give students access to virtual reality simulators and bench-top models so they can reach an acceptable level of motor proficiency before having to perform these skills on a patient. These skills centers allow for more cost-effective, tightly controlled teaching environment where the priority is on learning (Ziv, Small, & Wople, 2000).
In fact, the use of simulation as a training method has recently been embraced by the American College of Surgeons, who have recognized its value and potential benefit to the teaching curriculum (Soper & Fried, 2008).

In the field of rehabilitation, simulation has been used for years to train occupational and physical therapists (Chard, 1997; Stauffer, 1974). However, it has primarily been used as a way of improving students’ diagnostic and communication abilities by using standardized patients and designing role-play situations (Pentland, Hutton, MacMillan, & Mayer, 2003; Tomlin, 2005). Unlike in the field of surgery, simulation has yet to be studied as a way of improving clinical motor abilities, and there has been no research into the optimal ways in which it should be used for any skill set (i.e., diagnostic, communication or motor). One explanation for the lack of attention paid to motor performance in an educational setting is that motor dexterity is a less visible skill set in rehabilitation practice compared to surgery, making it easy for educators to overlook. However, practitioners of rehabilitation are often required to perform unique motor skills in their clinical setting such as suctioning, palpation, orthosis and splint construction, and patient transfer. A thorough keyword search of “simulation”, “rehabilitation”, “motor skills”, and “education” in PubMed, Web of Knowledge, and Google Scholar databases yielded no relevant results, whereas a similar search in medicine produces an abundance of research papers examining the use of simulation for education with an evidence based approach. The focus of this study was on the skill of orthosis-making, and tested the efficacy of an artificial hand model as a simulation tool. Although there are a variety of different kinds of orthoses that could be made to treat both upper and lower limb dysfunction, this study looked at the metacarphalangeal (MCP) stabilizing orthosis, which is commonly used to treat rheumatoid arthritis (RA).
Orthosis-making is a unique and complex task often requiring the clinician to exercise motor and cognitive abilities simultaneously. At the University of Toronto’s Occupational Therapy Department, students learn to make orthoses through didactic information by experts, and then get hands-on experience in a laboratory setting by practicing on each other (McKee, personal communication, January 2008). While practicing on another person’s hand is technically a form of simulation, it is limited: students are only learning to make orthoses on young, healthy, normal-functioning hands—hands that would not typically require the assistance of an orthotic device. Often, hands encountered in a clinical setting, especially those with RA, are sensitive to pain and have severe architectural abnormalities (Bielefeld & Neumann, 2005). For newly graduated occupational therapists, or those with limited experience in a hand clinic, these clinical characteristics present a unique challenge, and force the clinician to adopt a whole new skill set if the orthosis is to be fitted correctly.

While it is difficult to assess the role of pre-training in enhancing clinical performance, there is a significant body of literature from the fields of Psychology and Kinesiology on specificity of practice that provides some insight to this question. In motor learning research, the *specificity of learning hypothesis* proposes that motor skills are highly specific to the context in which they are learned, and that successful learning on one particular movement can not predict successful transfer to another (Henry, 1968). It is therefore felt that when learning to make orthoses, the closer the conditions of practice are to an actual clinical setting, the better prepared the clinicians will be.

The primary aim of simulation is to bridge the gap between what students learn outside of the clinical setting and what they will encounter as clinicians with real patients. By giving students a physical model to practice on that closely resembles the physical characteristics and movement patterns of a hand with RA, it is hypothesized that they would be better prepared for
clinical practice upon graduation, which will ultimately benefit the patients. However, before we can evaluate the learning potential of working with artificial hands that demonstrate characteristics of RA, the learning potential of working with a normal and healthy artificial hand needs to be established. Thus, the first step in this process is to demonstrate that a simple simulation tool has some value in training rehabilitation practitioners.
LITERATURE REVIEW

This literature review will summarize some of the current research on simulation and how it has been successful in a variety of medical fields. Next it will focus on rheumatoid arthritis, discussing its impact on individuals' health, common treatment methods, and typical abnormalities. A summary of the current research on orthoses will then be presented, followed by an assessment of their efficacy for treating the disease. Finally, it will show that the main gap in the research has been education and technical skills training, and how this study could impact the fields of occupational and physical therapy.

Simulation in Other Domains

In the field of surgery, the new paradigm for teaching technical abilities to trainees is to establish pre-clinical proficiency. At the heart of this model are simulation tools such as virtual reality and bench-top devices, which allow for unlimited and consequence-free practice (Aggarwal & Darzi, 2006; Debas et al., 2005; Reznick & MacRae, 2006). Research findings show that these training tools have had a positive effect on learning (Ali, Mowery, Kaplan, & DeMaria, 2002; Grantcharov et al., 2004; Van Sickle, Ritter, & Smith, 2006), and show that skills learned in a simulated environment transfer into the real-world clinical environment (Hamilton et al., 2002; Hyltander, Liljegren, Rhodin, & Lonroth, 2002; Shindholimath et al., 2003; Fried et al., 2004).

Surgery is not the only clinical field that is using simulation. Nursing education has benefited from the use of simulation devices, specifically from using artificial patients to develop trainees’ clinical skills (Alinier, Hunt, Gordon, & Harwood, 2005; Henneman, Cunningham, Roche, & Cumin, 2007; Quinn, Keogh, McDonald, & Hussey, 2003; Terman, 2007). And dentistry, which relies heavily on fine motor dexterity, has also started to use virtual reality as a way of preparing its clinicians (Rees et al., 2007; Welk et al., 2008; Wiernick, Puttemans, Swinnen, & Steenberghe, 2007).
While the primary objective of using simulation is to improve clinician competency and patient outcomes, a secondary benefit of simulation is that it can increase a student’s self-efficacy, or, one’s belief in their ability to complete a given task (Bandura, 1997) for performing various skills. Recent studies in the fields of both nursing and surgery have shown increased self-efficacy for performing technical skills after training in simulated environments (Boyd, Oliver, Salameh, 2006; Britt, R. C., Reed, Britt, L. D., & Holzman, 2007; Reilly & Spratt, 2007). Additionally, educators and clinical experts in these fields have acknowledged that simulation is becoming a valuable and necessary tool that should be adopted into training curricula (Aggarwal & Darzi, 2006; Boyd et al., 2006). While the medicine, nursing, and dentistry communities are all adopting simulation into their teaching programs, and exploring it through innovative research, simulation has remained largely unstudied in the field of rehabilitation for training clinicians’ clinical and technical skills.

Rheumatoid Arthritis

RA is a chronic autoimmune disease that causes pain and inflammation to both large and small joints of the body (Harris, 2005). While RA is a chronic disease that people will likely have to deal with for the rest of their life, it often progresses quickly within the first few years of onset. Two years after diagnosis, 55% of people with RA reported difficulty with normal activities such as shopping, household chores, and social activities and 31% reported having to reduce their number of working hours because of their condition (Scott, Smith, & Kingsley, 2005). Patients with RA have been reported to have a decreased life expectancy of 3.4 years compared with age and gender-matched controls (Wong, Ramey, & Singh, 2001). The Arthritis Society of Canada estimates that 300,000 (1 in 100) Canadians are affected by RA (The Arthritis Society, 2008).
The primary goals of treatment are to reduce pain, preserve function, and control damage to the joints ("American College," 2002). While pharmacological treatments are often used to control the progression of RA and manage its symptoms ("American College," 2002; Combe et al., 2007; Kennedy et al., 2005), non-pharmacological treatments such as the use of assistive devices, orthoses, physical therapy, occupational therapy, exercise, and dietary changes are also recommended as part of the treatment plan for RA ("American College," 2002; Combe et al., 2007; Gossec et al., 2006; Steultjens et al., 2002; Vliet Vlieland, 2007).

The disease presents itself bilaterally and typically affects the wrists, proximal interphalangeal, MCP, and metatarsophalangeal joints (Harris, 2005). While pain, inflammation, and stiffness are the predominant symptoms of all forms of arthritis, chronic synovitis (inflammation of the synovial capsule) of the MCP joint is often the hallmark of RA. There is inflammation in the surrounding connective tissue, causing instability that usually manifests in two ways: ulnar drift and palmar subluxation (Bielefeld & Neumann, 2005). Ulnar drift occurs when the weakened connective tissue is unable to hold the extensor digitorum communis (EDC) tendon in its place over the top of the MCP joint, and muscular tension from the thumb cause it to drift to the ulnar side of the joint capsule. This shifts the line of action to the ulnar side of the MCP joint, which in turn causes ulnar deviation of the fingers (Bielefeld & Neumann, 2005).

Palmar subluxation happens when the proximal end of the phalanx ruptures from its connective tissue to the MCP, and is displaced palmarly. This rupturing occurs because flexion of the fingers creates a “bow string” force on the pulley that runs on the palmar side of the MCP. Healthy joints are able to secure the flexor tendon, but a weakened joint from RA will allow the proximal head to rupture away and cause this deformity (Bielefeld & Neumann, 2005). These two abnormalities can result in dramatic loss of function for the individual with RA. Grip and
pinch strength are both reduced, and the ulnar drift reduces the functional length of the hand itself (Bielefeld & Neumann, 2005).

Orthoses and Rheumatoid Arthritis

Of all the non-pharmacological treatments for RA, orthoses, or splints, are one of the most widely used (Bielefeld & Neumann 2005; Malcus-Johnson, Carlqvist, Sturesson, Eberhardt, 2005; McKee & Rivard 2004). Bielefeld and Neumann (2005) regard splinting as the most accepted intervention to prevent the “progression of instability of the MCP joint” (p. 510). Orthoses are “any medical device added to a person’s body to support, align, position, immobilize, prevent or correct deformity, assist weak muscles or improve function” (Deshaies, 2002). They can be classified as either resting (immobilization) orthoses, which are intended to reduce pain and inflammation, or functional (activity) orthoses, which are intended to preserve function and reduce pain during periods of activity that cause stress on the joints (Spoorenberg, Boers, & Van Der Linden, 1994).

It is essential that orthoses are well-made and fit correctly, in order to realign tendons back into their normal line of action, thereby inhibiting further deformity. Additionally, by immobilizing affected joints, orthoses should provide rest and protection, which will reduce pain and inflammation (Bielefeld & Neumann, 2005). The extent to which orthoses can reduce pain, inflammation, and deformity is difficult to determine.

However, several studies have shown that orthotic intervention is effective for managing the symptoms associated with RA. Steultjens et al. (2002) conducted a review on the effects of orthoses on patients with RA by examining 16 studies that focused on splinting—7 of which were randomized control trials. The papers that were reviewed focused on outcome measures such as pain reduction, mobility, grip strength, and were also reviewed for methodological quality. The authors concluded that orthoses are effectively able to reduce pain immediately after
the orthosis is applied, and over a longer period of time. Additionally, they found that orthoses inhibit dexterity (functional ability) and increase grip strength.

Despite these positive findings, the efficacy of orthoses is not entirely conclusive. A review by Egan et al. (2001) examined ten studies, which included 449 participants and focused on the provision of orthoses for the treatment of RA. Although none of the studies were similar enough to aggregate results on any one variable, the authors concluded that orthoses have no effect on grip strength, pain, the number of swollen joints, or joint tenderness. However, it was concluded that after one month of use, participants preferred wearing their orthoses as opposed to not wearing them. The authors' final clinical recommendations were that because of the limitations to the reviewed studies, and that there is no evidence that orthoses have no detrimental effects, that patients should still be prescribed orthoses until more evidence is gathered.

Another possible explanation for why these two review papers came to different conclusions is that there was no assessment of user compliance. Instead, they chose to focus only on outcome measures such as pain and function. It was even acknowledged in the discussion of Egan et al.'s (2001) review that the amount of use may have varied widely among study participants. However, there have been several studies that measured user compliance and have found rates varying between 57-74% during the first 12-24 months (De Boer et al., 2008).

Perceived usefulness and comfort were cited to be responsible for 75% of the compliance rate (Agnew & Maas, 1995). De Boer et al.'s comprehensive study on wrist orthosis usage also found that 74 out of 128 (54%) patients who were prescribed functional wrist orthoses to manage RA were actually using them, with “use” being defined as wearing the splint at least once a month or more. What separated users from non-users tended to be whether or not they had pain and swelling.
In conclusion, the effectiveness of an orthosis appears to depend not only on how well it is made, but also on how well it is received by the individual. While its efficacy as an intervention is difficult to quantify, orthoses remain one of the most widely used forms of non-pharmacological treatment for RA.

**Gap in the Knowledge and Significance of this Work**

While the majority of research on wrist and hand orthoses has been devoted to studying their efficacy for treating symptoms of RA, there has been no research done on orthosis-making education, or on the skill development of clinicians. This type of study is crucial, because the effectiveness of an orthosis highly depends on how well it is made, which can ultimately impact how well it is received by the individual.

This study was the first to look at how simulation can be used as a tool to teach orthosis making. It is hoped that this research will lead to future work that will evaluate and make improvements to the technical skills education component in rehabilitation and occupational therapy programs, thereby improving the ability to implement evidence-based education.

**Objectives**

The primary objective of this study was to study the efficacy of an artificial hand for learning to make orthoses. To investigate this, one group of participants had a practice session that consisted of making five orthoses on the artificial hand, while another group practiced making five orthoses on a real human hand. Five trials were chosen because pilot work on the study indicated that was the maximum number of orthoses that could be constructed by a novice within two hours, which is the longest we could reasonably ask participants to volunteer.

The secondary objective was to study the effect of amount of practice on learning to make orthoses by including a third group of participants who made only one orthosis on a real hand during practice. In the motor learning literature, total amount of practice is proposed to be
the most important influence on how well a skill is learned (Schmidt & Lee, 2005, p. 322), therefore it was hypothesized that higher practice volume would have a positive effect on learning to make orthoses. However, the power law of practice also states that learning occurs most rapidly early on in practice, suggested that only one trial might be adequate for learning this task. Since it takes a considerable amount of time and effort to make just one orthosis, examining volume of practice is a variable worth examining in the current study (Schmidt and Lee, 2005, p. 322). Another reason for including a group that only had one practice attempt on a real hand was that it reflects the current teaching protocols for orthosis-making, as students at the University of Toronto typically get to practice making one orthosis of each design (McKee, personal communication, January 2008).

It should be noted that the HH1 group only practices the task of making an orthosis one time; they are actually practicing for approximately 20 minutes (based on data). This differs from the traditional notion of a single trial that is performed in a typical laboratory-based experiment. In this case a trial of a laboratory-based motor task may last for only a second or two. Thus, some caution must be used when interpreting the present data in reference to previous work on one trial learning.

In order to evaluate learning, all participants returned one-week after their practice session, and made one orthosis on a left human hand (all practice was done on right hands). The purpose of this was to compare the participants learning to make orthoses on the artificial hand with those learning on real hands in their ability to recall the skill on a real hand. A one-week retention test was chosen because we wanted to have a significant passage of time after the practice session to allow any performance effects to diminish, however it was felt that scheduling a retention test any longer than a week would have presented recruiting difficulties.
The third objective will be to assess the feasibility of the model hand by determining if it is a suitable teaching tool as it is, or if improvements and modifications should be made to it. We will determine this primarily through a survey, which participants will complete before and after their practice session.

**Hypothesis**

We hypothesize that the group practicing five times on a real human hand will outperform the other two groups on the transfer test for two reasons: 1) their practice model is more similar to the transfer model than the group practicing on the artificial hand, and 2) they will have had a significantly higher volume of practice compared to the other group practicing once on a real hand.
METHODS

Participants

Thirty-four first-year occupational therapy and physical therapy students (5 male, 29 female; 2 left-handed, 32 right-handed; mean age 24.8 years) from the University of Toronto participated in this study. Participants were recruited from first-year occupational therapy and physical therapy classes. All participants had no prior knowledge or experience with making orthoses. The study received ethics approval by the University of Toronto’s Office of Research Ethics, and informed consent was obtained from all participants.

Participants were randomly assigned to one of three groups. The first group (MH5) practiced by making five MCP-stabilizing orthoses on a right artificial hand. The second group (HH5) practiced by making five MCP-stabilizing orthoses on a right human hand. The third group (HH1) practiced by making one MCP-stabilizing orthosis on a right human hand. All participants then returned one-week after practice for a transfer test that consisted of making one MCP-stabilizing orthosis on a left human hand. See Table 2 for participant demographics.

Task Description

The participants’ task began by taking a sheet of clear plastic, wrapping it around the hand/model, and then using a permanent marker to draw an outline of the orthosis. This outline was then cut out and traced onto a dry piece of thermoplastic using a grease pencil. The thermoplastic was then submerged in water set to 95 degrees Celsius for approximately 15-20 seconds in order to make it easier to cut out. Once the thermoplastic was cut out, it was re-submerged in the water for approximately 25-30 seconds so it was be soft enough to be properly molded. The thermoplastic was then removed from the heating pan, the excess water was dried off, and it was then applied to the hand. Once it cooled and hardened, the participant was free to take it off the hand and make any cuts or modifications to it. This process continued until the
participant felt the orthosis was complete and fit properly. Finally, the edges were smoothed out and all pencil markings on the orthosis were removed.

**Apparatus and Materials**

*Model Hand & Researcher’s Hand*

The plastic model hand was constructed from data obtained by a laser scan of a right, male hand. Its outer shell is a thin, lightweight plastic, which was filled with standard caulking to provide extra protection from breaks. A comparison of measurements between the two hands is shown in Table 1. A picture of the model hand is shown in Figure 1.

![Figure 1. Photographs of the hand model used with participants in the intervention group.](image)

**Thermoplastic**

2.4mm thick Aquaplast® Watercolors™ solid, electric blue thermoplastic was used for construction of the orthoses. The sheets were cut into 15cm x 20cm sections. The thermoplastic material was graciously donated by Sammons Preston, Inc., Mississauga, ON.
Training video

The training video was a nine-minute demonstration of an expert occupational therapist constructing the custom fitted portion of the MCP stabilizing orthosis to a healthy left hand. The video was a close-up of a single hand, while the therapist constructed the orthosis. The video was augmented with verbal instructions by the expert as the skill was being performed. Participants viewed the video on a laptop computer that was set approximately 50 cm in front of them. This video is currently being used as a training tool in the Occupational Therapy Department at the University of Toronto.

Tools

Other tools used to construct the orthoses included: one pair of large scissors, one pair or small scissors for minor cuts and trims, one spatula, one permanent marker, one grease pencil, and one heating pan. Clear plastic bags were cut into 15cm x 20cm sections for the tracing portion of the task. Practice and transfer trials were recorded by a video camera set at a distance of 150cm away from the participant.

Procedure

Group 1 Procedure (Model Hand 5 - MH5)

Participants who were randomly assigned using a random sequence generator to the MH5 group were first asked to watch the training video one time through with no interruptions. After this initial viewing, the participants completed a pre-practice survey, which assessed their opinion of the video and their self-efficacy for making an orthosis on a real patient. After completion of the survey, the researcher explained how to properly handle the thermoplastics and accompanying tools (Appendix A). At this point, each participant was told that practice would continue either until five orthoses were complete, or two hours had elapsed. Participants were also told that no expert feedback would be given, and they would be responsible for determining
when each orthosis was complete. However, they were allowed unrestricted access to the training video throughout the practice session. The participants were allowed to make as many modifications to the orthoses as they saw fit; however once they began a new orthosis, they were prohibited from making modifications to, or referring to, any prior orthoses. At this point, participants were allowed to begin work on their first orthosis. At the end of practice, the participants completed the post-practice portion of the survey. The setup for the practice session is represented in Figure 2.

The participants returned one week later to complete a transfer test, where they constructed one orthosis on the left hand of the researcher from memory. Practice, verbal instruction, or reviewing of the training video was prohibited. The setup for the transfer test is represented in Figure 3.

![Figure 2. Practice setup for the MH5 group.]

**Group 2 Procedure (Human Hand 5 - HH5)**

Participants assigned to the HH5 group followed the same procedure as those in the MH5 group, except they practiced on the right hand of the researcher. The setup for the HH5 group’s practice session is represented in Figure 4. The setup for the transfer test is represented in Figure 3.
Group 3 Procedure (Human Hand 1 - HH1)

Participants assigned to HH1 group were, like the other two groups, asked to watch the video once through with no interruptions and given instructions on handling the materials. After this, they were told that their practice session would consist of making one orthosis, during which they would not be getting any feedback or access to the training video. Access to the training video was restricted in order to mimic current educational protocols, where students attempt making one orthosis after an introductory lecture from the instructor. At this point, they were given the option to review the training video as many times as they wished, up to a point where they felt confident they could correctly make one orthosis without aid from the video. Once they were done working with the video, it was turned off and participants began practice on their orthosis. The setup for the HH1 group’s practice session is represented in Figure 3.

Participants returned one-week later to complete the transfer test, which was, like the other two groups, to make one orthosis on the left hand of the researcher without feedback or reviewing of the video. The setup for the transfer test is represented in Figure 4.

![Figure 3. Retention test setup for all three groups.](image-url)
Measures of Performance and Learning

Checklist and Global Rating Scale

For all participants, every practice trial and transfer test was assessed by an unlicensed expert, not the experimenter, using a task-specific checklist (CL) and global rating scale (GRS), two tools commonly used to rate the performance of surgical trainees (Martin et al., 1997). The two tools compliment each other in that the CL is a purely objective look at whether critical steps are performed, and the GRS is a subjective rating of the performance and the final product. The CL and GRS used for this study (Appendix B) were validated by Stefanovich, McKee, and Carnahan (2008), who found that both tools were able to distinguish between novice and expert performers, and had high interrater reliability between an expert hand therapist and an unlicensed expert.

The GRS consisted of seven components, each rated on a 5-point Likert scale, of the orthosis-making skill. The first six components were grouped together (maximum score of 30) as they were all process related. That is, they evaluated how the skill was carried out. The final
category, a score for overall product quality (maximum score of 5) was also subcategorized for analysis. Each participant also received a total GRS score out of 35.

The CL consisted of 15 essential components—five process-related and ten product-related—of the MCP-stabilizing orthosis that were expected to be completed by each participant. The rater confirmed whether or not each component was completed, giving a score for process (maximum of 5), a score for product (maximum of 10), as well as a total score out of 15.

For the transfer test, the rater was blinded to the group allocation of each participant. However, blinded evaluation was not possible for the practice trials between the model hand group and the two groups practicing on real hands, as it was clear from the video which model was being used.

**Time to Complete**

Time to complete each orthosis (both practice and transfer) was obtained from the videotape and measured in seconds. Each trial began when the participant made the thumbhole cut in the plastic, ended when the participant handed the orthosis to the researcher or gestured that completion had been reached. If participants chose to watch the video during a trial, that time was removed from their total time to give a final “time to complete” value.

**Video Watching Behavior**

Both the total amount of time the video was being watched, and the total number of times the video was accessed was recorded for every practice trial in order to investigate its impact on performance. The HH1’s viewing session was not monitored for duration or frequency because it was done prior to practice, whereas the other two groups were allowed access to the video during practice, and we felt the two sets of data would have been too incompatible for analysis.

**Survey**

A survey (Appendix C) was handed out to each participant in the HH5 and MH5 group (the survey differed slightly for each group to address the different learning conditions). No
survey was given to the HH1 group because the survey was primarily focused on the participants’ opinions on simulation and their experience working with the model hand. The pre-practice portion of the survey was completed after the initial viewing of the training video and asked the participant about their opinion of the video, as well as their self-efficacy for making an orthosis on a patient. The post-practice portion of the survey asked the participants about their opinion of the practice model they used (either the healthy hand or the artificial model), their opinion of using the practice model they did not use (the model hand was shown to the HH5 group), their self-efficacy for constructing an orthosis on a patient, and their overall satisfaction with the practice session. Participants answered questions on a 5-point Likert scale (1=not at all, 5=extremely). There was also room at the bottom of the survey for participants to openly share their thoughts or suggest improvements. The survey was developed by the researcher specifically for this study.

Analyses

Sample Size Calculation

Estimates for means and variances for orthosis-making are not available in the literature. However, based on global rating and checklist scores and final products reported in the literature for the evaluation of surgical skills power estimates were calculated. Using a power of 0.8 and an alpha level of 0.05 the following sample sizes were determined: for the checklist 13 participants per group and for the global rating scores, 15 participants per group. Thus, we aimed for 15 participants per group (45 total) to give us adequate power to find statistically significant effects for our dependent variables.

Analyses of Dependent Variables

Descriptive statistics were done to describe the sample of participants. The following dependent variables were obtained: CL process, CL product, CL total score, GRS performance
score, GRS final product, GRS total score, time to complete, duration of video watching, and the number of times the video was accessed. For each dependent variable, the practice trials for the HH5 and MH5 groups were analyzed in a two-way 2 group (HH5, MH5) x 5 trial mixed analyses of variance (ANOVA) with repeated measures on the last factor. Separate one-way (3 group; HH5, MH5, HH1) ANOVAs were used to analyze the transfer performance of the three groups on all measures except video watching behavior (participants were not permitted video access during transfer). ANOVA effects significant at p < .05 were further analyzed using the Tukey HSD methods for posthoc comparison of means. Pearson correlations were used to investigate the relationship between time to complete and performance. A 2 group (HH5, MH5) x 2 trial (before practice, after practice) ANOVA was used to analyze the survey data.
RESULTS

Measurements of the Model Hand & the Researcher's Hand

<table>
<thead>
<tr>
<th>Distance (cm)</th>
<th>Model hand</th>
<th>Researcher’s hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>First metacarpal head to tip of first finger</td>
<td>6.8</td>
<td>6.4</td>
</tr>
<tr>
<td>Second metacarpal head to tip of second finger</td>
<td>9.9</td>
<td>9.5</td>
</tr>
<tr>
<td>Third metacarpal head to tip of third finger</td>
<td>10.6</td>
<td>11.0</td>
</tr>
<tr>
<td>Fourth metacarpal head to tip of fourth finger</td>
<td>10.2</td>
<td>10.6</td>
</tr>
<tr>
<td>Fifth metacarpal head to tip of fifth finger</td>
<td>6.6</td>
<td>8.6</td>
</tr>
<tr>
<td>Palmar side of third metacarpal head to base of palm</td>
<td>9.0</td>
<td>10.9</td>
</tr>
<tr>
<td>Distance between second through fifth fingers at the interphalangeal joint</td>
<td>0.6 - 1.0</td>
<td>not applicable</td>
</tr>
</tbody>
</table>

*Table 1.* A comparison of anatomical measurements of the model hand and the researcher's hand.

**Participants**

The demographics of the three groups are represented in Table 2.

<table>
<thead>
<tr>
<th>Group</th>
<th>n (males / females)</th>
<th>Handedness (R / L)</th>
<th>Age (years)</th>
<th>Clinical Affiliation (OT/PT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Hand (5)</td>
<td>12 (2 / 10)</td>
<td>10 / 2</td>
<td>24.1</td>
<td>11 / 1</td>
</tr>
<tr>
<td>Human Hand (5)</td>
<td>10 (0 / 10)</td>
<td>10 / 0</td>
<td>24.3</td>
<td>10 / 0</td>
</tr>
<tr>
<td>Human Hand (1)</td>
<td>12 (3 / 9)</td>
<td>12 / 0</td>
<td>25.8</td>
<td>12 / 0</td>
</tr>
</tbody>
</table>

*Table 2.* Group demographics.
Checklist

Practice

Checklist process: The ANOVA revealed an interaction for checklist process, $F(1,4) = 3.66$, $p = .009$. Posthoc analysis showed the source of the interaction to be trial 3, as the MH5 group’s score was significantly higher than the HH5’s. However, it is felt that this difference at trial 3 is due to chance, as there is no reasonable way to expect a momentary change in performance for either one of the two groups. Means are plotted in Figure 5. All error bars on all figures represent standard error.

Checklist product: There was a main effect for trial, $F(1,4) = 6.81$, $p = .017$. However, the posthoc test was not sensitive enough to show a significant difference between any two trials. Additionally, the ANOVA revealed a significant difference between the two groups $F(1,4) = 6.129$, $p = .023$, where the MH5 group’s mean score was higher than the HH5’s. Means for the trial effect and group effect are plotted in Figures 6 and 7, respectively.

Checklist total score: A main effect was found for group, $F(1,4) = 4.67$, $p = .044$, where the MH5 group’s mean score was higher than the HH5’s. Means are plotted in Figure 8.
Figure 5. Checklist process score during practice plotted as a function of trials. The source of the interaction is at trial 3.

Figure 6. Checklist product score during practice plotted as a function of trials. A main effect for trials shows improvement over practice.
Figure 7. Checklist product score of the HH5 and MH5 groups during practice.

Figure 8. Checklist total score during practice plotted as a function of trials. The MH5 group performed significantly better than the HH5 group.

Transfer Test

There was a significant effect for group for the analysis of checklist product, $F(2, 31) = 4.07, p = .027$. Tukey’s HSD test showed that the MH5 group’s checklist product score was
significantly higher than both the HH5 and HH1 group’s. No significant differences were found for checklist process ($p = .826$), or checklist total score ($p = .056$). The means for the product score are represented in Figure 9.

![Checklist Product Score](image)

*Figure 9.* Checklist product score during transfer. The MH5’s score was significantly higher than both the HH5 and HH1’s.

**Global Rating Scale**

*Practice*

GRS process: A main effect was revealed for trials, $F(1, 4) = 5.98, p < .001$. The posthoc test showed significant differences between trials 1 and 5 only, indicating that participants’ performance improved with continued practice. The means are plotted in Figure 10.

GRS product: The ANOVA revealed a main effect for trials, $F(1, 4) = 3.14, p = .019$. The Tukey’s HSD test was not sensitive enough to show a significant difference between any two trials. The means are plotted in Figure 11.
GRS total score: There was a significant interaction effect between trials and group, $F(1, 4) = 2.92$, $p = .027$. Tukey’s HSD test showed that there were significant differences between groups for trials 2, 3, 4, and 5. For all differences, the MH5 group’s mean was higher. The means are plotted in Figure 12.

![Figure 10. GRS process score during practice plotted as a function of trials. Participants improved between the first and last trials.](image-url)
Figure 11. GRS product score during practice plotted as a function of trials. A main effect for trials was found indicating improvement over practice.

Figure 12. GRS total score during practice plotted as a function of trials. The MH5’s score was significantly better than the HH5’s on trials 2 through 5.
Transfer Test

The ANOVA revealed a significant effect for groups for final product, $F(2, 31) = 3.73, p = .035$. Tukey’s HSD test showed that the MH5 group’s GRS product score was significantly better than the HH1 group, but not significantly better than the HH5 group’s. No significant differences were found between groups for performance ($p = .914$), or total score ($p = .914$). The means are represented in Figure 13.

Figure 13. GRS product score during transfer. The MH5’s score was significantly higher than the HH1’s only.

Time to Complete

Practice

Only one participant from both the MH5 and HH5 groups was not able to complete five orthoses within the two-hour time period. This participant was in the MH5 group and completed four orthoses. Their practice data for their four trials were included in the analyses.
The ANOVA revealed a main effect for trial $F(1,4) = 4.93, p = .001$. The posthoc test was not sensitive enough to detect a difference between any two trials. Means are plotted on Figure 14.

**Figure 14.** Time to complete during practice plotted as a function of trials shows significant reduction in completion time.

*Time to Complete*

The ANOVA revealed a significant effect for group for time to complete, $F(2, 31) = 3.23, p = .05$. Tukey’s HSD test showed that the MH5 group’s mean time to complete was significantly higher than HH1 group’s time, but not the HH5 group’s. The means are presented in Figure 15.
Time to Complete and Performance

The ANOVA results showed that on the transfer test, the model hand group made a superior final product and had a larger time to complete than the other two groups, which lead to the possibility that these two variables were related. To evaluate this hypothesis, a Pearson correlation was run between time to complete and all other measures of performance for all participants on the transfer test. Significantly positive correlations were found between time to complete and CL product score \((r(32) = .404, p = .03)\), CL total score \((r(32) = .400, p = .019)\), and GRS product score \((r(32) = .386, p = .024)\). The significant correlations are plotted in Figures 16, 17, and 18, respectively.
Figure 16. Correlation between time to complete and checklist product score for all participants on the transfer test.

$r = .404, p = .03$

Figure 17. Correlation between time to complete and checklist final score for all participants on the transfer test.

$r = .400, p = .019$
Figure 18. Correlation between time to complete and GRS product score for all participants on the transfer test.

Video Watching Behavior

Duration of video watching

A main effect was found for trial, $F(1,4) = 15.92, p < .001$. Tukey’s HSD test revealed mean differences between trial 1 and trial 3, 4, and 5, indicating that the video was primarily used during the first two trials of practice. No differences were found between the two groups. The means are plotted in Figure 19.
Figure 19. Time watching the training video during practice plotted as a function of trials shows video watching mainly occurred during the first two trials.

**Number of views**

The ANOVA revealed a main effect for trial, $F(1,4) = 21.763, p < .001$. Tukey’s HSD rest revealed mean differences between trial 1 and trials 2, 3, 4, and 5, which did not differ, indicating that the participants viewed the video most frequently during the first trial only. No significant differences were found between groups. Means are plotted in Figure 20.
Figure 20. The number of times the video was consulted during practice plotted as a function of trials shows the video was more frequently viewed during the first trial.

Survey

Self-efficacy

The 2 x 2 ANOVA showed a significant main effect for before and after practice. There was improvement in self-efficacy for making orthoses for before (2.29, ± 0.87) and after (3.12, ± 1.03) practice ($F(1) = 29.56, p < .001$). The means are plotted in Figure 21.
Self-efficacy for making orthoses before and after practice showing significant improvement.

**Practice Model Preference**

The 2 x 2 ANOVA also showed a significant main effect for model preference. Participants rated a real human hand significantly higher (4.71, ± 0.56) than the model hand (3.43, ± 0.98) on usefulness for learning to make orthoses, $F(1) = 28.95$, $p < .001$. Means are plotted in Figure 22.

**Figure 21.** Self-efficacy for making orthoses before and after practice showing significant improvement.

**Figure 22.** MH5 and HH5 groups' rating of perceived usefulness of the model hand and a human hand for learning to make orthoses.
Quality of the Model Hand

When asked, “What improvements or modifications would you make to the model hand in order to make it more effective?” 75% felt that the hand could have had more life-like properties such as having a softer surface, and moveable joints.

Additional Feedback

When asked to provide additional comments or thoughts, several participants expressed that they could have benefitted from external feedback on their performance. One participant responded:

“I felt that by the end I had a specific routine for making an orthosis that I was comfortable with. However, I can't be completely confident about the quality until I have external feedback from an expert.”
DISCUSSION

We were able to show that learning to make orthoses on an artificial hand is just as good as learning on a real hand. There were no differences between groups for process-related measures, however the group practicing on the model hand made a better final product than the groups practicing with real hands. Additionally, the model hand group took longer to complete their orthosis on the transfer test.

Transfer Test

Process Measures

On the transfer test, none of the groups outperformed the other in terms their actual process measures such as fluidity of movement, knowledge of fabrication, and respect for tissue. Given the specificity of learning hypothesis (Henry, 1968), which states that movements are highly specific and can not easily be transferred to other movements, the group practicing on the artificial hand model should have been at a disadvantage when transferring over to a real human hand, yet their performance did not reflect this, so it is possible that the two practice conditions were similar enough to allow transfer of learning.

This finding also raises the issue of model fidelity, or the degree of realism in simulation. Although the model hand was obtained by a laser scan of a real hand, the model itself was made out of a very hard, rigid plastic, and the fingers and joints were fixed, making it very different from the real hand that was used for the transfer test. These factors would classify the model hand as a lower-fidelity simulation tool compared to a real hand. Intuitively, it makes sense that a simulation tool should be as lifelike as possible in order to maximize preparation for clinical practice. However, recent studies on high and low-fidelity simulation indicate that learning on a model that is not 100-percent lifelike may be adequate for those learning a skill for the first time (Matsumoto, Hamstra, Radomski, & Cusimano, 2002).
Grober et al. (2004) conducted a study comparing low and high-fidelity simulation for novice trainees learning to perform microsurgery. The low-fidelity model being used was a piece of rubber tubing that the participants were required to suture, and the high-fidelity model was a live rat vas deferens. On a transfer test, the participants in the low-fidelity group performed just as well as those who practiced on the high-fidelity rat model. However, what was particularly surprising about this study was that in a questionnaire given to each of the participants after completing the study, 90% preferred working with the high-fidelity model to the low-fidelity one, and overall, the high-fidelity model received a higher rating for educational value. This study shows that there is a disconnect between a simulation tool’s perceived and actual benefit.

The findings from Grober et al. (2004) are similar to what occurred between the MH5 and HH5 groups in the present study. On the survey, both groups felt that a real human hand would be more useful for learning to make orthoses than the model hand. Additionally, 10 out of 12 participants in the MH5 group expressed the desire for more life-like qualities to the hand. Yet despite this, they still performed just as well as the HH5 group, and made a better quality orthosis on a real human hand one-week after practice.

Similarly, Matsumoto (2007) emphasized that it is not necessarily important for a model to look realistic, as long as the student has the opportunity to practice all the critical steps relevant to that skill. The hand model being used in the present study, while obviously missing some life-like characteristics, was the same as a real hand in that it allowed all of the critical steps of orthosis-making to be practiced.

Another explanation for why there were no group differences seen on the transfer test may have to do with a methodological aspect of the study. As previously mentioned, every participant was read a script after their initial viewing of the training video (see Appendix A). The purpose of the script was to give detailed instructions on how to properly handle the
materials, as this was not covered in the video. Additionally, the script gave a brief overview of the process of making the orthosis. In general, this script was very process-oriented, because it was concerned with how to do certain things pertaining to the construction process. It only touched lightly on any product-related aspects. It is possible that this script reinforced a lot of the process-related instructions in the training video and caused the participants to remember the process-related steps better than the product-related ones.

*Final Product Measures*

The group practicing on the model hand made the best quality orthosis compared to the groups that practiced on the human hands. We propose two possible explanations to explain the differences between groups on the transfer test. The first relates to possible differences in anxiety levels between the groups, and the second related to possible differences in task difficulty.

*Anxiety levels*

At this point, it is important to note that this rationale is highly speculative, as we had no direct measurements of stress or anxiety. This explanation evolved from anecdotal observations and informal conversations with participants after the conclusion of the study. However, we feel it is an important point to consider and it would be irresponsible to ignore it due to lack of evidence.

To properly make an orthosis, the practitioner cycles between fitting the orthosis on the hand, inspecting its fit, making necessary adjustments, and repeating this process until correct fit has been achieved. It is unrealistic to expect that an orthosis will fit properly after the initial cutout, and even experts go through this process of fitting and re-adjusting many times before they feel comfortable with their final product. It is believed that participants in the human hand groups may have felt more uncomfortable performing this skill during practice than the model hand group, as it was done in more personal environment involving direct human-to-human
interaction. Of the several comments that were observed, one of the more common ones were, “I’m probably doing such a bad job,” and “I feel like you’re staring at me,” indicating that the participants felt too self-conscious of their performance in front of the researcher. Other comments included “Sorry, I need your hand one more time,” and other apologetic sentiments, showing some participants felt like they were taking too much time, and that they felt uncomfortable asking for the researcher’s cooperation in lending them his hand for re-fitting.

After the conclusion of the transfer test for one of the participants in the model-hand group, the participant said, “I felt like with the model-hand, I could just mind my own business and focus on making the orthosis. During the transfer test, I felt like you (the researcher) were putting me under the microscope a bit, and it made me a little nervous.”

The relationship between anxiety and stress on motor performance is best explained by the Yerkes-Dodson Law, which states that motor performance is optimal with a moderate amount of arousal, but excessively high levels of arousal can be detrimental to performance (Yerkes & Dodson, 1908). Easterbrook’s (1959) cue-utilization theory explains the Yerkes-Dodson Law by linking arousal levels to one’s ability to attend to cues. When anxiety is at moderate levels, learners are aroused to the point where their attention is focused on the task, and they are able to attend to a large number of cues. But higher levels of arousal restrict the learners’ attention, and vital cues necessary for learning are not observed, resulting in a decrease in performance.

Higher arousal levels may explain why the HH5 group did significantly worse than the MH5 during practice for quality of the final product. It is possible that the HH5 group’s stress, brought on by the presence of the researcher, resulted in them not being able to properly attend to the cues necessary to learn. Contrasting this, the MH5 group had less interaction with the researcher, allowing them to feel comfortable enough to take their time, pay attention, and learn
the skill at a comfortable pace. When the MH5 participants returned for their transfer test, they had a better understanding of how the final orthosis should look and fit, and outperformed the HH5, despite practicing on a different model than the HH5 group.

Task difficulty differences

It has been proposed that for novice learners, motor performance is inversely related to task difficulty (Guadagnoli & Lee, 2004). That is, as the difficulty of a task increases, performance will decrease. Although we have no hard evidence to support the notion that a human hand is more difficult to practice on than the model, we can present anecdotal evidence for why it may be.

As previously discussed, because of the absence of some key lifelike characteristics, the model hand is much lower on the fidelity scale than a normal hand. Also, participants working with the model hand did not need to worry about injuring or damaging it, like they would with a human hand. The combination of these missing factors may have caused the task difficulty for the model hand to be significantly lower than working with the human hand.

Not having to attend to these lifelike characteristics could have freed up attentional resources for the group practicing on the model hand, and would explain why they had better checklist product scores during practice. Their superior final product scores during transfer (on both the CL and the GRS) may be due to the fact that during practice, they were able to take advantage of having a model with lower task difficulty and learn the skill better than the groups practicing on human hands.

Time to Complete

In addition to making better quality orthosis, the group practicing on the model hand took a significantly longer time to complete the orthosis than both groups that practiced on the real hand. However, this difference was only significant with the HH1 group. The difference with the
HH5 group was close to, but did not reach significance (p = .112). Why did the MH5 group take longer? One explanation is that they had a difficult time adjusting from making orthoses on a model hand to a human hand, and their increased time is simply a reflection of them not having learned a fluid routine. However, a more likely explanation is that their longer completion time was a result of their superior knowledge of orthosis-making.

In traditional motor learning literature, a faster completion time is usually correlated with better performance, assuming accuracy is maintained (Schmidt & Lee, 2005). However, the findings of the present study show the opposite, where the group producing the better quality orthosis takes longer to complete the skill. Although this seems to be an inconsistent finding, it actually makes sense when taking a closer look at the skill.

Motor skills can be classified into three different groups. The first is discrete skills, which have a recognizable beginning and end, such as tying a knot or throwing a ball. The second classification is continuous skills, which do not have an identifiable beginning or end, such as swimming or running. The third classification is serial skills, which are a combination of both, often being comprised of discrete skills that are strung together (Schmidt & Lee, 2005). Orthosis-making would most likely fall under the serial category, as each it requires the individual to perform a variety of movements in order to be done correctly. Also, there is no clearly definable end point; the practitioner must decide when each orthosis is complete.

Properly making an orthosis requires in depth knowledge of anatomy, the pathology being treated, the patient’s needs, and orthotics in general. The practitioner must take great care to ensure that the orthosis fits properly, it is cosmetically appealing, and the patient is satisfied with the final product. It is likely that experts may get faster at the discrete skills that go into making an orthosis, such as cutting out the pattern, or handling the heated thermoplastic, but their time to complete the entire orthosis may not necessarily be longer. In fact, completing an
orthosis too quickly may be a sign that the practitioner lacks the sufficient knowledge to construct it properly.

Stefanovich, McKee, and Carnahan (2008) used both experts and novices to validate the checklist and global rating scale used in the present study. Re-examination of the participants’ time to complete showed that experts, who outperformed novices on every measure, took an average of 27 minutes to complete their orthosis. This was significantly higher than the novices, who took an average of 17 minutes (p = .013) to make their orthosis. In the present study, it was shown through correlation analyses as the quality of the final orthosis increases, so does the time to complete it. It should be noted that the significant correlations were only found for the final product measures, not for the process measures.

**Practice Volume**

*Lack of Differences Between Human Hand Groups*

One of the most surprising results from this study was that there were no differences between the HH5 and HH1 groups on any of the transfer measures even though volume of practice is generally considered the most important variable for acquiring new motor abilities. One explanation for this is that the HH5 group performed worse than anticipated. The HH5 group was allowed access to the video during their practice trials, but because they had no expert feedback, they were unlikely to self-correct any mistakes or bad habits. This is supported by the fact that the overwhelming majority of video watching was done during the first two trials of practice. This might account for why the two groups’ performances were so similar—although the HH1 did better than expected, the HH5 group did not improve as much as they should have, given the amount of practice available to them.

While the HH5 group may have performed worse than expected, it is also possible that the lack of group differences are due to the HH1 group doing better than expected. The HH1
group was given one opportunity to practice making an orthosis, and they were not permitted access to the training video during this time. However, prior to their practice session, they were specifically encouraged to freely review the video as much as they wished, up to a point where they felt confident that they could correctly make one orthosis without aid from the video. This particular instruction could have motivated the participants to really focus on the video and get a firm grasp on the instructions prior to practice. However, no data exists to support this hypothesis, as no video watching behavior was recorded for this group.

Another explanation as to why there were no differences between the HH1 and HH5 groups is that it is possible that one trial is all that is needed to learn to become proficient at making orthoses. The power law of practice states that early on in practice there is a steep rise in learning, and as practice continues the learning curve starts to plateau. The average time to complete for the first trial for the MH5, HH5, and HH1 groups was 22.3, 17.7, and 22.3 minutes, respectively (no significant differences between groups). So even though the HH1 group’s practice time was considered low-volume, 22-minutes of orthosis-making, and 20% of the number of trials as the high-volume groups still represents a substantial amount of practice, and may be sufficient enough to learn the skill.

**Practice**

During practice, participants in the MH5 and HH5 groups got significantly faster, and at the same time, their scores improved. According to the correlation data on the transfer test, shouldn’t their time to complete increase with improved performance? The answer may be due to the lack of feedback they were provided during practice. The training video was the participants’ only source of information. External feedback was prohibited, so they had only a limited amount of information to know whether what they were doing was correct. Also, they had to decide when each orthosis was complete. The issue of limited feedback was cited by several
participants, who felt that with practice, they established a specific routine for making orthoses, and felt they got better and better at that routine. But they had no way of knowing whether they were actually making orthoses correctly, due to the brevity of information on the training video. Examination of the video watching behavior supports this, as the video was primarily accessed during the first two trials, and then significantly drops for the duration of practice. What can be concluded from this information is that with continued practice, the participants’ performance got more fluid, resulting in a decrease of their completion time. And although their CL and GRS measures did improve with practice, it is felt that if external feedback had been available, their scores would have drastically improved, along with an increase in their time to complete.

Self-efficacy

For both the HH5 and MH5 groups, self-efficacy for making an orthosis on a real patient improved after practice. While there were no significant differences between groups, this is an important finding, as it shows practice on a simulated hand model can lead to improvements in self-efficacy just as well as traditional practice.

Feasibility of the Model Hand

Although we were able to demonstrate practicing on an artificial hand is an effective teaching strategy, we feel that the hand model used in this study needs further modifications if it is to be used for other orthoses besides the MCP-stabilizing orthosis.

During the initial planning of this study, when we were deciding what type of orthosis was to be used, we were limited in our options due to certain characteristics of the model hand. As previously mentioned, the surface of the hand was very hard, making it difficult to use it to make any orthoses that required to be slipped over the fingers. Also, the joints were in a fixed position, meaning that practicing other orthoses where the hand would need to be held in another position would be impossible. These qualities were echoed by the participants on the post-
practice portion of the survey when asked what modifications they would like to see made to the hand model.

If an artificial hand is to be used in a formal teaching curriculum, it should have the ability to be used for a variety of orthoses. Having a model with movable joints, and a softer surface would allow this to happen.

**Limitations**

One of the more surprising findings from the study was that the HH1 group performed just as well as the HH5 group, despite only making one orthosis during practice. Prior to their practice session, the HH1 group was permitted to watch the video as much as they wanted until they felt like they could complete one orthosis without video feedback. Anecdotally, it was observed that there was a high variability between participants with respect to how much of the video they chose to watch. But because their viewing behavior was not recorded, it is difficult to assess whether this video had a significant impact on their performance, which could explain why they performed just as well as the HH5 group.

Additionally, no survey was given to the HH1 group, as the survey’s questions primarily focused on the participants’ opinion of either the model hand or a human hand. However, a major finding from the survey was related to self-efficacy differences before and after practice. Because the HH1 group completed no survey, it is impossible to tell how practice volume impacts changes in self-efficacy.

The survey was only given to participants before and after their practice session. A survey after the transfer test would have provided additional information on self-efficacy, as well as how participants felt about the practice models. For the group practicing on the model hand, it would have been helpful to know their perception of the practice models after making orthoses on both the model hand and the human hand.
The model hand group’s superior performance on the transfer test was attributed to the fact that the human hand groups likely had a higher level of anxiety during practice that resulted in them not learning the skill as well as the model hand group. However, this is only a theoretical explanation, as there were no actual measures of anxiety. Common methods of measuring anxiety include heart rate monitoring, questionnaires, and skin conductance monitoring.

**Future Directions**

The hand being studied had no architectural abnormalities and appeared to be healthy looking. The reason for this is that it was necessary to understand if learning to make an orthosis was even possible on a hand that was not real. Introducing an arthritic-looking model at this stage would have presented confounding variables, making it difficult to determine if any training differences were due to the hand being only a model, or the hand’s architectural differences. Future work in this area will examine the usefulness of a model hand with the physical characteristics of arthritis. This hand will have more life-like features such as moveable joints and a softer surface. Having these features will also allow for the study of different kinds of orthoses.

Along with developing a more lifelike hand model, it will also be a priority to understand more about how to introduce this model into the current curriculum. For example, is it wise to give novices a model like this to practice on, or should it be reserved for students who have learned some of the fundamentals of orthosis-making? Also, the role of expert feedback will also be studied. Allowing participants to receive coaching from an expert, as they do in their normal classroom setting, will promote better understanding of the optimal practice volume for learning orthoses.
Finally, although difficult to implement, transfer tests on a real individual with architectural abnormalities would be ideal for understanding the true worth of practicing on simulated hands.

**Final Conclusions**

Practicing on an artificial hand is just as good as a human hand for learning to make orthoses. It may even have certain advantages over real hands, as they could allow participants to feel less stressed during practice, enabling them to better grasp the critical steps of orthosis-making. Or, it may allow for lower task difficulty, which may be more appropriate for novice learners. Additionally, increased practice volume did not provide an advantage, although this may not be the case with an expert present to give feedback to the learner.
REFERENCES


APPENDICES

Appendix A

Script read to participants after completion of the training video.

“Here is the plastic (points to plastic) that you’ll use to make the initial trace onto. After you cut it out, you’ll trace it onto the dry thermoplastic with the yellow grease pencil. The thermoplastic is very thick and much too difficult to cut when it’s dry, so you’ll have to soften it up by putting it in the hot water for about 15 seconds. To take it out, just use the spatula and lift up one of the corners. Then grab the corner with your hands—you won’t burn yourself—and you can place it on the towel. Gently pat it to get the excess water off and then you can cut it out using the pair of large scissors.

After you have the thermoplastic cut out, it will be too dry to mold to the/my hand, so you’ll need to put it back into the water. This time, however, you’ll need to leave it in for about 25 seconds to get it pliable enough to mold.

After you take it out of the water and let the water evaporate, check it to make sure it’s not too hot, and then you can apply it to the/my hand. The orthosis will take longer to dry than the one in the video, as it is thicker and not perforated.

Any additional cuts or trims can be made with the smaller pair of scissors. You may also dip just the edge into the water instead of re-submerging the whole orthosis. Just make sure that all edges are smooth and pattern and trim marks have been removed.

I won’t be able to give you any feedback regarding if the orthosis is done correctly, and you will be the judge of when you feel each orthosis is complete.”
Appendix B – Checklist and Global Rating Score

Orthotic Fabrication Checklist – Finger MCP Stabilizing Orthosis

Instructions to Candidates:
A 45 year old man has had rheumatoid arthritis for five years and has developed finger MCP volar subluxation with ulnar drift and mild flexion contractures. Please fabricate a finger MCP-Stabilizing Orthosis.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Not done, correctly</th>
<th>Done, correctly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Appropriate choice of thermoplastic</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2. Safe use of scissors and/or knife</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3. Handles heated thermoplastic properly</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>4. Check temperature of heated thermoplastic before application to model</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>5. Sufficient surface area to stabilize the joints</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>PROCESS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Good conformity to contours – no gaping or indentations</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7. Finger MCP’s gently flexed</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>8. No restriction of finger; PIP flexion</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>9. No restriction of thumb motion – thumb eminence fully exposed</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>10. No restriction of the wrist</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>11. No pressure points; no ridges on inside edges of orthosis</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>12. All corners rounded off on the thermoplastic and edges smooth</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>13. No redness on the skin indicating pressure points</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>14. No imprints on outside surface of thermoplastic</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>15. All patient/imprints have been removed</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

MAXIMUM TOTAL SCORE (15)
TOTAL SCORE GIVEN

Checklist used from Stefanovich et al. (2008)
GLOBAL RATING SCALE OF FINGER MCP-STABILIZING ORTHOSIS FABRICATION

Please circle the number corresponding to the candidate’s performance regardless of the candidate’s level of training.

<table>
<thead>
<tr>
<th>Respect for Tissue</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequently used unnecessary force on tissues/ model or caused damage by inappropriate use of instruments /application of thermoplastic to the model</td>
<td></td>
<td></td>
<td>Carefully handled tissue/model but occasionally caused inadvertent damage</td>
<td>Consistently handled tissue/model appropriately</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Handling of Scissors</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeatedly makes insensitive or awkward cuts with scissors resulting in very rough edges</td>
<td></td>
<td></td>
<td>Competent use of scissors but occasionally appeared stiff or awkward or created some rough cuts</td>
<td>Fluid movements with scissors resulting in smooth edges</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Handling of Thermoplastic During Heating and Molding</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequently used unnecessary force leaving the thermoplastic very imprinted or very over stretched</td>
<td></td>
<td></td>
<td>Carefully handled thermoplastic but left some imprints or caused minor over stretching</td>
<td>Consistently handled thermoplastic appropriately with no obvious imprints from fingers or over stretching</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flow of Orthotic Fabrication</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequently stopped, Working and seemed unsure of next move</td>
<td></td>
<td></td>
<td>Demonstrated some forward planning with reasonable progression of procedure</td>
<td>Obviously planned course of fabrication with effortless flow from one move to the next</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Knowledge of Orthotic Fabrication</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deficient knowledge</td>
<td></td>
<td></td>
<td>Knew all important steps of fabrication</td>
<td>Demonstrated familiarity with all steps of the fabrication</td>
<td></td>
</tr>
<tr>
<td>Required specific instruction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>During most steps of fabrication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OVERALL PERFORMANCE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very poor</td>
<td></td>
<td></td>
<td>Competent</td>
<td>Clearly superior</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>QUALITY OF FINAL PRODUCT</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very poor fit and cosmesis</td>
<td></td>
<td></td>
<td>Competent fit and cosmesis</td>
<td>Clearly superior fit and cosmesis</td>
<td></td>
</tr>
</tbody>
</table>

Global rating score used from Stefanovich et al. (2008).
Appendix C
Survey for MH5 group

MCP Stabilizing Joint Orthosis Study

Date: ______________
Participant ID: __________
Gender: ______________
Handedness: ___________
Age: ___________
OT Year: ___________
Allocation: ___________

Pre Practice Questions:

1. You are confident that you could make a proper orthosis on a patient.
   1  2  3  4  5

2. The video provided you with all of the necessary information to properly construct an orthosis.
   1  2  3  4  5

Post Practice Questions

3. You are confident that you could make a proper orthosis on a patient.
   1  2  3  4  5

4. Practice on an artificial hand is a useful method to learn this type of orthosis.
   1  2  3  4  5

5. Practicing on a real hand would be a useful way to learn this type of orthosis.
   1  2  3  4  5

6. You enjoyed practicing on the artificial hand.
   1  2  3  4  5

7. The video provided you with enough feedback to answer any questions you might have had.
   1  2  3  4  5

8. What improvements or modifications would you make to the artificial hand in order to make it more effective?

9. Additional comments or thoughts.


Survey for HH5 group

MCP Stabilizing Joint Orthosis Study

Date __________________________
Participant ID: ....................
Gender: .........................
Handedness: ......................
Age: .............................
OT Year: ...........................
Allocation: ........................

Pre Practice Questions:

1. You are confident that you could make a proper orthosis on a patient.
   1  2  3  4  5

2. The video provided you with all of the necessary information to properly construct an orthosis.
   1  2  3  4  5

Post Practice Questions

3. You are confident that you could make a proper orthosis on a patient.
   1  2  3  4  5

4. Practice on a partner's hand is a useful method to learn this type of orthosis.
   1  2  3  4  5

5. Practicing on the artificial hand would be a useful way to learn this type of orthosis.
   1  2  3  4  5

6. You enjoyed practicing on the partner's hand.
   1  2  3  4  5

7. The video provided you with enough feedback to answer any questions you might have had.
   1  2  3  4  5

8. Additional comments or thoughts.