5-2014

Does Motor Learning Generalize Between Distinct Functional Upper Extremity Tasks in Older Adults?

Bergen Elyse Lindauer
Utah State University

Recommended Citation

Lindauer, Bergen Elyse, "Does Motor Learning Generalize Between Distinct Functional Upper Extremity Tasks in Older Adults?" (2014). *All Graduate Plan B and other Reports*. 393.
https://digitalcommons.usu.edu/gradreports/393

Does motor learning generalize between distinct functional upper extremity tasks in older adults?

by

Bergen Elyse Lindauer

A Plan B manuscript submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Health and Human Movement

Approved:

Sydney Schaefer, PhD Major Professor	Breanna Studenka, PhD Committee Member
Elizabeth Fauth, PhD Committee Member	

UTAH STATE UNIVERSITY
Logan, Utah

2014

Does motor learning generalize between distinct functional upper extremity tasks in older adults?

Bergen E. Lindauer[1] and Sydney Y. Schaefer[1,2,3]

[1]Department of Health, Physical Education, and Recreation, Utah State University; [2]Department of Physical Therapy, University of Utah; [3]Center on Aging, University of Utah

Running head: Generalization of Motor Learning

Corresponding author: Sydney Y. Schaefer, PhD
Department of Health, Physical Education and Recreation
Utah State University
7000 Old Main Hill
Logan, UT 84322 USA
Phone: (435) 797-8441
Fax: (435) 797-3759
Email: sydney.schaefer@usu.edu

Other authors: Bergen E. Lindauer, BS
Department of Health, Physical Education and Recreation
Utah State University
7000 Old Main Hill
Logan, UT 84322 USA
Phone: (435) 797-1854
Fax: (435) 797-3759
Email: bergen.e.lindauer@aggiemail.usu.edu

Number of words: 4,379

Number of figures: 7

Number of tables: 1

ABSTRACT

Background: The process of motor learning can decline with age, such that older adults tend to learn new motor skills at a slower rate and to a lesser degree than younger adults. The degree to which aging affects the generalization of motor learning, however, is unclear.

Objective: The purpose of this study was to test whether task-specific training on one functional motor task would 1) result in motor learning, and 2) generalize to two untrained tasks in older adults.

Methods: Twenty-one adults age 65 years and older participated in this study and were assigned to either a training group or a control group. The training group completed three days of training on a simulated feeding task with their non-dominant hand. The control group received no training. All participants were evaluated at pre-test and at post-test on the feeding task, as well as two other untrained functional upper extremity motor tasks (simulated dressing and writing).

Results: The training group significantly improved feeding task performance from pre-test to post-test, whereas the control group did not. These improvements due to motor learning did not, however, generalize to the two untrained tasks, as neither the training nor control group showed any improvement on the simulated dressing or writing tasks from pre-test to post-test.

Conclusions: These results suggest that, unlike younger adult samples in our previous studies, older adults may not generalize learned information across functionally distinct tasks. Thus, the process of generalization may be particularly susceptible to aging processes.

Keywords: task-specific training; generalization; aging; upper extremity

INTRODUCTION

Many older adults have difficulty performing activities of daily living (ADLs) that involve reaching and grasping (Covinsky, Lindquist, Dunlop, & Yelin, 2009; Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963). To address these difficulties, individuals can and do seek physical rehabilitation. One approach to physical rehabilitation is task-specific training, in which individuals repetitively practice a specific task that they find difficult or meaningful (Bayona, Bitensky, Salter, & Teasell, 2005; Hubbard, Parsons, Neilson, & Carey, 2009). Task-specific training has been shown to promote motor learning experimentally (Michaelsen, Dannenbaum, & Levin, 2006) but may have limited feasibility clinically. People are often functionally limited on a number of tasks, rather than on just one specific task, yet practicing them all with a task-specific approach in rehabilitation is not feasible given current clinical constraints (see Kimberley, Samargia, Moore, Shakya, & Lang, 2010; Lang et al., 2009). Thus, there is some expectation that what is practiced in rehabilitation will generalize to what is not practiced in rehabilitation.

Generalization is operationally defined as the improvement in one task due to experience or practice on a different task (Schmidt & Lee, 1999). Generalization has been reported experimentally 1) between different conditions of the same upper extremity task (Seidler & Noll, 2008); and 2) across distinct upper extremity tasks in healthy young adults (Schaefer & Lang, 2012) and in adults with chronic post-stroke hemiparesis (Schaefer, Patterson, & Lang, 2013). In cases of generalization across tasks, participants who trained on one functional motor task improved their movement rate on other novel untrained tasks, whereas participants with no training did not improve. The functional tasks used in these two studies were embedded in ADLs and performed with the non-dominant hand. In Schaefer and Lang (2012), participants' performance on a novel untrained task that simulated dressing was measured before and after practicing training on another novel task that simulated feeding. The simulated feeding task required participants to spoon beans between cups and the simulated dressing task required participants to fasten buttons on a button board. Movement rate on the simulated dressing task (i.e. the number of buttons fastened in 20 seconds) improved, but only after training on the feeding task, demonstrating generalization. Participants with no training showed no improvement on either task. Similarly, in Schaefer et al. 2013, participants with post-stroke hemiparesis showed a similar pattern of results in not one but two untrained tasks, the simulated dressing task and a block sorting task. The block sorting task was adapted from the widely used Box and Blocks Test (Mathiowetz, Volland, Kashman, & Weber, 1985), where participants transferred blocks from one side of a partition to the other side. These studies suggest that generalization across tasks is experience-dependent, yet we have not tested whether it is age-dependent.

Even primary aging, or normal aging (Eber, 2012), can affect aspects of motor performance, such as one's movement speed (Walker, Philbin, & Fisk, 1997) or reaction time (Fozard, Vercryssen, Reynolds, Hancock, & Wuilter, 1994; Hunter, Thompson, & Adams, 2001), as well as one's ability to learn new motor skills (Perrot & Pertsch, 2007; Smith et al., 2005; Tunney et al., 2003; Voelcker-Rehage, 2008). Despite the mounting evidence that normal aging affects motor learning, the degree to which aging affects the *generalization* of motor learning is still unclear, as there is evidence for (Langan & Seidler, 2011; Seidler, 2007) and against (Hinder, Schmidt, Garry, Caroll, & Summers, 2011) generalization in older adults. These findings are limited because the tasks used were not functional and not based on ADLs. The tasks used in this study were derived from ADLs.

The purpose of this study was to test whether healthy older adults would generalize task-specific training across different functional motor tasks. In this study, participants age 65 or older trained with their non-dominant hand on a simulated feeding task for three consecutive days. We also tested their motor performance on two other untrained functional tasks (simulated dressing and writing) before and after training (pre- and post-test, respectively), and compared them to a group of age-matched participants who did not receive any training. We hypothesized that only the participants who completed task-specific training of the simulated feeding task would improve their performance on that task (i.e. motor learning) and the two other untrained tasks (i.e. generalization) from pre-test to post-test.

METHODS

Participants

Twenty-one participants (mean ± SE age: 76.7 ± 6.6 years) participated in this study. Participants were excluded from this study if they had a neurological condition such as Parkinson's disease, Huntington's Disease, or a stroke, that could affect their motor function, or were under the age of 65 years. All participants were provided informed consent. The Utah State University Institutional Review Board approved this study.

We used several assessments to characterize general cognitive and motor function in our sample of participants. General cognitive status was measured with the Montreal Cognitive Assessment (MoCA). The MoCA is a reliable, easily administered, and brief cognitive screening test that assesses global cognitive status across various domains such as attention, concentration, executive function, memory, and language (Nasreddine et al., 2005). The maximum MoCA score is 30 points, with scores greater than or equal to 26 points considered as normal (Nasreddine et al., 2005). To measure tactile sensation, we used Semmes Weinstein monofilaments (Touch-Test™, North Coast Medical, Inc.), testing the distal end of the left and right index fingers only. We also tested maximal grip strength of the dominant and non-dominant hands using a hand dynamometer (Jamar, Sammons-Preston-Rolyan) (Andrews, Thomas, Bohannon, 1996; Schmidt & Toews, 1970). Hand dominance was determined using a modified Edinburgh Handedness Questionnaire (Oldfield, 1971).

General procedure

Motor tasks

The motor tasks in this study were selected because they simulate three functional upper extremity activities: feeding, dressing, and writing. We have also previously used the simulated feeding and dressing tasks for similar reasons in younger groups of participants (Schaefer & Lang, 2012; Schaefer et al., 2013). In this study, the simulated feeding task required participants to spoon two raw kidney beans at a time from a center proximal starting cup to three distal target cups as fast as possible. The cups (9.5cm in diameter) were secured to a board (60.5cm x 40.0cm), with three distal target cups secured radially at 45°, 90°, and 135° around the proximal starting cup (Fig. 1A). The board was placed such that the cups were oriented at the participant's midline, with the proximal starting cup about 15.24cm from the participant's midline. Participants performed 15 repetitions per trial. Thirty beans were placed in the starting proximal cup and participants were required to spoon them, two at a time, into the distal target cups. At the beginning of each trial, participants picked up a spoon with their non-dominant hand and spooned two beans at a time into each distal target cup, working from left to right. Participants were instructed to spoon two beans at a time and not drop beans off the spoon while transferring beans from the starting proximal cup to distal target cup. If the participants spooned more or less than two beans or drop a bean, they were reminded to follow the instructions. The trial ended when the participant finished spooning the beans into the distal target cups and put the spoon back down on the board. The measure of performance for each trial was the time taken to complete the 15 repetitions (i.e. “trial time”), with faster times indicating better performance. As noted in our previous studies (Schaefer & Lang, 2012; Schaefer et al., 2013), this task has been adapted from a clinically relevant assessment of hand function (Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969).

The simulated dressing task required participants to fasten buttons as quickly as possible with the non-dominant hand. Ten buttons (2.5cm in diameter) were sewn to heavyweight linen fabric attached to a wooden board (50.4cm x 50.2cm) (Fig. 1B). The buttons were sewn 5.3cm apart from each other, and 3.0cm from the edge of the fabric. The buttonholes were 3.7cm in length. Fabric weight (65.6 g/m^2) and thread count (15 per cm) was measured according to ASTM Test Methods D3776-96 and D3775-98 (ASTM International, 2001a, 2001b). Prior to starting the dressing task, the placket with buttons was folded over the board and the placket with buttonholes was flat on the table (Fig. 1B). Participants were instructed to fasten each button completely through the hole before moving on to the next button. The task started when the participant picked up the buttonhole side of the fabric to fold over the board, and ended when the participant fastened the last button. The participant started at the distal end of the button board and ended at the proximal end of the button board. The measure of performance was the time taken to fasten all 10 buttons (i.e. “trial time”), with faster times indicating better performance.

The writing task required participants to trace the phrase “browndog” within a standard template as fast as possible, while making as few errors as possible. Figure 1C illustrates this standard template. Participants were instructed to, “Write in between the double lines of the letters as fast as possible without picking your pen up, while at the same time making as few errors as possible.” The phrase was adapted from the pangram “The quick brown fox jumps over the lazy dog” yet using only the words that contained letters that could easily be written in cursive. On the template, the phrase was printed in cursive font (Calfish Script Pro Regular) and 24cm long, with the tallest letter being 4.5cm (Fig. 1C). Trial time started when the participant made contact with the pen and the paper, and ended when the participant reached the end point of the last letter. There were two measures of performance for the writing task. The primary measure of performance was the time taken to completely write the phrase within the lines (i.e. “trial time”), with faster times indicating better performance. The secondary measure of performance was the number of errors. An error was defined as writing outside the lines, touching a line with the pen, or picking the pen up off the paper. This writing task was adapted from the ‘star-tracing task’ (Gabrieli, Corkin, Mickel, & Growdon, 1993; Kumar & Mandal, 2005; Milner, 1962). Unlike the simulated feeding and dressing task described above, this was the only experimental task that we have not used previously to test generalization of motor learning. We developed this task as a standardized and quantifiable proxy for handwriting, given that it often becomes more difficult with age (Walton, 1997). We also anticipated that this task would be a reasonable probe for generalization, given that generalization has been shown to occur between various conditions (Rouleau, Salmon, & Vrbancic, 2002) and between hands (Kumar & Mandal, 2005) when performing the star-tracing task, from which the writing task was derived.

Participants performed all motor tasks while seated and with only their non-dominant hand. Participants were instructed to focus on completing the tasks as quickly as possibly, emphasizing movement speed. However, these tasks may not have been treated as speeded tasks, despite instructions, due to older adults focusing on the accuracy component of each task. Because eating with a spoon, manipulating buttons, and writing are typically performed with the dominant hand (Oldfield, 1971; Rigal, 1992), these experimental tasks may be well-practiced already and may not improve with training or generalization due to ceiling effects. Thus, to ensure task novelty and minimize pre-existing ceiling effects, all motor tasks were performed with the non-dominant hand. Participants were given no information regarding performance and movement strategy during training. Thus, a discovery learning approach was used in this study in which participants used trial and error to adapt their movement strategies over time (Orrell, Eves, & Masters, 2006; Taubert et al., 2010).

Experimental protocol

This study took place over three consecutive days (Fig. 2). All assessments (described above in “Participants”) were completed on day one. Immediately following these assessments, participants performed one trial of all three tasks in a random order with their non-dominant hand; this established their pre-test motor performance. Participants were then randomly assigned to the training group or the control group.

Training group

Immediately after establishing pre-test performance on day one, participants in the training group completed 50 trials of the simulated feeding task (Fig. 2). On days two and three, participants completed 50 additional trials per day of the simulated feeding (Fig. 2). Thus, the dose of task-specific training for simulated feeding was 2,250 total repetitions administered over the course of three days (15 repetitions per trial x 50 trials per day x 3 days). This dose has been shown previously to yield generalization in other populations (Schaefer et al., 2013). Then, immediately following training on day three, participants again completed one trial of all three tasks in a random order with their non-dominant hand to establish their post-test motor performance (Fig. 2). Grip strength was measured again at this time to ensure that improvements in motor performance were due to task-specific training rather than muscle strengthening.

Control group

In contrast to the training group, participants in the control group did not receive any task-specific training on any motor task. Instead, they returned on day three to complete one more trial each of the simulated feeding, dressing, and writing tasks with their non-dominant hand (Fig. 2) as their post-test performance.

Data analysis

JMP 8.0 (SAS Institute Inc., Cary, NC) was used for all statistical analysis (α=.05). *T*-tests and chi-square tests determined whether the training and control groups were matched for age, sex, education, general cognitive status, tactile sensation, and pre-test non-dominant hand grip strength. Three separate 2 x 2 repeated-measures analyses of variance (ANOVAs), one for each motor task, determined the effects of group (training vs. control) and session (pre- vs. post-test) on trial time, with group and session as between and within-subject factors, respectively. When warranted, posthoc analyses were conducted using the Tukey-Kramer Honestly Significant Difference (HSD). Based on our hypotheses, we expected a significant interaction between group and session on trial time, such that only the training group would improve from pre- to post-test, suggesting that training had generalized. Because performance on the writing task was measured not only by trial time, but also by the number of errors, an additional 2x2 repeated measures ANOVA determined the effects of group (training vs. control) and session (pre- vs. post-test) on the number of errors made in the writing task. Given the range of MoCA scores and ages within the training group, we also tested whether the amount of improvement (i.e. change score) for each motor task was related to three participant characteristics: MoCA score, age, and grip strength. To calculate each training group participant's change scores for each motor task, we subtracted post-test trial time from the pre-test trial time (pre minus post). This score also normalized pre-test performance across participants by accounting for varying levels of pre-test performance. One-sample *t* tests were then used to determine whether the training group's change scores were significantly different from zero for the feeding, dressing, and writing tasks. We then used Pearson Product Moment correlations to test the extent to which these change scores for the training group were related to specific participant characteristics (MoCA, age, and pre-test non-dominant grip strength).

RESULTS

Participant characteristics

Table 1 summarizes the participant characteristics for the training (n=11) and control group (n=10). Age ($t(1)=.14$, $p = .71$), MoCA score ($t(1)=1.51$, $p=.23$), sex ($X^2(1, n=21)=1.18$, $p = .27$), and sensation ($t(1)=.93$, $p=.34$). The groups were not different between pre-test non-dominant grip strength ($t(1)=.17$, $p=.67$). Moreover, non-dominant hand grip strength was not different across participants from pre-test to post-test ($t(1)=.0012$, $p=.97$). The training group did, however, had an average of two years less education compared to the control group ($t(1)=7.73$,

$p<.05$). Although the design of the study was to test training over three days, two participants were unable to complete the entire dose over three days, due to fatigue. Therefore the remaining trials were carried over to the next training day to be completed (i.e. training dose administration equaled four days).

Performance of the simulated feeding task: Evidence of motor learning

As shown in Figure 3A, participants in the training group improved their performance on the simulated feeding task, as shown by a decrease in mean trial time over the course of task-specific training. There was a significant interaction between group (training vs. control) and session (pre- vs. post-test) on trial time ($F_{1,1}=5.28$, $p<.05$). Post-hoc analyses showed that, as hypothesized, mean trial time for the training group was significantly lower (i.e. faster) at post-test compared to pre-test ($p<.05$), whereas the control group showed no significant change from pre- to post-test ($p>.05$). Moreover, mean trial times at pre-test were similar between the training and control groups ($p>.05$), indicating that both groups' baseline performances were comparable at the start of the study (Fig. 3B).

Performance of the simulated dressing and writing tasks: Evidence of generalization?

In contrast to our hypothesis, there were no significant interactions between group and session on mean trial time for the dressing task ($F_{1,1} = 0.69$, $p =.42$) or the writing task ($F_{1,1}=1.97$, $p =.17$). There were no significant main effects of group on mean trial time for the dressing task ($F_{1,1}=.57$; $p =.46$) or the writing task ($F_{1,1}=.35$; $p =.56$). There were also no significant main effects of session on mean trial time for the dressing task ($F_{1,1} = 0.22$; $p =.64$) or the writing task ($F_{1,1}=.0001$; $p =.99$). These results are shown collectively in Figure 4.

The number of errors was a secondary measure of performance for the writing task. Similar to the above results for trial time, however, there was no significant interaction between group and session ($F_{1,1}$=1.24; *p* =.28), nor a main effect of group ($F_{1,1}$=.56; *p* =.46) on the number of writing task errors. The mean number of writing task errors is shown for each group in Figure 5.

To illustrate the extent to which performance on the three motor tasks changed from pre- to post-test, we calculated change scores for each participant. Figure 6 shows the mean change scores for the training and control groups for the feeding, dressing, and writing tasks. Positive values indicate improved performance. Consistent with our ANOVA results above, there was little change from pre- to post-test for all groups and tasks, except for the training group in the feeding task. One-sample t-tests indicated that no change scores were significantly different from zero (all *p*-values >.18), except for the training group in the feeding task (*p*<.05).

Effect of participant characteristics on learning and generalization

To further interpret the above findings, we tested whether MoCA score, age, and pre-test non-dominant grip strength of participants in the training group were related to their amount of learning and generalization (i.e. change scores) using Pearson Product Moment coefficients (r^2 values). Figure 7 summarizes these findings, with no significant linear relationships between change score and MoCA score (left column), age (center column), or pre-test non-dominant grip strength (right column) for the feeding (top row), writing (middle row), or dressing (bottom row) tasks. All r^2 values ranged from .0001 to .195 (p=.17 to .97). Thus, in this small sample, the amount of motor learning or generalization was unrelated to age, global cognitive status, or grip strength.

DISCUSSION

The purpose of this study was to test whether healthy older adults would generalize task-specific training across different functional motor tasks. We hypothesized that only the participants who completed task-specific training of the simulated feeding task would improve their performance on that task (i.e. motor learning) and the two other untrained tasks (i.e. generalization) from pre-test to post-test. As predicted, the training group improved performance on the simulated feeding task with three days of training, whereas the control group who received no training on that task did not. These results supports recent findings that motor learning occurs through task-specific training (Arya, Garg, Sharma, Agarwal, & Aggarwal, 2012; Blennerhasset & Dite, 2004; Christie, Bedford, & McCluskey, 2011; Michaelsen et al., 2006), that is repetitive, salient, and specific (Bayona et al., 2005; Hubbard et al., 2009), but also extends the idea of experience-dependent learning in older adults (Ausenda & Carnovali, 2011; Roderigue, Kennedy, & Raz, 2005; Voelcker-Rehage & Willimczik, 2006). Contrary to our other hypothesis, however, we found that the training group did not show any significant improvement from pre- to post-test on the untrained simulated dressing and writing tasks. These results suggest that although there was motor learning through task-specific training, this degree of learning did not generalize to improve dressing and writing task performance. In addition, general cognitive status (MoCA), age, and grip strength did not appear to affect the amount of motor learning or generalization (i.e. change score from pre- to post-test).

Our most important finding was that motor learning, as a result of task-specific training on the feeding task, did not generalize to the dressing and writing tasks in older adults. This is contrary to our recent findings in adults with post-stroke hemiparesis, demonstrating that a comparable dose of task-specific training (~2,250 repetitions) on the feeding task over five days generalized to other untrained upper extremity tasks, the simulated dressing task and the block sorting task (Schaefer et al., 2013). Similarly, in young healthy adults, one day (~350 repetitions) of task-specific training on the feeding task generalized another untrained upper extremity task, the simulated dressing task (Schaefer & Lang, 2012). Unlike these previous findings, older adults in this current study were not able to generalize motor learning after task-specific training.

Numerous factors may contribute to the lack of generalization of motor learning in this current study. One factor may be an effect of age, such that younger and middle-aged adults may be able to generalize motor learning to a greater degree than older adults. In our previous studies, the mean ± SD age of participants was 58.9 ± 7.5 years (Schaefer et al., 2013) and 26.6 ± 4.3 years (Schaefer & Lang, 2012), which is lower than that of the participants in this current study (76.7 ± 6.6 years). Generalization and the rate at which it occurs may be age-dependent, much like motor performance and learning as well. Aging is associated with declines in motor performance and learning. For example, older adults take much longer to complete a variety of tasks such as point-to-point movements (Cooke, Brown, & Cunningham, 1989; Goggin & Meeuwsen, 1992; Ketcham, Seidler, Van Gemmert, & Stelmach, 2002), handwriting (Conteras-Vidal, Teulings, & Stelmach, 1998; Dixon, Kurzman, & Friesen, 1993), and grasping (Bennett & Castiello, 1994; Carnahan, Vandervoort, & Swanson, 1998). Similarly, reaction time slows with aging as observed in a variety of motor tasks (Fozard et al., 1994; Seidler, 2006; Walker et al., 1997). Aging can also affect the amount and rate of learning new skills, as evidenced by slower acquisition of a ball-juggling task (Perrot & Bertsch, 2007), a visuomotor task (Smith et al., 2005), and a walker to car transfer task (Tunney et al., 2003), compared to younger adults. Thus, there is substantial evidence that aging affects motor learning. Further studies are needed, however, to determine whether or not older adults are unable to generalize learned information at all, or whether the rate of generalization is slower as compared to young adults.

A second yet related factor affecting generalization of motor learning may be the relationship between the trained and untrained motor tasks. Our previous data suggested that spatiotemporal similarity between tasks (i.e. comparable hand paths and shoulder/elbow joint rotations) is not necessary for generalization to occur (Schaefer et al., 2013). As noted above, however, participants in this study were older compared to those in the previous studies, which suggests that with advancing age, generalization may be more difficult when tasks are functionally or spatiotemporally dissimilar, such as feeding, dressing, and writing. Moreover, although training on the feeding task did not improve trial times or error rates on the dressing and writing tasks in this study, there may be other learning-related improvements that were not tested for, such as changes in variability (Sosnoff & Newell 2006) or attentional requirements (Floyer-Lea & Matthews 2004; Luu, Tucker, & Stripling, 2007). Generalization of motor learning is likely characterized by a number of variables; thus, future studies are needed to quantify generalization in metrics that are relevant to advancing age.

Finally, the training schedule may be a third factor that affects the generalization of motor learning. In this current study, participants performed 2,250 repetitions of the feeding task over three days (see Fig. 2). This dose of training is similar to that in our previous study, except that it was ‘administered’ over five days (Schaefer et al., 2013). Thus, the participants in the previous study had additional time to consolidate their motor learning compared to the participants in this study. Because consolidation is the process of transferring information from short-term memory to long-term memory (McGaugh, 2000), it plays a critical role in motor learning (Krakauer & Shadmehr, 2006; Maquet, 2001; Peigneux, Laureys, Delbeuck, & Maquet, 2001; Shadmehr & Brashers-Krug, 1997; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002). Consolidation may also be necessary for generalization (Censor, 2013; Kantak, Sullivan, Fisher, Knowlton, & Winstein, 2011; Witt, Margraf, Bieber, Born, & Deuschl, 2010), which suggests that a given dose of task-specific training could be administered over a longer period to enhance generalization in older adults.

These results suggest that the generalization of motor learning may be susceptible to aging processes, consistent with previous studies that show age-related declines in motor learning. One consideration for future studies in aging and motor learning is how to best ‘capture’ how and what older adults do learn. In this study, movement speed was emphasized. Although participants were instructed to complete tasks as quickly as possible, they may have instead focused on maintaining accuracy, given the tendency for older adults to emphasize accuracy rather than speed (Brébion, 2001; Salthouse, 1979). Thus, measures of accuracy may be more appropriate for quantifying motor performance in older adults rather than movement speed. Nevertheless, these findings have direct implications for older patient populations in physical rehabilitation, where there is not enough time to train specifically at a high dose on necessary ADLs. Collectively, the potential factors previously listed suggest an interaction between what, when, and how much task-specific training is needed in rehabilitation to maximize not only motor learning but also generalization in older patient populations.

REFERENCES

Andrews, A. W., Thomas, M. W., & Bohannon, R. W. (1996). Normative values for isometric muscle force measurements obtained with hand-held dynamometers. *Physical Therapy*, *76*(3), 248-259.

Arya, K. N., Verma, R., Garg, R. K., Sharma, V. P., Agarwal, M., & Aggarwal, G. G. (2012). Meaningful task-specific training (MTST) for stroke rehabilitation: A randomized controlled trial. *Topics in Stroke Rehabilitation, 19*(3). 193-211.

Ausenda, C. D., & Carnovali, M. (2011). Transfer of motor skill learning from the healthy hand to the paretic hand in stroke patients: a randomized controlled trial. *European Journal of Physical and Rehabilitation Medicine, 47*(3), 417-425.

Bayona, N. A., Bitensky, J., Salter, K., & Teasell, R. (2005). The role of task-specific training in rehabilitation therapies. *Topics in Stroke Rehabilitation*, *12*(5), 58-65.

Bennett, K. M., & Castiello, U. (1994). Reach to grasp: changes with age. *Journal of Gerontology*, *49*(3), 1-7.

Blennerhassett, J., & Dite, W. (2004). Additional task-related practice improves mobility and upper limb function early after stroke: A randomized controlled trial. *The Australian Journal of Physiotherapy, 50*(4), 219-224.

Brébion, G. (2001). Language processing, slowing, and speed/accuracy trade-off in the elderly. *Experimental Aging Research, 27*(1), 137-150.

Carnahan, H., Vandervoort, A. A., & Swanson, L.R. (1998). The influence of aging and target motion on the control of prehension. *Experimental Aging Research, 24*(3), 289-306.

Censor, N. (2013). Generalization of perceptual and motor learning: A causal link with memory encoding and consolidation? *Neuroscience, 250,* 201-207.

Christie, L., Bedford, R., & McCluskey, A. (2011). Task-specific practice of dressing tasks in a hospital setting improved dressing performance post-stroke: A feasibility study. *Australian Occupational Therapy Journal, 58*(5), 364-369.

Contreras-Vidal, J. L., Teulings, H. L., & Stelmach, G. E. (1998). Elderly subjects are impaired in spatial coordination in fine motor control. *Acta Psychologica (Amst), 100*(1-2), 25-35.

Cooke, J. D., Brown, S. H., & Cunningham, D. A. (1989). Kinematics of arm movements in elderly humans. *Neurobiology of Aging, 10*(2), 159-165.

Covinsky, K. E., Lindquist, K., Dunlop, D. D., & Yelin, E. (2009). Pain, functional limitations, and aging. *Journal of the American Geriatrics Society, 59*(9), 1556-1561.

Dixon, R. A., Kurzman, D., & Friesen, I. C. (1993). Handwriting performance in younger and older adults: Age, familiarity, and practice effects. *Psychology and Aging, 8*(3), 360-370.

Eber, J. T. (2012). *Aging and Older Adulthood (3rd ed.).* Chichesester: John Wiley & Sons.

Floyer-Lea, A., & Matthews, P. M. (2004). Changing brain networks for visuomotor control with increased movement automaticity. *Journal of Neurophysiology, 92*(4), 2405-2412.

Fozard, J. L., Vercryssen, M., Reynolds, S. L., Hancock, P. A., & Quilter, R. E. (1994). Age differences and changes in reaction time: The Baltimore Longitudinal Study of Aging. *Journal of Gerontology, 49*(4), 179-189.

Gabrieli, J. D., Corkin, S., Mickel, S. F., & Growdon, J. H. (1993). Intact acquisition and long-term retention of mirror-tracing skill in Alzheimer's disease and in global amnesia. *Behavioral Neuroscience, 107*(6), 889-910.

Goggin, N. L., & Meeuwsen, H. J. (1992). Age-related differences in the control of spatial aiming movements. *Research Quarterly for Exercise and Sport, 63*(4), 366-372.

Hinder, M. R., Schmidt, M. W., Garry, M. I., Carroll, T. J., & Summers, J. J. (2011). Absence of cross-limb transfer of performance gains following ballistic motor practice in older adults. *Journal of Applied Physiology, 110*(1), 166-175.

Hubbard, I. J., Parsons, M. W., Neilson, C., & Carey, L. M. (2009). Task-specific training: Evidence for and translation to clinical practice. *Occupational Therapy International, 16*(3-4). 175-189.

Hunter, S. K., Thompson, M. W., & Adams, R. D. (2001). Reaction time, strength, and physical activity in women aged 20-89 years. *Journal of Aging and Physical Activity, 9*, 32-42.

Jebsen, R. H., Taylor, N., Trieschmann, R. B., Trotter, M. J., & Howard, L. A. (1969). An objective and standardized test of hand function. *Archives of Physical Medicine and Rehabilitation, 50,* 311-319.

Kantak, S. S., Sullivan, K. J., Fisher, B. E., Knowlton, B. J., & Winstein, C. J. (2011). Transfer of motor learning engages specific neural substrates during motor memory consolidation dependent on the practice structure. *Journal of Motor Behavior, 43*(6), 499-507.

Katz, S., Ford, A. B., Moskowitz, R. W., Jackson, B. A., & Jaffe, M. W. (1963). Studies of illness in the aged. The index of ADL: A standardized measure of biological and psychosocial function. *Journal of the American Medical Association*, *185*, 914-919.

Ketcham, C. J., Seidler, R. D., Van Gemmert, A. W., & Stelmach, G. E. (2002). Age-related kinematic differences as influenced by task difficulty, target size, and movement amplitude. *Journals of Gerontology: Psychological Sciences and Social Sciences, 57*(1), 54-64.

Kimberley, T. J., Samaargia, S., Moore, L. G., Shakya, J. K., & Lang, C. E. (2010). Comparison of amounts and types of practice during rehabilitation for traumatic brain injury and stroke. *Journal of Rehabilitation Research and Development, 47*(9), 851-862.

Krakauer, J. W., & Shadmehr, R. (2006). Consolidation of motor memory. *Trends in Neurosciences, 29*(1), 58-64.

Kumar, S., & Mandal, M. K. (2005). Bilateral transfer of skill in left- and right-handers. *Laterality, 10*(4), 337-344.

Lang, C. E., Macdonald, J. R., Reisman, D. S., Boyd, L., Jacobson Kimberley, T., Schindler-Ivens, S. M., Hornby, T. G., Ross, S. A., & Scheets, P. L. (2009). Observation of amounts of movement practice provided during stroke rehabilitation. *Archives of Physical Medicine and Rehabilitation, 90*(10), 1692-1698.

Langan, J., & Seidler, R. D. (2011). Age differences in spatial working memory contributions to visuomotor adaptation and transfer. *Behavioural Brain Research, 225*(1), 160-168.

Luu, P., Tucker, D. M., & Stripling, R. (2007). Neural mechanisms for learning actions in context. *Brain Research, 1179,* 89-105.

Mathiowetz, V., Volland, G., Kashman, N., & Weber, K. (1985). Adult norms for the Box and Block Test of manual dexterity. *The American Journal of Occupational Therapy, 39*(6), 386-391.

Maquet, P. (2001). The role of sleep in learning and memory. *Science, 294*, 1048-1052.

McGaugh, J. L. (2000). Memory – a century of consolidation. *Science, 287*(5451), 248-251.

Michaelsen, S. M., Dannenbaum, R., & Levin, M. F. (2006). Task-specific training with trunk restraint on arm recovery in stroke: Randomized control trial. *Stroke, 37*(1), 186-192.

Milner, B. (1962). Les troubles de la memoire accompagnant des lesions hippocampiques bilaterales [Memory impairment accompanying bilateral hippocampal lesions]. In *Psychologie de l'hippocampe*. Paris: Centre National de la Recherche Scientifique.

Nasreddine, Z. S., Phillips, N. A., Bedirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA; A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society, 53*(4), 695-699.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*(1), 97-113.

Orell, A. J., Eves, F. F., & Masters, R. S. (2006). Implicit motor learning of a balancing task. *Gait and Posture, 23*(1), 9-16.

Peigneux, P., Laureys, S., Delbeuck, X., & Maquet, P. (2001). Sleeping brain, learning brain. The role of sleep for memory systems. *Neuroreport, 12*(18), 111-124.

Perrot, A., & Bertsch, J. (2007). Role of age in relation between two kinds of abilities and performance in acquisition of new motor skill. *Perceptual and Motor Skills, 104*(1), 91-101.

Rigal, R. A. (1992). Which handedness: Preference or performance? *Perceptual and Motor Skills, 75*(3 Pt 1), 851-866.

Rodrique, K. M., Kennedy, K. M., & Raz, N. (2005). Aging and longitudinal change in perceptual motor skill acquisition in healthy adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 60*(4), 174-181.

Rouleau, I., Salmon, D. P., & Vrbancic, M. (2002). Learning, retention and generalization of a mirror tracing skill in Alzheimer's Disease. *Journal of Clinical and Experimental Neuropsychology, 24*(2), 239-250.

Salthouse, T. A. (1979). Adult age and the speed-accuracy trade off. *Ergonomics, 22*(7), 811-821.

Schaefer, S. Y., & Lang, C. E. (2012). Using dual tasks to test immediate transfer of training between naturalistic movements: A proof-of-principle study. *Journal of Motor Behavior, 44*(5), 313-327.

Schaefer, S. Y., Patterson, C. B., & Lang, C. E. (2013). Transfer of training between distinct motor tasks after stroke: Implications for task-specific approaches to upper-extremity neurorehabilitation. *Neurorehabilitation and Neural Repair, 27*(7), 602-612.

Schmidt, R. T., & Toews, J. V. (1970). Grip strength as measured by the Jamar dynamometer. *Archives of Physical Medicine and Rehabilitation, 51*(6), 321-327.

Schmidt, R. A., & Lee, T. D. (1999). *Motor Control and Learning* (3rd ed.). Champaign, IL: Human Kinetics.

Seidler, R. D. (2006). Differential effects of age on sequence learning and sensorimotor adaptation. *Brain Research Bulletin, 70*(4-6), 337-346.

Seidler, R. D. (2007). Aging affects motor learning but not savings at transfer of learning. *Learning & Memory, 14*(1-2), 17-21.

Seidler, R. D., & Noll, D. C. (2008). Neuroanatomical correlates of motor acquisition and motor transfer. *Journal of Neurophysiology, 99*(4), 1836-1845.

Shadmehr, R., & Brashers-Krug, T. (1997). Functional stages in the formation of human long-term motor memory. *The Journal of Neuroscience, 17*(1), 409-419.

Smith, C. D., Walton, A., Loveland, A. D., Umberger, G.H., Krysio, R.J., & Gash, D.M. (2005). Memories that last in old age: Motor skill learning and memory preservation. *Neurobiology of Aging, 26*(6), 883-890.

Sosnoff, J. J., & Newell, K. M. (2006). The generalization of perceptual-motor intra-individual variability in young and old adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 61*(5), 304-310.

Taubert, M., Draganski, B., Anwander, A., Müller, K., Horstmann, A., Villringer, A., & Ragert, P. (2010). Dynamic properties of human brain structure: Learning-related changes in cortical areas and associated fiber connections. *Journal of Neuroscience, 30*(35), 11670-11677.

Tunney, N., Taylor, L. F., Gaddy, M., Rosenfield, A., Pearce, N., Tamanini, J., & Treby, A. (2003). Aging and motor learning of a functional motor task. *Physical and Occupational Therapy in Geriatrics, 21,* 1-16.

Voelcker-Rehage, C., & Willimczik, K. (2006). Motor plasticity in a juggling task in older adults – a developmental study. *Age and Ageing, 35*(4), 422-427.

Voelcker-Rehage, C. (2008). Motor-skill learning in older adults – a review of studies on age-related changes. *European Review of Aging and Physical Activity, 5,* 5-16.

Walker, M. P., Brakefield, T., Morgan, A., Hobson, J. A., & Stickgold, R. (2002). Practice with sleep makes perfect: Sleep-dependent motor skill learning. *Neuron, 35*(1), 205-211.

Walker, N., Philbin, D. A., & Fisk, A. D. (1997). Age-related differences in movement control: Adjusting submovement structure to optimize performance. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 52*(1), 40-52.

Walton, J. (1997). Handwriting changes due to aging and Parkinson's syndrome. *Forensic Science International, 88*(3), 197-214.

Witt, K., Margraf, N., Bieber, C., Born, J., & Deuschl, G. (2010). Sleep consolidates the effector-independent representation of a motor skill. *Neuroscience, 171*(1), 227-234.

FIGURE CAPTIONS

Figure 1. Motor tasks. (A) Top view of the simulated feeding task. Proximal starting cup and distal target cups were secured to a board. Distal target cups were placed around the proximal starting cup at a distance of 10.7cm and at angles of 45°, 90°, and 135° around the proximal starting cup. Participants spooned beans from the proximal, starting cup to the distal target cups. (B) Top view of the simulated dressing task buttonboard. Buttons were fastened on the left panel of the button board and buttonholes were on the right panel of the button board. Participants fastened the buttons as quickly as possible starting from the distal end of the buttonboard. (C) Writing task template. Participants began to trace between the font's borders starting at the top of the 'b' and ending at the tail of the 'g'. Participants traced in between the boarder as fast as possible, while making as few errors as possible. Note: not actual size.

Figure 2. Diagram of training schedule across three days. After pre-test on Day 1, participants were randomized to a training group or a control group. Then, only the training group completed 50 trials of the feeding task on Days 1, 2, and 3, resulting in a training dose of 2,250 repetitions total. The control group did not receive any training. All participants were then evaluated again during Post-test on Day 3. Gray shading indicates sessions in which all motor tasks were completed in a random order.

Figure 3. (A) Group mean ± standard error trial time for the training group over 150 trials (50 trials/day x 3 days) of training on the feeding task. Faster trial times indicate better performance. (B) Mean ± standard error trial time for the pre- and post-test performance on the feeding task for the control and training groups. Faster trial times indicate better performance. *$p<.05$. Note:

the x-axis is the number of trials, not training day. Two people needed an additional fourth day to complete the training, 150 trials.

Figure 4. (A) Mean ± standard error trial time for the pre- and post-test performance on the dressing for the control and training groups. (B) Mean ± standard error trial time for the pre- and post-test performance on the writing task for the control and training groups. Faster trial times indicate better performance.

Figure 5. Mean ± standard error number of writing errors for the pre- and post-test performance on the writing task for the control and training group. Lower numbers of errors indicate better performance.

Figure 6. Mean ± standard error change score on the feeding, dressing, and writing tasks for the Control and Training group. Change score is the change in trial time from pre- to post-test; scores >0 indicate improvement from pre- to post-test. *$p<.05$

Figure 7. Linear relationships between each task's change score (pre minus post, in sec) and MoCA score, age, and pre-test non-dominant grip strength. **- - -** indicate best fit line with corresponding r^2 values. Note on display: MoCA score (left column), age (center column), grip strength (right column); feeding (top row), dressing (middle row), writing (bottom row). Scores >0 indicate improvement from pre- to post-test.

Table 1. Participant characteristics

Participant	Age (years)	Sex	MoCA[a]	Hand tested[b]	Education (years)	Sensation[c]	Grip strength (kg)[d]	Training dose administration (days)[e]
C01	71	F	24	L	18	2.38	26	
C02	72	M	26	L	16	3.61	43.33	
C03	71	F	26	L	22	2.83	18	
C04	71	M	27	L	24	3.61	29.33	
C05	86	M	6	L	16	3.61	29	
C06	84	M	21	L	22	3.61	33.33	
C07	80	F	24	L	18	2.83	8.33	
C08	87	M	22	L	12	3.61	14	
C09	83	F	20	L	19	2.83	2.67	
C10	68	M	30	R	20	4.31	37.9	
Control mean ± SD	77.3 ± 7.4		22.6 ± 6.5		18.7 ± 3.5		24.2 ± 13.1	
T01	73	F	23	L	17	2.83	22.67	3
T02	76	F	24	L	16	3.61	19.33	4
T03	80	M	19	L	12	3.61	37.3	4
T04	76	F	27	L	14	3.61	18.33	3
T05	68	M	27	L	16	2.83	41.33	3
T07	74	M	27	R	14	3.61	44	3
T08	68	F	28	L	14	3.61	31.33	3
T09	76	F	28	L	16	4.31	20.67	3
T10	75	M	23	R	21	3.61	32	3
T11	83	F	28	L	12	3.61	17.33	3
T12	89	F	24	L	12	3.61	6.67	3
Training mean ± SD	76.2 ± 6.1		25.3 ± 2.9		14.9 ± 2.7		26.5 ± 11.6	
Total mean ± SD	76.7 ± 6.6		24 ± 5.0		16.7 ± 3.6		25.37 ± 12	

Note: M: male; F: female

[a] Maximum MoCA score = 30. Scores above 26 are considered normal.

[b] Hand Tested was the non-dominant hand, determined by Edinburgh Handedness Questionnaire.

[c] Sensation of the hand tested. Semmes-Weinstein monofilaments.

[d] Grip Strength of the hand tested. Average of three consecutive measurements. Measured using a hand dynamometer.

[e] Timeline of training dose (150 trials) administration for the training group.

FIGURES

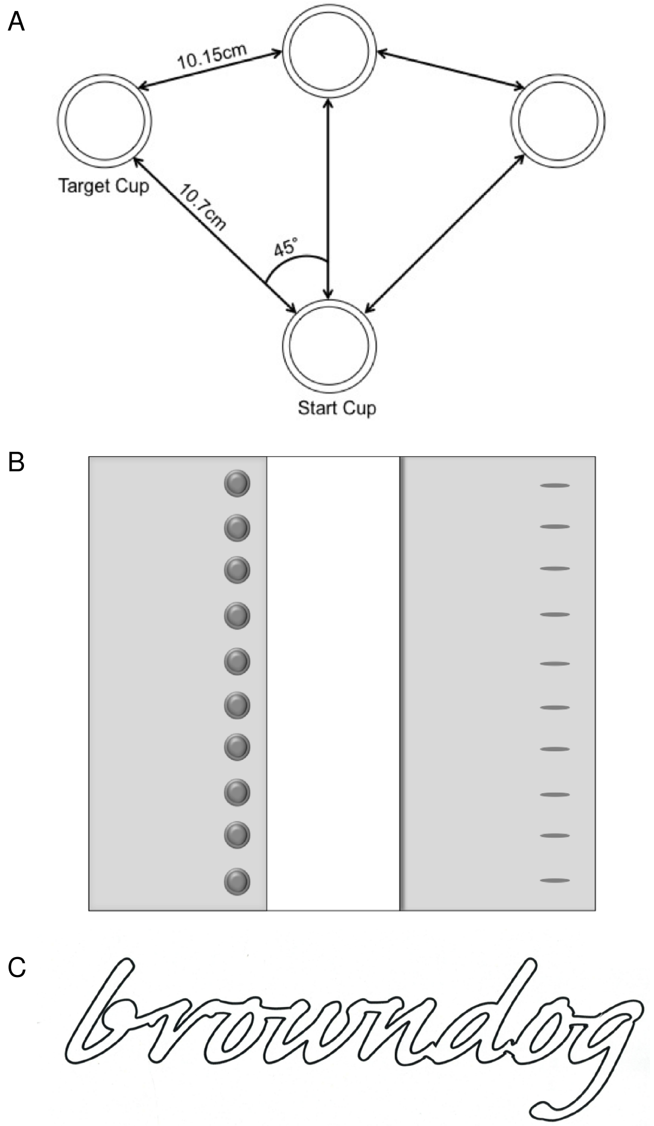

Figure 1.

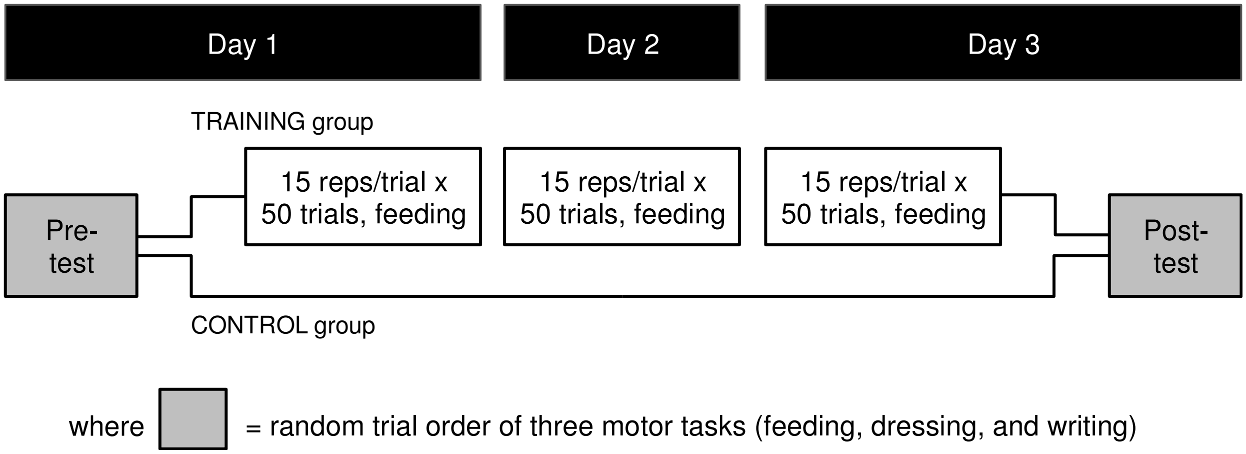
Day 1
Day 2
Day 3
TRAINING group
Pre-test
15 reps/trial x 50 trials, feeding
15 reps/trial x 50 trials, feeding
15 reps/trial x 50 trials, feeding
Post-test
CONTROL group
where ▨ = random trial order of three motor tasks (feeding, dressing, and writing)

Figure 2.

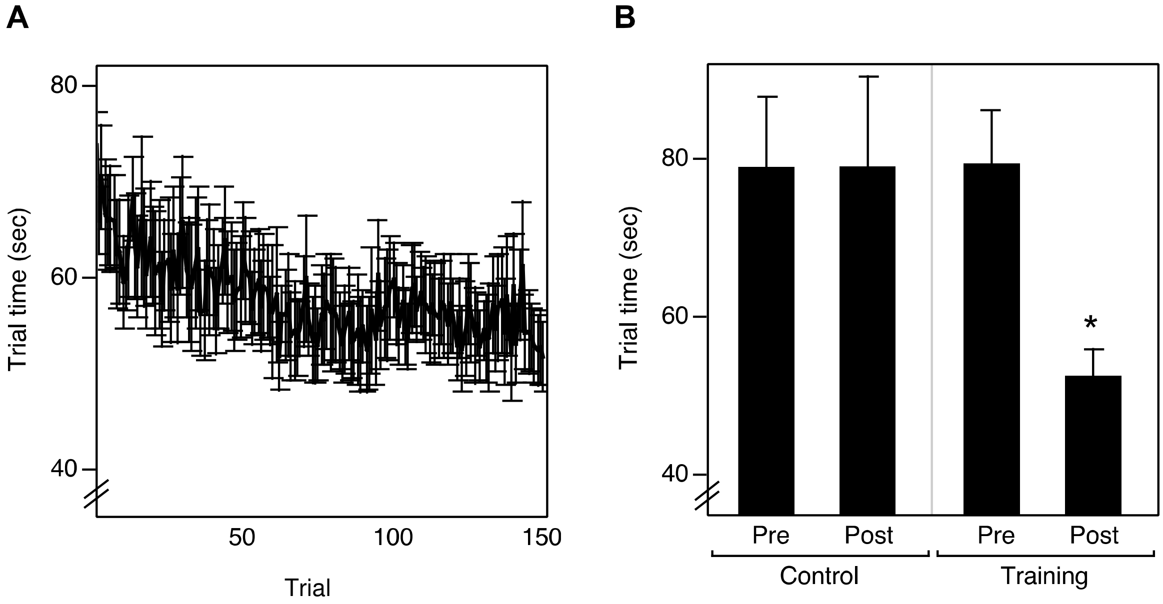
A
B
Trial time (sec)
80
60
40
50
100
150
Trial
Trial time (sec)
80
60
40
*
Pre
Post
Pre
Post
Control
Training

Figure 3.

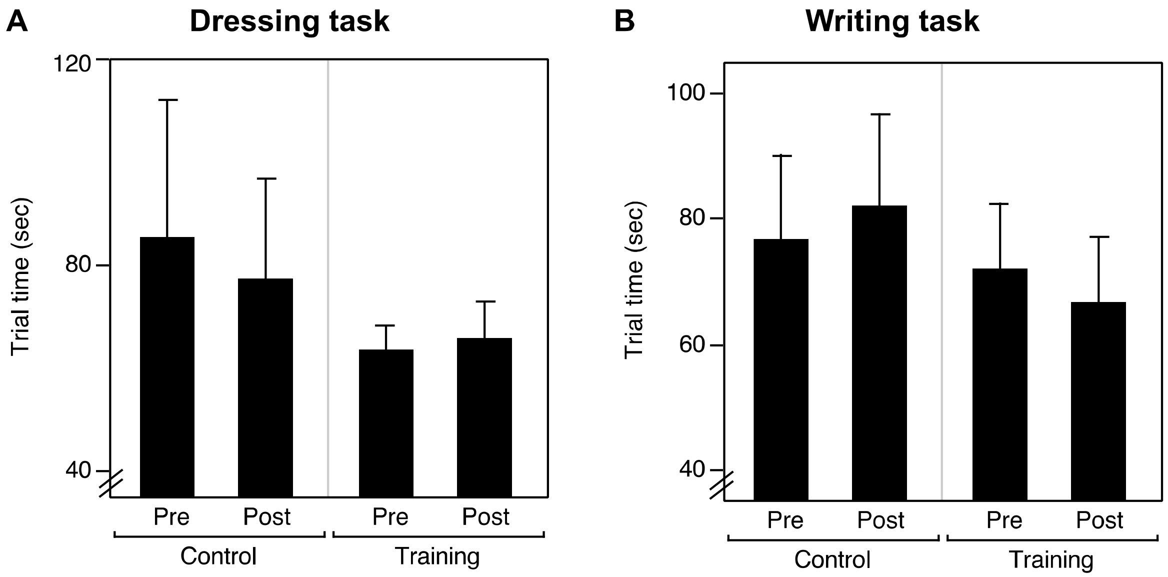
A
Dressing task
120
80
40
Trial time (sec)
Pre
Post
Pre
Post
Control
Training
B
Writing task
100
80
60
40
Trial time (sec)
Pre
Post
Pre
Post
Control
Training

Figure 4.

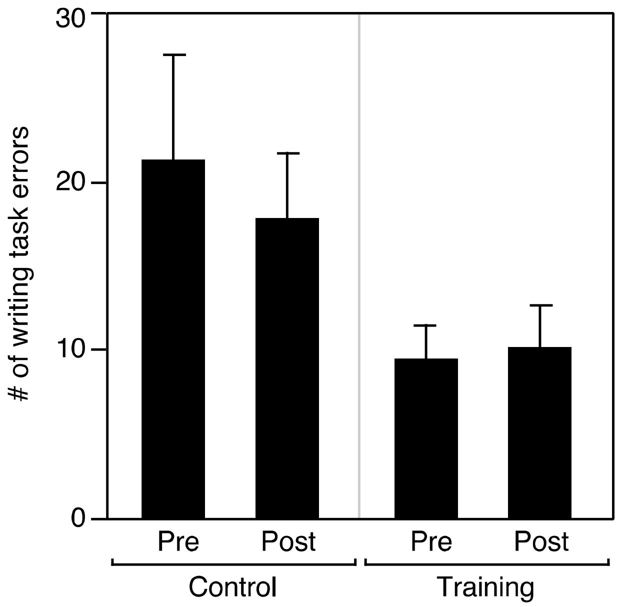
30
20
10
0
# of writing task errors
Pre
Post
Pre
Post
Control
Training

Figure 5.

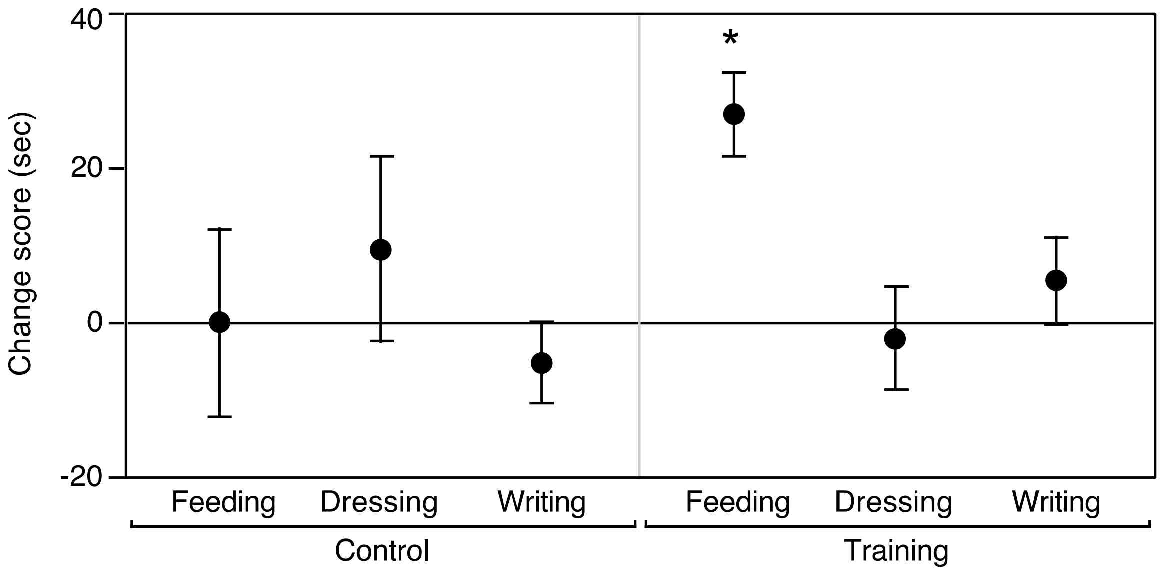
40
20
0
-20
Change score (sec)
*
Feeding
Dressing
Writing
Feeding
Dressing
Writing
Control
Training

Figure 6.

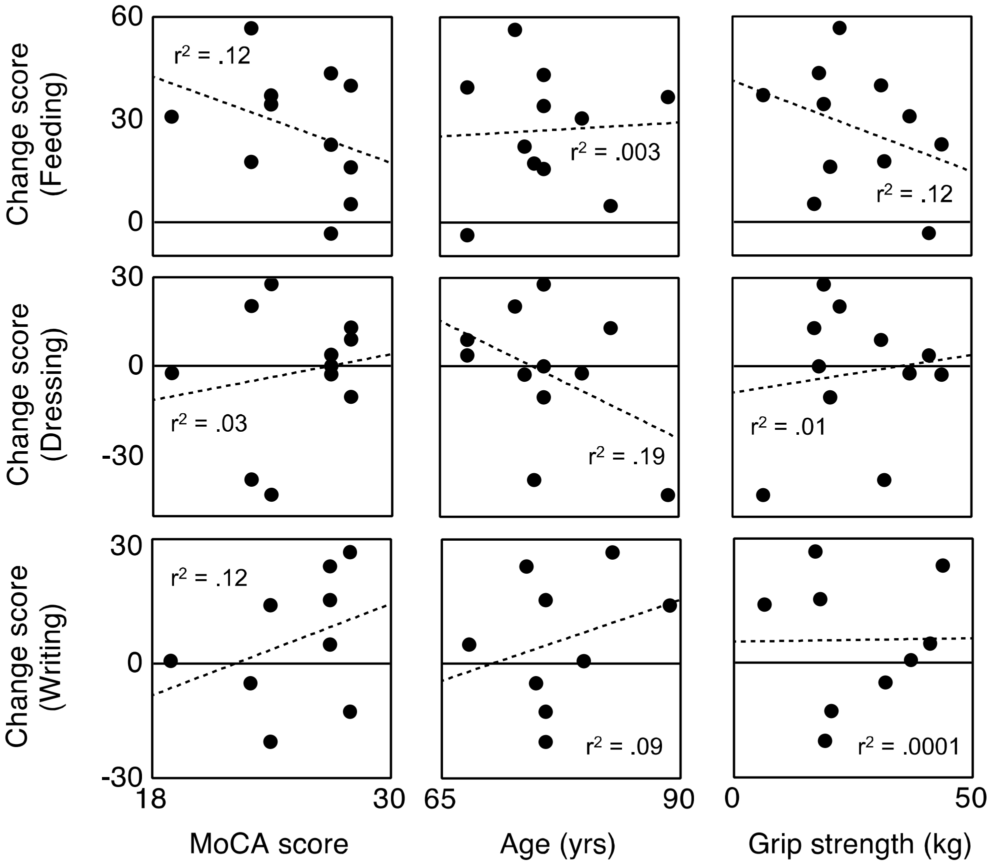
60
30
0
-30
30
0
-30
30
0
-30
Change score (Feeding)
Change score (Dressing)
Change score (Writing)
r² = .12
r² = .003
r² = .12
r² = .03
r² = .19
r² = .01
r² = .12
r² = .09
r² = .0001
18
30
65
90
0
50
MoCA score
Age (yrs)
Grip strength (kg)

Figure 7.