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# Age-Related Changes in Attention During Motor Learning

James E. Gardner

*Utah State University*

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# AGE-RELATED CHANGES IN ATTENTION DURING MOTOR LEARNING

by

James E. Gardner

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## Summary

Theories of motor learning predict that humans require high levels of attention to perform new motor tasks, but little to no attention for those that are well-learned. Thus, practicing a task may decrease the amount of attention required to perform it. To test this theoretical relationship between attention and task practice, we used a physiological proxy for attention known as electrodermal activity (EDA). We hypothesized that 1) EDA (proxy for attention) would decrease over the course of training and that 2) attention would be higher overall in older adults than in younger adults when performing the same task. This second hypothesis was based on the tendency for older adults to require more attention than younger adults during a given motor task. Two groups of participants (young adult- n=5; mean ± SD age=22.4 ± 2.1 yrs vs. older adult- n=5; age=75.8 ± 5.2 yrs) practiced 150 trials of a novel upper extremity task over three days. During each trial, we measured 1) task performance, defined as movement time (seconds, or s) and 2) EDA (μSiemens, or μS) using wrist-worn sensors. Contrary to our first hypothesis, EDA increased with practice, suggesting that additional training may be necessary to reduce the task's attentional requirements. Results did, however, support our second hypothesis, with higher EDA in older adults compared to younger adults throughout practice. This suggests that older adults may use more attention than younger adults to perform a given task in order to compensate for other age-related declines in sensorimotor function.

## Introduction

Naerly 50 years ago, Fitts and Posner (1967) presented a multi-stage theory of motor learning, which suggests that the attentional demands of a movement decrease with practice. In other words, as humans practice a task, the amount of attention needed to perform it decreases. The initial stage, or cognitive stage, is characterized by slow, inefficient movements and flagrant errors. Also, the person significantly attends to large parts of the movement during this stage. For example, when young children learn to write, they tend to write slowly, making elementary errors such as writing letters backwards. The second stage, or associative stage, shows greater fluidity of motion and a lesser degree of attention. However, the person still directs their attention to certain aspects of the movement. The final, or autonomous, stage shows consistent and automatic movement, as its name implies. At this stage, the movement has been learned and no longer requires high levels attention to be performed. Adults who have been writing for many years have reached this third stage, finding writing to be second nature or automatic. In summary, extensive practice is needed to reach the automaticity (little to no attentional demand) in motor learning.

While this theory connects motor performance and attentional state, a measure of attention is needed to further understand how motor learning takes place. While the idea of attention is intuitive, defining or measuring attention can be a challenge (Kahneman, 1973). One definition of attention is the finite capacity of an individual to process information (Woolacott and Shumway-Cook, 2002), given that dual-tasking (i.e. attending to two things at once) can impair performance on one or both tasks. Generally speaking, this impaired performance is thought to reflect how attentional capacity is finite. Thus, performing a motor task must require some portion of that limited capacity. If the attentional demand of performing two activities, such as a motor and non-motor task, at once exceeds the limited attentional capacity, then the decrement in performance, termed dual-task interference, of one or both activities allows us to make inferences about that attentional demand of a particular motor task (Woolacott and Shumway-Cook, 2002). Dual-task interference may be quantified by measuring how performance of two simultaneously performed tasks (e.g. one motor task and one non-motor task) changes before and after training on the motor task only. Improvement on the trained task but not the untrained task may indicate that the attentional demand of performing the motor task has decreased due to practice. However, the use of dual task is limited in that it can only give a snapshot of how we divide attention at a given moment. Attempting to measure changes in dual-task interference after every trial of motor training would result in *training* under dual-task conditions, in which both tasks would be practiced and possibly learned. This would make it difficult to determine whether decreased dual-task interference is due to practice on the first or second task. Thus, dual-task is limited in its ability to measure how attention changes over many trials of motor training.

An alternative measure of attention is electrodermal activity (EDA), a measure of skin conductance that depends on perspiration. Because the eccrine glands responsible for this secretion are innervated solely by the sympathetic nervous system, EDA has been used as a non-invasive physiological measure of a sympathetic neural drive. EDA be a proxy for emotion (Sequeira et al., 2009), stress (Setz et al., 2010), attention or cognitive load (Critchley, 2002; Shi et al., 2007; Shibagaki et al., 1994) and motor task difficulty (Macintosh et al., 2007). EDA results in continuous time-series data that gives more than a snapshot of attention for a given moment. Thus, EDA allows us to investigate attention during motor training without the limitations of dual-task. Therefore, the purpose of this study was to use EDA to measure attention over the course of motor learning. We hypothesized that attentional levels (as measured via EDA) would decrease throughout training.

Motor skill is associated with many activities performed throughout life (e.g. writing, grasping, walking, driving a car, etc.). However, there are impairments in sensorimotor function associated with the process of aging which may be responsible for the decrements in motor skill often seen in older adults (Ketcham and Stelmach, 2001). Though the process of motor learning takes place throughout life (e.g. learning to walk, learning to ride a bike, learning to walk with a cane), older adults tend to require more time and improve less on a given motor task than younger adults (Buch et al., 2003; Howard and Howard, 1997; Ruch, 1934; Seidler, 2006). Older adults also experience greater distractibility that young adults when performing multiple tasks simultaneously (Göthe et al., 2007). This is thought to be attributed to decreased processing efficiency in older adults, which suggests that a given motor task may require higher levels of attention from older adults than young adults to attain comparable levels of performance (Voelcker-Rehage and Alberts, 2007). The second purpose of this study, therefore, was to investigate whether the attentional demands of a motor tasks were different between young and older adults over the course of motor training. We hypothesized that older adults would require higher levels of attention compared to young adults throughout training, as evidenced as higher EDA.

## Methods

To test our hypotheses, we recruited two self-reported healthy groups of participants, a group of young adults (n=5; age=22.4 ± 2.1 yrs) and a group of older adults (n=5; age=75.8 ± 5.2 yrs). All participants in this study signed an informed consent form prior to beginning the experiment. This study was approved by the USU Institutional Review Board.

### *Motor Task Performance*

The task on which the participants trained was a modified version of an upper extremity motor task developed by our lab to simulate feeding (Schaefer et al., 2013). The task involved using a plastic spoon to scoop 30 beans, two at a time, from one proximal cup into one of three distal cups in series, for a total of 15 reaches. This comprised one trial of the task. Each participant completed 150 trials of the task over three days of training. To most effectively model the process of motor learning, the participants completed the task with their non-dominant hand, which ensured that the task was novel. The participants were instructed to complete the task as fast as possible. No instruction was given about how to manipulate the spoon. Motor performance was recorded as the time to complete one trial of the task as measured using a stopwatch.

### *Electrodermal Activity (EDA)*

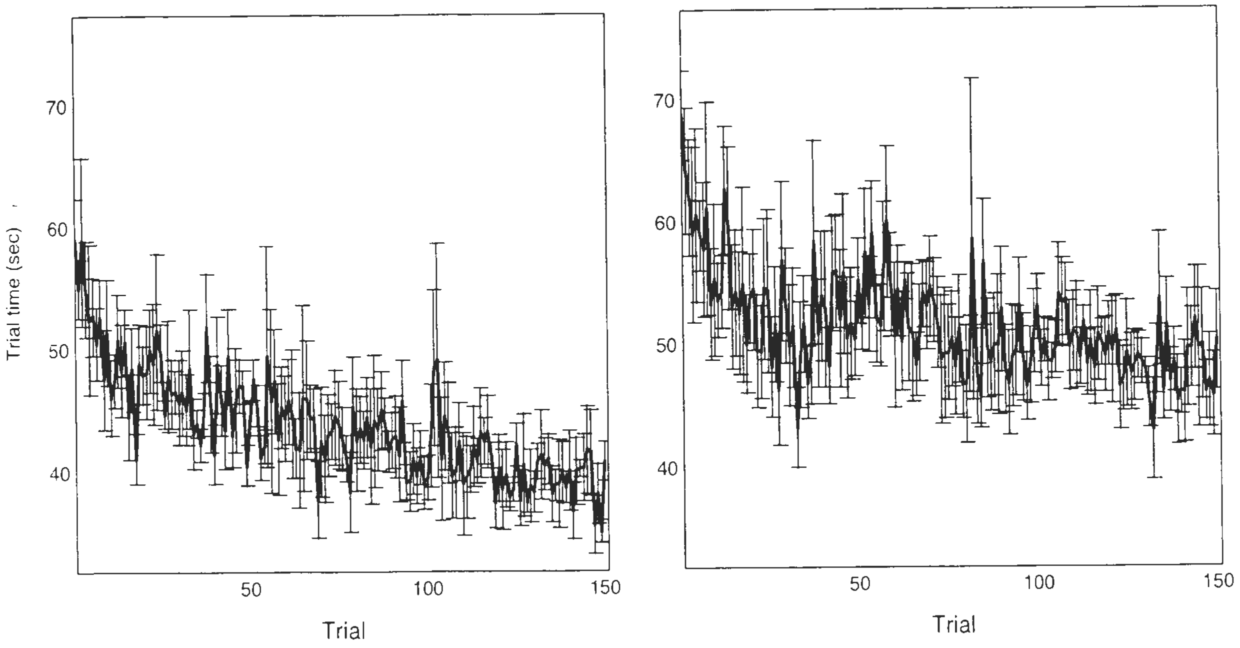
We measured EDA during motor training using Q-sensors (Affectiva, Waltham, MA). These wearable sensor modules use disposable Ag/AgCl electrodes (diameter of 15mm). Sensors were placed bilaterally (Obrist, 1963) on the ventral side of the wrist (Poh et al., 2010). Sampling frequency for the sensors was set at 16 hertz. The clock for each sensor was synchronized to the computer system prior to data collection.

Baseline measures were taken before data collection for each day of training. To obtain baseline EDA, each participant was instructed to relax and clear their mind while staring at a blank corkboard for ten minutes (Boucstein et al., 2012; Obrist, 1963; Poh et al., 2010). The sensor modules can be time-stamped by pressing a button located on the exterior of the sensor. The researcher, who also wore a sensor, used this button to time-stamp the beginning and end of the baseline period on their own sensor. The researcher marked their own sensor because pressing the participant's sensors might have caused inaccurate timing, physical discomfort to the participant, and changes to electrodermal measures. After collecting baseline measures, the participant began training on the motor task, completing 50 trials of the task during each day of training. The researcher recorded similar time stamps on their own sensor to mark the commencement and completion of each trial of training.

Standard measures for motor performance data were obtained using JMP, Version 10 (SAS Institute Inc., Cary, NC). EDA data were processed using Ledalab (Benedek and Kaernbach, 2010) a software package based in MATLAB (The MathWorks, Inc., Natick, MA) which analyzes skin conductance data. The time series data were first corrected for artifact, undesired alterations to the data due to sensor signaling errors. Next, a low-pass (0 to 3 Hz) Butterworth filter was applied. We then ran a continuous decomposition analysis to separate the tonic (smooth and slow-changing underlying waveform) data from the phasic (rapidly changing peaks) data (Benedek and Kaernbach, 2010). Because we were investigating changes in attention over the time course of training and not treating each peak individually, we extracted the tonic data for final reporting. The tonic data were compiled based on the previously recorded time stamps for each day of training, including baseline measures and trial-by-trial data.

**Results and Discussion**

Both groups showed improvement in motor performance over the course of training, which suggests that learning took place (Figure 1). However, older adults did not reach the same level of performance as young adults. Contrary to our first hypothesis, tonic EDA increased over the course of training in both groups. These results may suggest that additional training is necessary to learn the tasks such that participants achieve automaticity (decreased attentional demand). A study which involves higher doses of training on the task may show such results.



A. Young

B. Older

Figure 1- Motor performance over the course of training in A) Young and B) Older adults, where a decrease in movement time represents improvement.

The data support our second hypothesis, showing higher EDA in older adults than young adults. Older adults tend to experience decreased motor learning compared to young adults. This may be due to the diminished sensorimotor function associated with aging. Older adults have also been shown to be more susceptible to distractibility than young adults, suggesting that their ability to divide attention decreases with age. Thus, the higher levels of attention seen in this study may show one mechanism by which older adults compensate for age-related declines in sensorimotor function. Future work investigating motor training and EDA is needed to further understand the effect of age on attention.

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