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Memories that last in old age: motor skill learning and memory preservation

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Abstract

Using an automated test panel, age-associated declines in learning, remembering and performing a novel visuomotor task were assessed in 497 normal adults ranging from 18 to 95 years old. As predicted, task performance times slowed with increasing age in the cross-sectional portion of the study. However in the subsequent longitudinal study, while motor learning was significantly slower in adults over 62 years old, motor memory was pristinely preserved in normal adults from 18 to 95 years old. When tested 2 years after the first training session and without intervening rehearsal, mean performance times were retained and continued to improve by 10% in young adults and 13% in aged adults, reflecting long lasting preservation of motor memories. While the maximum lifetime of an unpracticed, novel motor memory in humans is not known, the present study suggests that new motor memories can be retained for at least 2 years without rehearsal in normal aged adults. This age-resistant component of motor memory stands in contrast to the well-known decrements in other motor and cognitive processes with human aging.

Keywords: Aging; Skill learning; Motor learning; Motor memory; Memory preservation

1. Introduction

Brain aging and functional declines are often considered synonymous. For brain motor circuitry and functions, most research to date supports this view. It has been repeatedly demonstrated that reaction time and motor speed slow progressively with advancing age [6,8,14,23,29,31]. Motor learning also slows with advancing age [20,37], with a recent study suggesting a decline in motor cortical plasticity with age as a functional correlate [25]. A possible exception to the general rule of functional brain deterioration with aging may lie in motor memory functions. Motor memory falls into the domain of procedural memory, which includes all skills and habits that are unconsciously retrieved in performing specific tasks [26,36]. Some studies have suggested that procedural memory functions are well preserved in normal aging, and involve the same frontal, parietal, cerebellar, and basal ganglia networks as in younger persons [5,15,19]. In the present study employing a computerized human movement analysis panel [9,29] and a novel visuomotor task, age-associated changes in motor speed, learning and memory were assessed in normal adults from 18 to 95 years old. Age-associated changes in learning and performing the task were measured in a large cross-sectional analysis of 497 individuals. Longitudinal changes in motor performance times and motor memory were evaluated in a subset consisting of 151 subjects tested 2 years later.

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In retrospect, the present study was inadvertently designed to test the limits of ultra-long term motor memory on motor performance. The initial purpose of the experiment was to longitudinally follow declines in motor performance in normal aging. By waiting 2 years between testing subjects and not providing intervening practice opportunities, it was assumed that motor memory of the previous testing period would have little effect on performance time. The importance of practice on motor performance in aging has been demonstrated in several seminal studies. Salthouse [24] found that skilled typists were able to maintain their speed of typing up to 72 years of age, with continuous practice assumed to be an important factor. Similarly, Krampe and Ericsson [13] reported that continuous practice was important for professional pianists to maintain their performance skills, including motor speed, into advanced age. In addition to practice, timing between training and testing is an important factor in motor learning and memory studies. Learning of a motor skill is stable for several hours after the training session ends, provided there is no interference from immediate subsequent training on another similar motor task [2,34]. A night of sleep results in a further increase in speed above the initial learning performance, without a loss of accuracy (memory consolidation) [16,35]. While consolidated motor memory traces are retained for at least 5 months in adults less than 40 years of age [28], the effects of aging on memory consolidation and retention are unknown.

Thus, the present study was designed to test three assumptions: (1) that task performance times slowed significantly with increasing age; (2) that motor learning of the task slowed with age; and (3) that memory of the task, without intervening practice, would fade and have little significant effect on performance times 2 years later. The results confirm the first two assumptions and are consistent with the literature. However, longitudinal testing revealed that motor memories can be preserved in aging without intervening practice. The performance times of both young and aged subjects on the first trial in the second testing session were as fast as the final trial in the original testing session conducted 2 years earlier.

2. Methods

2.1. Subjects

All data was collected under institutionally approved protocols with informed consent obtained from all individuals. The research subjects consisted of 315 females and 188 males ranging in age from 18 to 94 years. All older subjects (>58 years) were recruited as part of a longitudinal study of cognitively and neurologically normal healthy aging individuals tested yearly at the University of Kentucky's Alzheimer's Disease Research Center. This longitudinal cohort serves as a control group for the study of patients with Alzheimer's disease, and participants are tested extensively on an annual basis to detect subtle memory and other cognitive changes [27]. Subjects who initially had, or who developed, any such changes were excluded from the study (21 subjects). Younger subjects (<58 years) were recruited locally and consisted mostly of University personnel and students responding to posters or word-of-mouth. All 503 subjects underwent testing on the human movement analysis panel (hMAP) at least once. Six of the older subjects were later removed as outliers (see Section 2.3), leaving a population of 497 subjects.

A longitudinal subgroup ($n = 151$) underwent testing on the hMAP twice, once at baseline and once at a repeat interval of at least 12 months. In this subgroup there were 30 younger subjects, 18 males and 12 females aged 24–45 years; mean interval for repeat studies was 2.3 years (range 1–4.8 years). There were 121 older participants evaluated: 38 males (average age at baseline 77.5 years $\pm$ 7.9 S.D.) and 83 females (average age at baseline 75.0 years $\pm$ 6.1 S.D.). The mean interval for the repeat studies for older subjects was 2.0 years (range 1–3.5 years).

2.2. Behavioral testing

An automated hMAP was used to measure hand fine motor performance times on a series of four object retrieval tasks of increasing difficultly [9,26]. Testing was performed in a quiet, well-lit room free of noise and other distractions. A short (5 min) demographic questionnaire was administered at the beginning of each session. To avoid fatigue and interference effects, no other testing was performed either before or after any session. The hMAP tests administered were identical between sessions. There was no difference in reward or expectation in the second session (both first and second sessions were volunteer without payment). The testing was repeated five times for both the left and the right hand on each level of difficulty. The fourth and last task required a unique sequence of wrist and finger movements to maneuver a hexagonal metal nut over a double-S curved rod before removing it from a small plexiglass receptacle (Fig. 1). Double-S fine motor performance was selected for detailed analysis for motor learning and memory performance in the longitudinal study, because it was the last motor skill learned and therefore not subjected to interference from immediate subsequent training on similar tasks. The test battery of four motor tasks was completed in less than 30 min for each subject.

2.3. Statistics

Data for the group analysis consisted of the fine motor performance trial times for the dominant and the non-dominant upper extremities (five trials for each hand per subject). Hand dominance for the purposes of this study was defined as writing use together with customary use in fine motor manipulation in at least two other non-writing tasks.

Effect of hand dominance and sex was assessed by a repeated measures analysis of variance (ANOVA) procedure on the averaged five-trial performance times for each hand, with sex as the between-factor. For comparison of within-