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Is procedural memory relatively spared from age effects?

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Abstract

Numerous types of age-related deficits in the nervous system have been well documented. While a distinction between general types of memories that are susceptible to compromise with advanced age has been fairly well agreed upon, it is often difficult to determine exactly which specific processes are detrimentally influenced. In this study, we used a paradigm that enabled us to distinguish between effects associated with gross motor deficits and those due to learning and memory of a motor skill, per se. In terms of both latency and errors, senescent animals were, on average, impaired in their ability to traverse an elevated obstacle course, compared to younger animals. Yet, if gross motor abilities are accounted for, a fraction of these deficits is readily explained. Moreover, if individual baseline performance differences are normalized, no memory differences are evident across age groups. These observations suggest that memory for a procedural task is not impaired with advanced age.

Keywords: Learning; Memory; Aging; Rat; F344/BN; Performance deficits

1. Introduction

Age-related deficits in learning and memory range from simple reflex-slowing [8] to impairments on complex, cognitively-demanding memory tasks [6]. This seemingly broad spectrum of impairments suggests that a systematic examination of age-related memory deficits may be difficult. However, distinguishing between the specific types of memories affected by aging is potentially of great utility in the study of these deficits. For example, procedural (implicit) memories are frequently assessed using performance-based tasks and are often unaffected with advancing age. In contrast, declarative (explicit) memories are tested using more cognitively-based procedures and appear to be relatively more vulnerable during the aging process [5,6,9].

While observations of age-related deficits in humans and animals have increased our understanding of the effects of age on neuronal processing, studies of memory commonly yield data that are difficult to generalize and problematic to interpret. Non-mnemonic effects frequently introduce variables that result in ambiguous findings, confounding the investigation of constructs such as working memory. Such interpretations are further muddled when factors such as motoric performance [7,20,27] and/or ability [22,25,29] are not considered. The acrobatic conditioning paradigm was developed to disentangle effects due to learning, per se, and those associated with non-specific factors such as handling and general motor activity [4]. Using this paradigm, distinct patterns of brain changes have been shown to be associated with learning-related neuronal activity (motor skill learning is associated with new synapse formation), and with non-skilled activity (motor activity in a treadmill or activity wheel is associated with new capillary formation). Skill acquisition on this obstacle course generalizes to a variety of novel tasks [12].

In this study, we have employed the acrobatic conditioning paradigm in an attempt to determine whether motor skill acquisition impairments that typically accompany advanced age might be ascribed to learning-specific processes or whether they are related to deficits in other areas such as gross motoric abilities. We hypothesized that once general motoric differences were accounted for, performance

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on a procedural task would be less affected by the aging process, paralleling findings in human aging research. To assess performance, latency and errors were both evaluated. In addition, within- and between-day savings scores were analyzed to assess learning within days and memory across days. Thus, both the real value of savings and motor performance effects were taken into account in evaluating the effects of aging on acquisition of a procedural motor task.

2. Methods

2.1. Subjects

Fifty-four naïve, female, F344/BN rats were obtained from the National Institutes of Aging and permitted to acclimate to the animal colony for 1 month prior to commencement of experiments. Animals of three age groups were evaluated in these experiments: young (2-month-old), adult (6-month-old) and senescent (28–30-month-old). All animals were housed socially with age-matched cohorts in standard laboratory cages in a room maintained on a 12/12 h light/dark cycle with light onset at 6:00 a.m. daily. All experimentation was conducted during the light phase, typically during the morning hours. Subjects were pseudo-randomly assigned to either an acrobatic conditioning (AC) group ($N = 9$ per age group) or a motor control (MC) group ($N = 9$ per age group), with both conditions represented in each cage. The Institutional Animal Care and Use Committee approved all procedures prior to the study.

2.2. Behavioral training

Animals were trained to traverse an elevated obstacle course consisting of a series of ladders, ropes, wooden dowels and chains, requiring considerable motor coordination to complete (previously described in [4]). The latency to complete the task and the frequency of errors were recorded for each trial. An error (foot fault) was defined as anytime the paw of the subject slipped off the surface of the obstacle course. During each daily training session, subjects received three consecutive trials with an inter-trial interval of approximately 1 min. While each trial was being conducted, the cage-mate MC subject was permitted to walk along an elevated platform over a distance comparable to the AC course. The MC platform was made of clear plastic and elevated at a height similar to the AC course in an attempt to approximate the anxiety associated with both maneuvering across the raised AC course and exposure to a relatively open, well-lit environment. All animals were trained successively in a random order across days and the apparati were cleaned between subjects. Animals within a single cage were trained until the AC animal reached criterion performance of an average latency to complete the task in a single session of no greater than 150 s. Thereafter, subjects were trained for an additional 5 days.

2.3. Statistical analysis

Data were analyzed using an ANOVA and when appropriate, a repeated-measures design. Post hoc analyses of specific comparison points were accomplished using Tukey's HSD test for multiple comparisons. For all statistical tests, a minimum significance level of $P = 0.05$ was used.

3. Results

3.1. Mean days to criterion

Animals in all three age groups were able to reach criterion performance on the skill-learning course within a reasonable number of days. The mean number of days to reach criterion was determined to be statistically different between groups ($F(2, 24) = 8.317$, $P = 0.002$) and is depicted in Fig. 1. Post hoc analyses indicated that the mean number of days required to meet criterion in the aged group was significantly greater than both the young and adult groups ($P < 0.005$), which did not differ statistically from each other.

3.2. Latency to complete task: first 6 training days

The latency to traverse the AC course was recorded for each trial and averaged for the daily session. Fig. 2 illustrates these mean data for the three age groups across the first 6 training days. A repeated measures ANOVA indicated a significant main effect for group ($F(2, 24) = 10.218$, $P = 0.001$), a main effect for training day ($F(5, 120) = 60.076$, $P < 0.001$) and an interaction effect ($F(10, 120) = 2.365$, $P = 0.014$). Post hoc analyses of these data indicated that the senescent group was significantly slower than the young group across all 6 days and slower than the adult group across the first 5 training days. No statistically significant differences in latency measures were observed between the young and adult groups, although a trend towards significance developed across the last few training days of the evaluated period.

As gross motoric deficits associated with aging might account for the latency differences observed in the older group on the motor skill task, the latency to traverse the MC course was recorded for each trial and averaged for the daily session. Fig. 3 shows these mean data for the three age groups across the first 6 training days. A repeated measures ANOVA indicated a significant main effect for group ($F(2, 24) = 12.535$, $P < 0.001$), a main effect for training day ($F(5, 120) = 24.63$, $P < 0.001$) and an interaction effect ($F(10, 120) = 2.271$, $P = 0.018$). Post hoc analyses of these data indicated that the aged group was significantly slower than both the young and adult groups across the first