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Proactive and retroactive transfer of middle age adults in a sequential motor learning task

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ABSTRACT

We assessed the effects of aging in the transfer of motor learning in a sequential manual assembly task that is representative for real working conditions. On two different days, young (18–30 years) and middle-aged adults (50–65 years) practiced to build two products that consisted of the same six components but which had to be assembled in a partly different order. Assembly accuracy and movement time during tests, which were performed before and after the practice sessions, were compared to determine proactive and retroactive transfer. The results showed proactive facilitation (i.e., benefits from having learned the first product on learning the second one) in terms of an overall shortening of movement time in both age-groups. In addition, only the middle-aged adults were found to show sequence-specific proactive facilitation, in which the shortening of movement time was limited to components that had the same the order in the two products. Most likely, however, the sequence-specific transfer was an epiphenomenon of the comparatively low rate of learning among the middle-aged adults. The results, however, did reveal genuine differences between the groups for retroactive transfer (i.e., effects from learning the second product on performance of the first). Middle-aged adults tended to show more pronounced retroactive interference in terms of a general decrease in accuracy, while younger adults showed sequence-specific retroactive facilitation (i.e., shortening of movement times for components that had the same order in the two products), but only when they were fully accurate. Together this suggests that in the learning of sequential motor tasks the effects of age are more marked for retroactive transfer than for proactive transfer.

1. Introduction

Aging adversely affects motor performance and learning. Elderly people not only act more slowly, deliberately, and, occasionally, less accurate but also do require greater efforts to achieve enduring improvements in motor performance. The sometimes problematic loss of motor efficacy in late adulthood stands out the most, but the very first signs of a decline in motor learning may already arise at the age of 40 years in middle adulthood (Perrot & Bertsch, 2007; Voelcker-Rehage, 2008; Voelcker-Rehage & Willimczik, 2006). At the age of 60 years or beyond, however, the decline in learning becomes much more ubiquitous, as for instance has been shown for sequential motor learning (Seidler, 2006; Shea, Park, & Braden, 2006). Many have pointed to the weakening of executive function as major determinant of the age-related decline in motor learning (Craik & Bialystok, 2006; Zelazo, Craik, & Booth, 2004). As a point in case, the gains in motor performance after explicit motor learning, which strongly relies on the conscious processing of declarative information in working memory, are often less well retained than the performances increases following implicit learning (Chauvel et al., 2012; Ren, Wu, Chan, & Yan, 2013; Steenbergen, van der Kamp, Verneau, Jongbloed-Pereboom, & Masters, 2010).

An issue in motor learning that has relatively been overlooked is whether, except for the rate of learning, aging also affects the transfer of learning. In other words, how the learning of one motor action affects the performance and learning of a similar but not identical second action. Indeed, across the life span, motor performance often needs to be modified or re-learned when circumstances demand. It is not uncommon, for example, that workers after having learned to assemble a product from various components, have to learn to build a second product out of the same components in a (partly) different order or with one component replaced. Particularly, age-related changes in motor learning must also be evaluated in terms of the degree to which it facilitates or hinders subsequent performance and learning of slightly different actions. Accordingly, the current study compares the transfer of sequential

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learning by young and older adults in a representative manual assembly task, in which a product is built by gathering six components in a fixed sequence.

The motor learning literature typically distinguishes *proactive* and *retroactive* transfer. Proactive transfer occurs when learning a new motor action influences the performance or learning of a similar action in the future. Retroactive transfer occurs when learning a new motor action impacts the performance of a previously learned action (Blank, 2005; Hanseeuw, Seron, & Ivanoiu, 2012). These transfers can either be beneficial (i.e., facilitation) or detrimental (i.e., interference). In the case of sequential motor learning, as in the current manual assembly task, transfer can occur on at least two levels. First, transfer can appear as a general accommodation to the task constraints, which would for instance be reflected in an overall speeding up of movement execution. For instance, Seidler (2007) had young and older adults practice a series of joystick movements to targets at different orientations. Half of the participants practiced successive blocks in which they moved toward 30°, 15°, and 45° targets, respectively, while the other half practiced successive blocks toward 45°, 15°, and 30° targets. Proactive facilitation was present for accuracy in the target orientation block that was practiced last (i.e., 45° in one group and 30° in the other) regardless of the age-group. Yet since motor learning did not involve a sequence of movements, transfer reflects general accommodation only; with single movements, no sequence-specific transfer can occur. Transfer that is specific to the order of the learned sequence is the second level at which transfer can occur. In this case, the speeding up (or slowing down) is restricted to movements within the sequences that are performed in the exact same order but does not encompass movements within the sequences that have a different order. Such transfers have been investigated in a series of studies. Indeed, Panzer and colleagues examined proactive and retroactive transfer in young adults who learnt a 16-target movement sequence on one day, followed by practice of a similar sequence but with two targets altered on the second day (Panzer & Shea, 2008; Panzer, Wilde, & Shea, 2006). It was found that practice on the first sequence did not benefit learning of the second sequence (i.e., no proactive facilitation), while practice of the second sequence degraded performance of the first sequence (i.e., retroactive interference)(Panzer et al., 2006). Prolonging practice of the first sequence, however, resulted in proactive facilitation becoming stronger, while retroactive interference reduced or even disappeared (Panzer & Shea, 2008). Panzer et al. argued that transfer is related to the relative stability of the memory representations of the two sequences; the sequence with the stronger representation impacts the other. Thus, when the first sequence is strengthened by longer practice, proactive facilitation is increased and retroactive interference is reduced.

Executive functions are crucial to manipulating, storing and retrieving of movement sequences and are thus at stake in the transfer of motor learning. Yet it is these functions that are often degraded among older adults (Salthouse, 1990). In addition, it has been reported that older adults are less apt to efficiently combine different discrete movements into one smooth sequential motor action (Shea et al., 2006; Verwey, 2010; Yan, 2000). Transfer after sequential motor learning has not been studied in older adults, but the less efficient merging of discrete movements into one sequence, and the resulting weak memory representation of the movements sequence, may on the one hand jeopardize older adults' ability to profit from proactive transfer and on the other hand increase the likelihood of retroactive interference.

Previous work did investigate the transfer of learning in older adults for cognitive tasks, such as recalling different lists of words. This pointed to reduced proactive and retroactive transfer in older adults. For example, when learning a second list of words, older adults show increased intrusion of words from the originally memorized list (Hasher, Chung, May, & Foong, 2002; Murphy, West, Armilio, Craik, & Stuss, 2007). In addition, older adults have been shown to be more vulnerable for retroactive interference than younger adults (Hedden & Park, 2001). The increased interference with aging is explained by a weakening of inhibition, making it more difficult for older adults to eliminate previously memorized words when recalling a list. It has been proposed that interferences during motor transfer were a biased motor behavior due to the earlier learned motor task (Walter & Swinnen, 1994). In case of sequential motor learning, the weakening of inhibition processes could make older adults more prone to interference. This contrasts to the hypothesis that learning in older adults results in weaker representations that are easily overwritten. However, the cognitive load in these exclusively cognitive tasks is much higher and probably unrepresentative of the cognitive demands in motor actions, raising the issue to what degree these findings can be generalized to sequential motor learning.

In sum, the current study investigates the effect of age on proactive and retroactive transfer in the learning of sequential manual assembly task. We focused on middle-aged adults between 50 and 65 years old because this age-group is part of the workforce in the manual assembly industry, where the ability to efficiently and flexibly learn motor actions is an important requirement. Accordingly, the task was chosen as representative as possible for a worker in the assembly industry and involved assembling a product out of components that need to be combined in a fixed order, and hence, require a fixed sequence of successive movements. Participants learned to build two similar products, with half the components being assembled in the same order. It was expected that compared to the young adults, middle-aged adults' less efficient ability to blend single discrete movements into one smooth sequence during practice would result in weaker memory representations (i.e., the amount of practice was the same for both groups). Consequently, we anticipated reduced proactive facilitation and increased retroactive interference for sequence-specific learning (i.e., for the sequences that were the same across the two products) for middle-aged adults compared to young adults. However, a general speeding up was expected for both age-groups (i.e., proactive and retroactive facilitation).

2. Methods

2.1. Participants

Nineteen young adults between 18 and 30 years of age (mean age = 22.5, SD = 3.5 years) and eighteen middle-aged adults between 50 and 65 years of age (mean age = 58, SD = 4.5 years) participated in the study. All participants were self-proclaimed right-handers, had normal or corrected to normal vision, and reported that they did not suffer from chronic pain of the right forearm, shoulder, and/or hand. They received a small monetary reward for participation. The participants provided written informed consent before the study but were kept naive to the purpose of the experiment until after completion of the study when they were fully debriefed. The local institution's ethical committee approved the study.

2.2. Apparatus and stimuli

The gross assembly task of the ATA©-workstation (Assembling Task Apparatus, Top Productivity, The Netherlands, see Fig. 1A) was used (for a full description, see Verneau et al., 2014). This workstation is developed to evaluate workers' capability for performing different types of assembly tasks (e.g., gross and fine assembly, sorting, etc.). It creates an environment to autonomously learn (i.e., without an instructor) to construct a product by sequentially assembling (i.e., reach, grasp, orient and place) six components in a fixed order. Through the dedicated PG-viewer software, the workstation monitors the worker's actions and directs him or her through the assembly task in a step-by-step fashion. For the current study, the workstation had a series of six bins, each of which was filled with one component. The bins were positioned directly behind the workspace where the product was to be built. Each bin was equipped with a movement sensor that registered when the worker's hand entered the bin; a light bulb above the bin indicated from which bin the next component was to be picked. Above the row