Human Movement Science 52 (2017) 215–222

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

The role of cognition for different stages of visuomotor adaptation in younger and older adults

Anja Simon *, Otmar Bock

Institute of Physiology and Anatomy, German Sport University Cologne, Am Sportpark Muengersdorf 6, 50933 Cologne, Germany

ARTICLE INFO

Article history:
Received 19 April 2016
Revised 21 February 2017
Accepted 26 February 2017
Available online 8 March 2017

Keywords:
Learning stages
Interaction cognition – motor control
Visuomotor adaptation
Age effects
Inhibition
Automation

ABSTRACT

A recent model identified three stages of learning, the first drawing on cognitive flexibility, the second on inhibition, and the third on automation. We explored the validity of this model for visuomotor learning and found that adaptation is associated with inhibition early during adaptation and with automaticity later on. An initial association with cognitive flexibility remained inconclusive. This work employs another marker of cognitive flexibility and extends our work to older adults.

Twenty young and 20 older adults completed three cognitive tasks (switch task, Stroop task and four-choice-reaction-time-task). They performed a visuomotor adaptation task under 60° rotation of visual feedback. Based on their cognitive scores, participants were divided into good and poor performers.

Young adults outperformed older adults in visuomotor adaptation tasks and in cognitive tasks. Switch task performance was not associated with adaptation in either age group. Stroop performance was associated with early and four-choice-reaction-time-task with late adaptation in young adults. In older adults, Stroop performance was associated with early as well as late adaptation whereas four-choice-reaction-time-task was not associated with adaptation. All associations were present during adaptation, but not during de-adaptation.

Our findings do not confirm the existence of the first postulated learning stage for the case of adaptation. They support the second and third stage in young persons for strategical components of adaptation. In older adults, the duration of the second stage seems to extend so that the third stage was not reached within the duration of our experiment. We conclude that degraded cognition in older age could explain why adaptation is impaired while aftereffects remain intact.

1. Introduction

A recent model (Chein & Schneider, 2012) argues that learning proceeds in three stages; an early stage in which changes of strategy, creativity, flexibility and the generation of new behavioural routines are important, a middle stage in which selective attention and inhibition play a predominant role, and a late stage characterized by automatization. We recently explored the validity of this model for motor learning in a visuomotor adaptation paradigm in young adults (Simon & Bock, 2015, 2016). Specifically, we argued that persons with high flexibility and creativity should be at an advantage during

* Corresponding author.
E-mail address: a.simon@dshs-koeln.de (A. Simon).

http://dx.doi.org/10.1016/j.humov.2017.02.011
0167-9457/

the early stage of adaptation, and therefore should outperform other persons at the beginning of adaptation, but not later on. Flexibility and creativity were assessed by Abbreviated Torrance Task for Adults (ATTA; Goff, 2002) and a measurement of divergent thinking, the Alternative Uses Task (AUT; Guilford, 1967). We found that creativity had no impact on adaptation whereas good divergent thinking was associated with superior adaptation performance, but not in terms of the suggested model. The association of divergent thinking was not limited to the onset of adaptation but rather persisted and increased until adaptation was completed. Thus, there was no evidence for the existence of the first stage of the learning model, whereas the middle and later stage could be verified for visuomotor adaptation in younger adults (Simon & Bock, 2015). We found that good abilities for selective attention measured by Stroop word-colour interference task (Stroop, 1935) were associated with superior performance mainly during the first half of adaptation, and good abilities for automated movement execution measured by a four-choice reaction time task (Eversheim & Bock, 2001) were associated with superior performance mainly during the second half of adaptation. Furthermore, correlations of cognitive performance and initial errors during the time course of adaptation indicated that the second learning stage is reached after completing one episode (24 trials). This suggests a rather short early learning stage for visuomotor adaptation which probably occurs within a dozen movements. The second stage also only persists for roughly two episodes, before the correlations indicate a stronger association to automatization, suggesting the beginning of the third learning stage (for detailed description see Simon & Bock, 2015, especially Fig. 3).

Notably, both studies found that the associations observed during the adaptation phase did not extend to aftereffects (Simon & Bock, 2015, 2016). Since aftereffects are thought to be pure indicators of adaptive recalibration while the adaptation phase is thought to reflect workaround strategies as well (McNay & Willingham, 1998; Redding & Wallace, 1996), our findings might represent the effects of selective attention and automation on strategic adjustments rather than on adaptive recalibration. This outcome is relevant for the well-known decline of adaptation in older age, which also was attributed to the loss of strategic adjustments rather than to degraded recalibration (Bock, 2005; McNay & Willingham, 1998; Redding & Wallace, 1996). Specifically, the age-related decline was associated with impairments in several cognitive domains: executive functions (Anguera et al., 2012; Bock & Girgenrath, 2006; Eversheim & Bock, 2001), explicit knowledge (Hegele & Heuer, 2013) and divergent thinking (Simon & Bock, 2016). We found that the association of divergent thinking and adaptation is abolished in older adults, due to the degraded divergent thinking abilities. In fact, the association with divergent thinking was strong enough to account for the effects of age on adaptation (Simon & Bock, 2016).

The present work extends our past studies in two ways. First, we scrutinize Chein and Schneider's early learning stage with another marker of cognitive flexibility, switch task performance (Crone, Ridderinkhof, Worm, Somsen, & van der Molen, 2004). Second, we compare the role of selective attention and automatization for adaptation in different age groups. We reasoned that the varying functions might have different impacts on visuomotor adaptation in the two age groups as it was the case with explicit knowledge (Hegele & Heuer, 2013), executive functions (Anguera et al., 2012; Bock & Girgenrath, 2006; Eversheim & Bock, 2001) and divergent and convergent thinking (Simon & Bock, 2016). We hypothesize that this is due to the known age-related decay of the cognitive parameters (Hultsch, MacDonald, & Dixon, 2002; Karbach & Kray, 2009; McCrae, Arenberg, & Costa, 1987; Reimers & Maylor, 2005; Simonton, 1991; Van der Elst, 2006). At least altered associations of the cognitive performance and the adaptational success during the time course of learning in older adults are to be expected.

In summary, this study assessed whether the Chein and Schneider model can be generalized across age groups and if the decline of cognitive performance is closely related to changes in visuomotor adaptation. Additionally, a new prospective predictor (switch task performance) for early adaptational success was investigated.

2. Methods

2.1. Participants

Twenty young (23.20 ± 1.99 years, eight females) and 20 older volunteers (69.99 ± 4.88 years, nine females) participated in the study. All young participants were students of the University of Cologne or the German Sport University Cologne. Older adults were recruited from a volunteer testing pool of the Institute of Physiology and Anatomy of the German Sport University Cologne. Experiments were approved by the authors' local ethics committee, and participants signed an informed consent statement before participating in the study. All participants had normal or corrected to normal vision, were in self-reported healthy condition and had no prior experience in sensorimotor research.

2.2. Experimental procedures

Each participant performed three cognitive tasks in fixed order, and then a visuomotor adaptation task with 60° rotated vision. All tasks were displayed on a 15 inch monitor.

A modification of the *Switch task* (Karbach & Kray, 2009) was used to assess participants' cognitive flexibility. Sixteen pictures of vegetables and 16 pictures of fruits were sequentially presented, either in large or in small. Large stimuli had a size of 9 × 5.5 cm and small stimuli had a size of 3.5 × 2.5 cm. Participants had to discriminate by pressing one of two keys whether the momentarily presented picture was a fruit or vegetable (task A), or whether it was large or small (task B). There were