Aging and cognitive control

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Chapter 5

Summary and general discussion

The global speed hypothesis of aging states that age-related cognitive decline can be attributed to a decrease in the speed with which elementary cognitive operations are carried out. The decrease in information processing speed places limits on the level of performance that can be reached on most cognitive tasks (Eearles, Connor, Smith & Park, 1997; Salthouse, 1996). This hypothesis can be contrasted to hypotheses that attribute age-related effects on performance on executive control tasks to specific control deficits.

Cognitive control refers to organizing and monitoring cognitive processes. It is crucial for making behavior adaptive and controlling behavior according to intentions and internal goals. The concept of cognitive control implies endogenous control of processes and, in that sense, can be contrasted with situations in which behavior is cued, triggered or prompted explicitly from or by the environment. Cognitive control has been conceptualized as a unitary process that is the same in the different situations. It has also been conceptualized as a composite of fractionated control processes. In case of the second conceptualization, cognitive control processes in one situation can be different and distinct from processes in another situation.

Summary

Chapter 1 reviews some of the theories that posit that age-related differences can be accounted for solely by one general aspect of cognition (e.g. Birren, 1956; Cerella, 1985; Eearles et al., 1997; Salthouse, 1996), and other theories that hold that effects of age on cognition are more specifically limited to executive control functions (e.g. Bryan & Luszcz, 2001; Mayr, Spieler & Kliegl, 2001; Rabbitt, 1997; Wecker, Kramer, Wisniewski, Delis & Kaplan, 2000). Also, some of the most influential models of cognitive control are reviewed in chapter 1. In chapter 2 and 3 studies on cognitive aging are reported focussing on a specific function of cognitive control.

In chapter 2, a study is presented in which the sensitivity and reliability of four different prospective memory tasks for assessing effects of normal aging were tested, using a group of older and a group of younger adults. From the perspective of the frontal lobe hypothesis of cognitive aging, prospective memory tasks are particularly interesting and relevant, because performance on prospective memory tasks requires both planning and intention-activation (keeping a prospective intention activated during performance on another task). These two functions are generally believed to involve the frontal lobes. Thus, according to the frontal lobe hypothesis of cognitive aging, robust age-related performance differences on prospective memory tasks should be expected. The tasks were differentiated on various dimensions such as perceptual saliency of prospective target events, frequency of occurrence of prospective targets, complexity of prospective-memory instructions, and provision of feedback after prospective-memory errors. The role of goal maintenance (or maintaining prospective intentions) and basic mental speed as mediators for age effects on prospective memory performance were discussed.

In three of the four prospective memory tasks some participants failed to comply with the task instructions and showed little to no responses to the prospective cues, sometimes together with failures to reproduce the relevant instructions during task debriefing. Some of the 'prospective memory non-performers' performed well within normal range on the associated background tasks. This suggests some degree of specificity of their prospective memory problems in these tasks. Other 'prospective memory non-performers' performed also very poorly with respect to accuracy in background task performance, suggesting a profound misunderstanding of task instructions. All but one non-performers were from the older group of participants. Thus, complete failures to follow prospective memory instructions were limited almost entirely to the group of older adults.

Two tasks were found to provide sensitive and reliable tools for assessing effects of normal aging on prospective memory abilities. Both tasks, in different ways, focussed on the participant's ability to maintain prospective intentions properly activated and accessible. Consistent with this perspective, prospective memory accuracy in the two tasks was substantially correlated. This correlation was mediated largely by age.

In chapter 3 effects of age on task-switching were reported. Consistent with previous research local switch costs were larger for old than for young adults, but not disproportionally so. Also consistent with the existing literature, global switch-costs were disproportional larger for old than for young adults (see e.g. Kray, 2005). Specifically, the study reported in chapter 3 was aimed at whether or not residual switch-costs, which are switch-costs that still exist when ample time to prepare in advance is provided, in old and young adults were attributable to the same factors. At the level of mean reaction times (RT's) no significant age-related differences were found in residual switch-costs. But in the present study, residual switch-costs were examined in a more detailed way, using analysis of RT distributions. The distributional analysis revealed residual switch-costs in younger adults to be attributable completely to inconsistencies of engaging in advance preparation, replicating results reported by De Jong (2001) and by Nieuwenhuis and Monsell (2002). Moreover, the older and younger groups did not significantly differ with respect to advance preparation. For the group of old adults, though, this failure to engage (FTE) account of residual switch-costs did not suffice. Evidently, engaging in advance preparation did, for old adults, not suffice to attain similar levels of preparation on switch trials as on no-switch trials. Thus, for older adults extra time after the onset of the imperative stimulus was needed. A possible explanation for the time it took to respond (even when engaged in advance preparation during PI) for old adults in the present study is that is could reflect a decrement of quality of retrieval of the task set information from LTM, which would be consistent with the "LTM retrieval" interpretation of local switch costs proposed by Mayr and Kliegl (2000). Mayr and Kliegl (2000) hypothesized that local switch-costs reflect a process of actively retrieving task-set related information from LTM.

Related to the task switching study is research studying prospective memory, which typically measures whether a retrieval of an intention can be maintained in the face of high interference situations. Several studies have dealt with aging and prospective memory, and old adults are often found in these studies to show worse performance than young adults under conditions of relatively low environmental support and relatively high interference (Einstein, Smith, McDaniel and Shaw, 1997; Maylor, 1996; Vogels, Dekker, Brouwer and De Jong, 2002, chapter 2 this thesis).

In Chapter 4, a more general approach was taken to study the relations between cognitive control functions and aging. Firstly, instead of focusing on one cognitive control function, several aspects of cognition were taken into account. Speed of processing, intelligence and several cognitive control functions were measured by means of different cognitive tasks. Secondly, another approach was taken than in the former two chapters with respect to the age cohorts. Instead of two age-groups, one older group and one younger group, participants were recruited from four age-groups, one young group (ages between 20 and 30 years) and three older (from 50 years old) groups. Factor analysis, applied prior to structural equation modeling, resulted in the identification of two factors which were comprised of variables indicating, respectively, executive (control) functions and working memory. These results can be compared to the factor structure of executive functions that Myiake et al. (2000) postulated by means of confirmatory factor analysis. Myiake et al. (2000) postulated three factors representing the executive functions of shifting between tasks or mental sets, updating and monitoring of working memory representations, and inhibition of dominant or prepotent responses. The WM factor in the current study is quite similar to the updating factor postulated by Myiake et al. (2000) and the factor labeled executive function in the current study appears to be compatible with a mixture of the factors shifting and inhibition found in the Myiake et al. (2000) study.

Using structural equation modeling, four models postulating different relationships between age and latent factors and cognitive measures were compared. The pattern of age-effects on performance on cognitive tasks was most accurately represented by the model that postulated a direct effect of age on the EF factor and an effect of the EF factor on the WM factor; thus according to this model the age-effects on WM-tasks performance are mediated strictly by age-effects on executive functioning.

These results are compatible with the results of a study of Span (2002). Using structural equation modeling Span (2002) tested whether a model without an executive factor would describe the performance data of the children, adults and older adults in their study significantly worse than a model in which both a speed factor and an executive factor were postulated. Span (2002) found that the EF factor was necessary only to account for older adults' response latency data of the executive function tasks and that older adults differed from young adults on both the speed and executive factor.

Comparing the age groups revealed different patterns of age sensitivity of the respective cognitive variables. These patterns suggest that cognitive performance that is highly dependent on speed is sensitive to aging in the sense that consequences are already manifest at the population aged between 50 and 60, while in cognitive performance that is more dependent on executive functions, age-related decrements are more pronounced later in life.

Validity of speed indices

Concerning the issue of the relation between cognitive aging and speed of information processing, the studies reported in this thesis contribute by repeatedly finding that, at least for some purported and often used, measures of speed it is evident that it is not a pure measure of speed and that performance on such tests are not independent on executive function. This, for example concerns the DSST. In chapter 4 performance on the DSST showed very clear age-related differences. With structural equation modeling we showed that the DSST did relate to other performance measures in the same manner as the Raven SPM test did, supporting Parkin and Java's (2000) argument that the DSST performance measure should not be interpreted as a 'pure' measure for perceptual speed and is partly related to intelligence and to working memory. This argument is in agreement with the suggestion made in chapter 2 of this thesis (Vogels et al., 2002). In Vogels et al. (2002) reaction times on the background task of a prospective memory task were argued not to reflect "basic mental speed", but rather to reflect the capacity or ability to keep various relevant stimulus-response associations activated so that the requisite response can be quickly and effectively triggered by an imperative stimulus. This argument led Vogels et al. (2002) to suggest that correlations between prospective memory performance and speed of reaction-time performance are mediated by individual differences in the capacity or ability to keep various relevant stimulus-response associations activated rather than by individual differences in basic mental speed. Thus, in general, some of the measures that are often used as indicators for speed of information processing or perceptual speed are also dependent on cognitive control processes. This implicates a nuance in confirming a global speed hypothesis of on basis of age-related differences in performance on these tasks.

Heterogeneity

One of the salient outcomes of the three studies and previous findings by others (e.g. Ylikosky, 1999, Gunstad, 2006) concerns the heterogeneity of the cognitive performance decline with aging. As reviewed above, the study in chapter 2 on prospective memory showed that, although as a group the older adults performed worse than the young adults with respect to prospective memory, some older subjects showed performance similar to the young subjects, while some older participants performance much worse on the prospective memory indicators. With respect to task-switching, as evidenced in chapter 3, a related observation was made. Although the distribution functions of RT's and the interpretation of the distribution modeling were straightforward when pooled over groups, it was stressed that there were notable individual differences especially in the older age-group. Finally, in chapter 4, several instances were reported of heterogeneous nature of effects of aging on performance on cognitive tasks. The most salient outcome of the trailmaking test was the greater spread of performance in the older groups than in the young group in the B-version, while this difference in spread of performance was not apparent in the A-version. Larger individual differences for the older groups than for the young group were also found in the Raven standard progressive matrices test, the MODS-R working memory tasks, the switch task and the dual-task paradigm.

These results concerning heterogeneity suggest that when studying cognitive aging, limiting examination of group means of performance over tasks does not suffice. Much information lies in individual differences (within group variability) and within task variability (Gunstad et al., 2006). The theoretical implications of these results concern the universality of cognitive aging. This argument has been eloquently made by Rabbitt, Lowe and Shilling (2001). They argue that one of the most common causes in the central nervous system in old age are cerebrovascular accidents or insufficiencies of cerebrovascular circulation. These changes occur more often with increasing age and more often in the frontal lobes than in other areas of the brain (Shaw et al., 1984). Consequently, Rabbitt et al. (2001) argue, the increasing incidence of focal brain changes, particularly in the frontal lobes, and the resulting local deficits, is more likely to underlie effects of aging on cognition than a continuous and progressive unfolding of particular patterns of deficits in all, or most members of a population.

In addition to the theoretical implications of the heterogeneous nature of effects of age on cognition, there are also more practical implications. For example, in light of the labor market and the rising retirement ages and low birth rates, a practical implication of the heterogeneity of effects of aging on cognitive performance is that the age of an individual solely is not a reliable indicator of (worsened) quality of work potential. A major source of employees is overlooked when policy of this subject is based on the age of individuals.