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«Cognitive training in younger and older adults: effects on brain and behavior»

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ABSTRACT

Cognitive functions tend to decline with advancing age, even though this does not apply to all functions to the same degree or at the same time. With the present work, we aimed at providing an important cornerstone for the deeper understanding of cognitive aging and the development of means to foster autonomy in older age. We investigated the behavioral and cerebral mechanisms underlying a cognitive training intervention.

The purpose of the present work was first to better understand the behavioral plastic potential in younger and older adults by implementing a working memory (WM) training program. Second, we intended to aliment the current discussion about transfer effects to untrained tasks, whose existence, degree and extent are not clear at present. Third, we aimed at gaining insights into the underlying cerebral plastic mechanisms of training effects and, to our knowledge for the first time, of transfer effects. To this end, we recorded electroencephalogram (EEG) measures at pre-test and post-test on the trained and a near transfer task. By this means, we were finally able to contribute to the debate about the functional meaning of the cerebral changes during cognitive aging, i.e., the frontal over-activation, which naturally occurs in older age and which is still not fully understood. We further aimed at improving several methodological issues that are not systematically respected in training studies to date and do therefore not allow to fully understand the effects of training. First, a crucial ingredient was the inclusion of a younger group which served as an optimal reference group for older adults. Second, in order to provide a control for retest and placebo effects occurring within a training intervention, we included both a no-contact as well as a placebo training group.

We expected to find plastic changes in both age groups during the training, but more pronounced in younger as compared to older adults. We hypothesized similarly to find effects of training in the untrained near transfer tasks measuring WM capacity. Furthermore, we examined whether WM training generates transfer in a fluid intelligence measure, a hypothesis which has gained mixed support. These effects were expected to be found in both WM training groups, but more pronounced in younger as in older adults. On the cerebral level, we hypothesized changes in components of event-related potentials (ERP) which are related to decision-making and attentional resource allocation processes, the N2 and the P3 component. We expected them to decrease in amplitude due to training since we hypothesized that less attentional resources are needed after training to respond to the trained task and the untrained near transfer task. Additionally, we predicted to find less frontally oriented voltage

maps for the N2 and the P3 components. Amplitude in N2 and P3 is usually decreased and less frontally oriented in cognitively lower demanding tasks as compared to higher load tasks.

We implemented a WM training using a verbal *N*-back training procedure during 10 daily sessions of 30 minutes of training in the laboratory. Before and after training, we conducted a large battery of tests in order to evaluate the changes from pre-test to post-test. The battery of cognitive tests included measures of WM, inhibition, processing speed and fluid intelligence. In order to disentangle the training effects from placebo effects, we included an implicit task training in a similar procedure with a duration of 10 sessions about 30 minutes of training per day. Furthermore, we included a no-contact control group, which did not complete a training intervention between the assessment of the cognitive test battery at pre-test and post-test. EEG measures were recorded at pre-test and post-test during the trained verbal task and during a spatial near transfer task.

Results at the behavioral level revealed that the performance of both age groups improved over the 10 WM training sessions. Younger adults exhibited a generally higher training level than older adults and improved faster during training by reaching the asymptote later than older adults. This resulted in a magnified age difference at the end of the training. Further analyses showed that fluid intelligence performance explained individual differences in initial training performance independent of age group. Age group, in turn, accounted for individual differences in the growth curve beyond individual differences in fluid intelligence. As regards training effects, a clear effect of training in the younger and older WM training group was observed for the trained verbal 2-back task as compared to both control groups. The WM load cost, i.e., the difference between the low load 0-back condition and the higher load 2-back condition, also decreased significantly for both WM training groups. Moreover, a near transfer effect was found in the spatial *N*-back task, which was present for the 2-back task as well as for the WM load costs. Similar to the verbal task, the effects were comparable for both age groups. In terms of far transfer effects, there was an effect in the Stroop task, which was also present in the placebo control group. No further transfer effects were found for other WM measures, the fluid intelligence measure or for the processing speed tasks.

The ERP analyses for the verbal 2-back task revealed that both age groups as compared to the control groups showed an activation increase for the N2 and, as expected, an activation decrease for the P3 component. This was reflected by a change from a frontal positivity towards a central negativity and a posterior positivity. Overall, the activation became less distributed over the scalp, tending towards a more selective recruitment in central and posterior regions. These changes were found to describe a reorganization pattern. We observed the inverse pattern for the untrained spatial *N*-back task: The frontal sites showed more positivity in the P3 component after training for the WM training groups whereas the posteriorly oriented maps decreased in presence. This resulted in a redistribution pattern, indicating that similar processes were engaged after training contrary to the verbal task, in which the reorganization pattern showed a change in processes.

The results of the training performance were in line with our predictions, since age differences were increased after training. As regards the findings from training and transfer tasks, we found the predicted gains in the trained and a near transfer task (the spatial *N*-back task), but not in additional WM tasks or the fluid intelligence measure. These findings are in line with a growing body of literature which supports the evidence of preserved, even though attenuated, behavioral plasticity in older age. The small transfer effects in younger as well as in older adults also provided support for the currently mixed body of evidence. Furthermore, transfer effects from WM training to a fluid intelligence measure are currently under debate, since results are even more contradictory. The ERP results revealed that cerebral plasticity was also preserved in older adults and that a similar change in younger and older adults was observed. We were able to link our findings with the scaffolding theory, which states that frontal areas are more activated and therefore attentional resources are preferably recruited in order to respond to the increased demands during learning. When these demands persist, the processes become more efficient which is reflected in decreasing frontal attentional recruitment. The former pattern was found in the near transfer task where frontal recruitment was observed. For the trained task in turn, the latter pattern, that is, decreased frontal recruitment (P3) and a more efficient early process (N2), was found. The results provided additionally evidence regarding the debate concerning the interpretation of age-related cerebral changes. They revealed that a similar change in older adults as compared to younger adults in cerebral processes seems to be beneficial. That is, we were not able to find a differential change due to training in younger and older adults. Thus, we concluded that the frontal over-activation in older as compared to younger adults does not necessarily describe a beneficial functioning.

Taken together, the present dissertation presents evidence that training studies have a great potential to contribute to the understanding of the mechanisms of cognitive aging. Moreover, our findings call for the integration of training studies in more applied contexts by targeting on effects that might transfer into older adults’ everyday life.