Satellite symposium
Cognitive ageing: Electrophysiological methods and training interventions

Michael Falkenstein & Nele Wild-Wall

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The first part of the symposium provides an overview about age-related alterations of cognitive functions, as assessed with electrophysiological methods, i.e. electroencephalography (EEG) and event-related potentials (ERPs). With these methods several types of age-related neuronal alterations can be described, including underactivation of relevant or compensatory processes, overactivation of detrimental processes, and a restructuring of the functional components.
Dorothea Hämmerer assessed reinforcement learning with a combination of electrophysiological recordings and computational models and found an impaired feedback evaluation in children and old adults, which was also reflected in the P3 following feedback.
Juliana Yordanova used a four-choice reaction task with the aim of elucidating the reasons of the age-related reduction of the error negativity (Ne), a marker of error detection. Their data suggest that alterations in the organization of theta networks in old subjects could explain the reduced Ne.
Nele Wild-Wall investigated young and elderly subjects in a 2-back and 0-back control task using ERPs and source localisation. The ERPs show that different functional processes underlie the reduced task performance under high working memory load in elderly subjects.
István Czigler investigated ERPs in an auditory memory scanning task. Age-related differences emerged in later stages of processing, i.e., while gating processes were similar in the two age-groups, specific stimulus properties were less selectively processed in elderly.
Finally, Edward Golob used EEG and ERP to assess changes in various cognitive domains in old and very old people, taking into account individual differences within the groups. Moreover he will show the potential of EEG/ERPs for the early diagnosis and development of AD pathophysiology years before cognitive deficits are manifest.

The second part of the workshop provides a broad overview about training interventions as a possibility to prevent or improve an age-related cognitive decline. The talks will focus on the neuronal mechanisms of physical and cognitive training interventions in aging. A better understanding of the underlying mechanisms and effects of training interventions on neural plasticity and the enhancement of cognitive functioning may enable practitioners to set up highly efficient interventions. The talks will give an important contribution to this understanding.
The first two talks will target physical training. In the first talk, Kirk Erickson will focus on cognitive effects of aerobic exercise and related mechanisms of neural plasticity. The second talk by Claudia Voelcker-Rehage, Ben Godde and colleagues will show differential effects of aerobic and coordination training on cognitive functions in the elderly.

The remaining talks will focus on the effects of cognitive training interventions. In the third talk, Adam Gazzaley will show the neural correlates and transfer effects of visual discrimination training for improving visual working memory. Notger Müller will present effects of a combined physical and cognitive training in patients with mild cognitive impairment. Hubert Dinse will discuss the effects of dancing on neuro-cognitive plasticity in aging, as dancing ideally combines physical and cognitive-coordinative training elements. Finally, Nele Wild-Wall and colleagues will present effects of a broad cognitive training intervention compared to physical and relaxation training on performance and ERP measures in cognitive tests.

Schedule of Events

9:00 - 9:10 h	Welcome and Introduction part I (M. Falkenstein)
9:10 - 9:30 h	Talk 1. Investigating age differences… by D. Hämmerer and cols.
9:30 - 9:50 h	Talk 2. Response-related theta… by J. Yordanova & V. Kolev
9:50 - 10:10 h	Talk 3. Different functional processes… by N. Wild-Wall and cols.
10:10 - 10:30 h	Talk 4. Age-related event-related potential… by I. Czigler
10:30 - 10:45 h	*Break*
10:45 - 11:05 h	Talk 5. EEG analyses of cortical… by E. Golob
11:05 - 11:10 h	Introduction part II (N. Wild-Wall)
11:10 - 11:30 h	Talk 6. Aging, Exercise, and … by K.I. Erickson
11:30 - 11:50 h	Talk 7. 12 months of physical… by C. Voelcker-Rehag and cols.
11:50 - 12:10 h	Talk 8. The influence of perceptual … by A. Gazzaley
12:10 - 12:30 h	*Break*
12:30 - 12:50 h	Talk 9. The effect of a combined… by . Müller
12:50 - 13:10 h	Talk 10. Beneficial effects of … by J-C. Kattenstroth and cols.
13:10 - 13:30 h	Talk 11. Evaluation of effects of ... N. Wild-Wall et al., IfaDo
13:30 - 14:00 h	Plenum and final discussion

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Talk 1.
Investigating age differences across the lifespan in reinforcement learning with a combination of electrophysiological recordings and computational models

Hämmerer, D.1, Biele, G2, Lindenberger, U. 1, & Li, S.-C. 1

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Children and elderly are unimpaired on reinforcement learning tasks compared to younger adults when feedback stimuli are 100% valid but impaired when feedback is probabilistic (e.g. Eppinger et al. 2007). This suggests that especially under conditions that make high demands on linking outcomes and actions, children and elderly experience difficulties. We hence expected a reduced impact of prediction errors and a reduced sensitivity to past reinforcements in children and elderly. Since learning from action outcomes is an adaptive process we combined EEG and cognitive modelling to investigate the dynamics of reinforcement learning across the lifespan. Children, adolescents, younger adults, and older adults were tested on a reinforcement learning task while recording EEG. The sensitivity parameter reflecting the impact of past reinforcements on choices was reduced in children and older adults, suggesting more random choice behaviour. Finally, in line with the assumption that feedback evaluation is impoverished in children and older adults, they showed a weaker relation of prediction errors and the P3 following feedback as compared to younger adults.

Talk 2.
Response-related theta oscillations play an important role for error production during aging

Yordanova J., Kolev V.
Institute of Neurobiology, Bulgarian Academy of Sciences, Sofia, Bulgaria

Error negativity (Ne) decreases with advancing age in humans indicating differences in error processing and performance monitoring between young and old subjects. However, the origins of aging-related reduction of Ne are not known. It has been demonstrated that Ne results from the synchronization of neuroelectric oscillations from the delta (1-4 Hz) and theta (4-7 Hz) frequency bands that are generated over fronto-central midline cortical regions. So far, it has not been established whether age-dependent differences in error processing originate from a reduced power of oscillations, from a decreased capacity to synchronize oscillations after errors, or functional mechanisms activated already before Ne also may be involved. Response-related potentials (RRPs) were recorded in young and older adults during a four-choice reaction task. Power and synchronization of RRP delta and theta components of Ne were analyzed. Also, oscillatory activity generated during response production at motor cortical regions contra-lateral and ipsi-lateral to the responding hand was evaluated. Total power of both delta and theta Ne components increased after errors in the two age groups. Although this increase was less pronounced in older adults, the major age difference was in the substantial decrease of theta synchronization during Ne. Notably, theta oscillations generated before Ne at motor regions, especially ipsi-laterally, were also reduced in older relative to young subjects. Age-related Ne reduction results from an overall decrease in the power of delta and theta oscillations and from a substantial loss in the ability to synchronize theta oscillations during error processing. Differences in theta oscillations between young and older adults exist not only during error processing indexed by Ne, but also before Ne during incorrect response execution. Thus, alterations in the organization and synchronizing properties of oscillatory theta neural networks may account for age-related differences in error response execution and monitoring in humans.

Talk 3.
Different functional processes may explain task- and age-related performance decline under high working memory load

Nele Wild-Wall, Patrick D. Gajewski, Michael Falkenstein

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The present study aimed to elucidate age-differences in performance under high working memory (WM) load. We especially examined neurocognitive processes which may lead to differential performance pattern. A two-choice and a 2-back task, incorporating different amounts of WM load, were performed by young and middle-aged participants. Both tasks used the same stimulus set consisting of letters. Event-related potentials were recorded during task performance. Specifically, the P3 was calculated in non-target trials of the 2-back task as a correlate of resource distribution under high WM load. Expected age-related differences of the neuronal sources were explored by sLORETA.
Response speed of the older participants was generally lower. Under low WM load they traded speed for accuracy leading to equal performance efficiency of the two groups. When taking response speed into account, an age-related performance decline was evident in the 2-back task under high WM load.
The P3 for correct non-target trials in the high load task was decreased and peaked later in the older vs. young group. This was paralleled by lower activation in frontal and right parietal brain areas. Only the young participants showed lower P3 amplitudes in correct non-target trials immediately before missed target trials vs. correctly recognized targets which was paralleled by lower activation in the posterior cingulum and the right insula.
In sum, performance of the middle-aged group was characterized by declined working memory processes. In contrast, young participants flexibly tuned their cognitive resources which led sometimes to lapses of attention. Different functional processes may explain the reduced task performance under high working memory load when comparing young and middle-aged participants.

Talk 4.
Age-related event-related potential differences in auditory encoding and target processing

István Czigler

Institute for Psychology, Hungarian Academy of Sciences, Budapest

In comparison to vision, relative little research is devoted to the possibility of equally important age-related changes in auditory selective attention, and the consequences of attentional selectivity on task performance. Results of event-related potential (ERP) studies using traditional stimulus set-type designs do not report considerable age-related changes in early selection processes. In a version of the memory scanning tasks, in two age groups we compared early (N1) and later (LPC) ERP components to task-relevant and irrelevant auditory events. The stimuli were aversive noises and rich sounds. In a sequence of four stimuli either the noises or the tones had to memorize, and decide later whether a probe was, or was not a member of the to-be-remembered set. Performance was higher in the younger group. N1 to the stimuli of the sequences were generally larger in the older group, and task-relevant stimuli elicited larger N1. However, unlike in the visual modality, no age-related difference emerged between the N1 amplitudes to the relevant and irrelevant stimuli. As an age-related effect, in case of the sound stimuli (the more difficult condition) N1 was larger in the low-performing participants, while in the younger group we obtained the opposite relationship. In the younger group we obtained large P3 (P3b) amplitude difference between the ERPs to relevant and irrelevant stimuli, while in the older group P3b the difference was absent (noises) or it was small (sounds). As these results show, in the auditory modality considerable age-related differences emerged in later stages of processing, i.e., while gating processes were similar in the two age-groups, specific stimulus properties were less selectively processed in elderly.

Talk 5.
EEG analyses of cortical dynamics in normal and abnormal aging

Edward Golob

Department of Psychology and Program in Neuroscience, Tulane University, USA

Electromagnetic measures such as EEG and MEG can be used to assess neocortical activity with millisecond precision. Analysis of EEG data using advanced signal processing methods permits the detailed study of spectral and temporal properties during task performance (time-frequency analysis) as well as identification of independent sources of cortical activity (independent component analysis). Here we apply these methods to the challenge of understanding neural mechanisms of differences in cognitive function in normal aging and age-related neurological disorders. In all of the studies EEG was recorded while subjects performed various behavioral tasks examining auditory stimulus discrimination, selective attention, and resistance to distracting stimuli. Studies assessed differences in cortical activity throughout advanced age by comparing young-older subjects (age ~65-75) to the oldest-old (age ~85-90+). Cortical responses associated with individual differences in cognitive ability were also examined by comparing subjects having high vs. low working memory capacity, with separate analyses in young (age 18-22) and older subjects. Lastly, we studied rare cases of Alzheimer's disease (AD) that are attributable to genetic mutations (termed "familial AD"), which provides an opportunity to study the development of AD pathophysiology years before cognitive deficits are manifest. Relative to controls event-related potentials in familial AD had widespread slowing, while time-frequency and ICA analysis identified differences in EEG responses that were not phase locked to stimulus onset. Findings will be discussed with respect to perspectives on cortical function provided by time-frequency and ICA analyses, and how they may relate to mechanisms of brain and cognitive aging.

Talk 6.
Aging, Exercise, and Brain Function

Kirk I. Erickson

University of Pittsburgh, USA

Brain tissue decays in late adulthood, leading to impaired memory function and increased risk for dementia. With escalating health care costs and an increased proportion of people over 65, it is imperative that low-cost, accessible preventions and treatments for brain tissue loss are discovered. In this talk, I will present data showing that in a one-year randomized controlled trial, moderate intensity exercise increases the volume of certain brain regions including the hippocampus and that increased volume leads to improvements in memory. We also demonstrate that increased hippocampal volume is associated with greater levels of brain-derived neurotrophic factor, a putative mediator of neurogenesis in the dentate gyrus of the hippocampus. These results reveal the importance of fitness and exercise on brain morphology and suggest that aerobic exercise is protective against hippocampal decay and may even reverse manifest deficits that increase the risk for dementia. Finally, we demonstrate that exercise enhances brain function by influencing the connectivity between regions. Greater connectivity within several brain networks enhances the communication between brain areas and is related to better cognitive function. In sum, we claim that neurocognitive function is enhanced by aerobic exercise interventions and that this provides evidence for brain plasticity in old age.

Talk 7.
12 months of physical exercise positively influence cognitive functioning and brain activation in older adults

Claudia Voelcker-Rehage, Ben Godde, Ursula M. Staudinger

Jacobs-University, Bremen, Germany

We performed a 12-months longitudinal study to investigate how physical activity (cardiovascular and coordination training) influences brain activations and cognitive functions in cognitive and motor tasks. 72 participants aged 62 to 79 years were trained 3 times a week for 1h each either in a walking or coordination training group. Motor and cognitive performance was tested at the beginning, after 6, and after 12 months. Changes in brain activation for cognitive and complex motor tasks were examined using functional MRI. Both intervention groups improved in executive functioning (flanker task), but only coordination training led to improved perceptual speed performance (visual search task). In both groups, prefrontal areas showed decreased activation after 6 and 12 months when performing the executive control task, as compared to a control group (relaxation and stretching), indicating more efficient information processing. Furthermore, cardiovascular training was associated with increased activation in the sensorimotor network, whereas coordination training was associated with stronger activation of the visual-spatial network. For the complex motor tasks (walking forward and backwards), walking training led to more specific motor activations and less need for cognitive control, whereas low fit older adults had to recruit more frontal resources for cognitive control and planning. Our data suggest that besides cardiovascular training also other types of physical activity improve cognition of older adults. The mechanisms, however, that underlie the performance changes seem to differ depending on the intervention. Moreover, high fitness corresponds with more automation and less cognitive control of complex motor tasks, which might help to free up cognitive resources.

Talk 8.
The influence of perceptual training on working memory in older adults

Adam Gazzaley MD, PhD.

Departments of Neurology Physiology and Psychiatry, W.M. Keck Foundation Center for Integrative Neuroscience, University of California, San Francisco

Normal aging is associated with a degradation of both perceptual abilities and working memory. We recently explored the behavioral and neural effects of perceptual discrimination training in healthy older adults (ages 60-89 years), notably its ability to transfer benefits to working memory performance. We evaluated two groups of participants before and after either ten hours of visual discrimination training over a three to five week period (training group) or no training (control group). Stimuli used in the training program were Gabor patterns, which expanded or contracted two successive times per trial. Participants pressed one of two buttons for each movement to indicate whether they perceived the stimuli expanding or contracting. We demonstrated that visual discrimination training transfers to improvements in an untrained perceptual task, as well as improved visual working memory. Remarkably, performance reached the level of young adults after limited training. Using electroencephalography (EEG), we reveal neural evidence of functional plasticity in visual cortex. Specifically, early visual processing changes within the first 200 ms of stimulus presentation occurs during stimulus encoding only in the training group and is strongly correlated with subsequent working memory improvement ($r = 0.82$). Of note, perceptual discrimination training did not improve WM performance beyond control levels in the setting of interference, which generated a new study directed at enhancing interference processing. These findings demonstrate the strength of the perceptual discrimination training approach by offering evidence of transfer-of-benefit and a neural mechanism underlying cognitive improvement.

Talk 9.
The effect of a combined motor and cognitive training on cognitive function, structural and functional MRI and BDNF plasma levels in MCI patients

Notger G. Müller

German Centre for Neurodegenerative Diseases, Magdeburg, Germany

Although mild Cognitive Impairment (MCI) is regarded as a major risk factor for later dementia, to date there is no approved pharmacological intervention. Therefore, we asked whether a non-pharmacological intervention program can improve cognitive and brain function in these patients. We randomized 40 subjects with MCI into two groups, one received a 12-week combined motor-cognitive training, the other served as a control group and received training later (waiting list design). Another control group comprised healthy elderly.
The study was completed by 19 subjects in the MCI training group and 19 subjects in the MCI control group. Compared to the healthy control group the MCI training group was impaired in the MMSE ($p<.001$), verbal working memory ($p= .047$) and verbal ($p=.033$) and figural ($p=.033$) episodic memory. After training, the MCI intervention group showed significantly improved measures in verbal episodic memory ($p=.001$), figural episodic immediate ($p=.002$) and delayed recall ($p=.003$) and alertness ($p=.026$). Compared to the MCI control group improvements were significant for verbal episodic memory ($p=.041$), visual episodic memory ($p=.017$) and alertness ($p=.002$). MCI patients with an initially high BDNF level profited more from the training. Hippocampal volume was slightly increased after training; fMRI (resting state, episodic visual memory) demonstrated training induced functional changes in different neuronal networks.

Talk 10.

Beneficial effects of a six-months dance class on somatosensory cortex processing of elderly individuals parallel restoration of sensorimotor and cognitive performance

Jan-Christoph Kattenstroth 1, Tobias Kalisch 2, Hubert Dinse 1

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We have recently shown that a year-long schedule of regular dancing activities has beneficial impacts on physical and mental fitness of elderly individuals (Kattenstroth et al. 2010, Frontiers in Aging Neuroscience). Dancing provides a unique combination of physical activity, emotional, social, acoustic, musical, and affective features resulting in a high compliance with little drop-outs. Accordingly, we have dancing regarded as an equivalent to an “enriched environment” for elderly humans, which enforces sensory, motor, and cognitive abilities. We here extended these studies to explore in a pre-post design the efficacy of dancing as an intervention therapy for elderly individuals to delay and counteract age-related deterioration of sensorimotor and cognitive functions. We investigated the impact of a 6-month professional senior dancing class (1 hour per week) in a group of neurologically healthy elderly subjects (aged 60 to 94years, n=25) having no record of either dancing or sporting activities for at least five years. To obtain information about behavioral effects, we assessed cognitive, postural, sensorimotor performance, and reaction times. Possible impacts on brain organization were investigated by recording tactile evoked SEPs (somatosensory evoked potentials) by means of high-density EEG. All parameters were assessed prior to the beginning of the class and after completion 6 months later.
Following the dance intervention we found significant improvements for postural, cognitive, and sensorimotor performance. SEP analysis showed that the individual gain of improvement was associated with a reduction of the age-related expansion of the hand representation in primary somatosensory cortex as characterized by the distance between the dipoles of the right index and little finger. These data show that the age-related increase of the hand representation (Kalisch et al. 2010, Cerebral Cortex) is reversible by an intervention program of only 1 hour per week. We conclude that dance is an effective approach to enforce and maintain plasticity processes in elderly populations thereby ameliorating age-related degradation.

Talk 11.
Evaluation of effects of cognitive and physical training interventions on performance in two cognitive transfer tasks in seniors

Nele Wild-Wall, Claudia Wipking, Michael Falkenstein & Patrick D. Gajewski

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Data are presented from an intervention trial which tested effects of a physical and a cognitive training intervention on cognitive performance in senior participants (65 to 88 years). The participants were randomly assigned to a cognitive, a physical and a control group. The training groups received a 4-month training intervention. Before and after the training cognitive performance was tested with different tests. Alongside, event-related potentials (ERPs) were recorded in order to elucidate more closely the neural underpinnings of expected training gains. Results of two selected cognitive transfer tasks revealed improved performance after training only for the cognitive training group compared to the other groups. More specifically, target detection improved after training in a visual search task. In addition, lower error rates were observed in a cued task-switching version of the Stroop-task. The training gains were paralleled by specific changes in the ERP which may pinpoint the loci of the functional effects of the training induced plasticity. The present results illustrate the usefulness of cognitive training in older participants. The lack of significant effects after the physical training intervention may be due to the relatively short training intervention of 4 month as other studies suggest rather longer interventions to be efficient.