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Event-related potential indices of inter-individual and age differences in visual attention capacity

Iris Wiegand[1,2], Thomas Töllner[2], Mads Dyrholm[1], Hermann J. Müller, Claus Bundesen[1], Kathrin Finke[2]

[1] Center for Visual Cognition, Department of Psychology, University of Copenhagen
[2] General and Experimental Psychology, Department of Psychology, Ludwig-Maximilians University Munich

Introduction

Individual differences and age-related decline of cognitive abilities depend on the availability of central processing resources. According to the Theory of Visual Attention (TVA, Bundesen, 1990), attentional capacity is limited by two distinct parameters:
1. Visual Processing Speed C: The amount of information that can be processed within a certain time
2. Visual Short-Term Storage Capacity K: The maximum number of objects that can be perceived at one point in time

Research questions & study aim:
- Are inter-individual differences in *Processing Speed C* and *Storage Capacity K* supported by distinct neural mechanisms?
- Do the same mechanisms account for age-related decline of the two abilities?

⇨Identification of neuro-cognitve correlates of inter-individual and age differences in TVA parameters of attentional capacity

Methods

Participants

N=40, 20 younger, 20 older

		Age	Sex	Educ.	IQ
Younger	all	26.3 (3.0)	10/10	13.0 (0)	113.4 (8.9)
	high K	26.8 (2.6)	6/4	13.0 (0)	114.6 (12.0)
	low K	25.8 (3.7)	4/6	13.0 (0)	109.8 (6.3)
	high C	26.7 (2.6)	5/5	13.0 (0)	111.8 (10.5)
	low C	25.9 (3.7)	5/5	13.0 (0)	112.4 (8.7)
Older	all	67.0 (3.9)	9/11	11.3 (1.5)	133.8 (8.0)
	high K	68.1 (4.5)	6/4	11.3 (1.6)	135.6 (5.1)
	low K	66.5 (3.5)	3/7	11.4 (1.7)	131.8 (10.8)
	high C	66.3 (4.3)	4/6	11.1 (1.7)	134.6 (10.5)
	low C	68.3 (3.5)	5/5	11.5 (1.6)	132.6 (3.2)

- Visual acuity ≥0.63 (Snellen chart)
- No chronic somatic, psychiatric, neurological disease (questionaire)
- No beginning dementia (MMSE)

Statistics

Participants of each age group were divided into groups of high- and low performers, based on median-splits of individual *C*- and *K*–values.
Two ANOVAS were run for each ERP component (DV: mean amplitudes):
- *C*-Level (high/low) * Age (young/old)
- *K*-Level (high/low) * Age (young/old)

Component	Time Window	Electrodes
Anterior N1	90 – 120 ms	F3, Fz, F4, FC3, FCz, FC4
Posterior N1	130 - 170 ms	PO7, POz, PO8, O1, Oz, O2
(R)CP	200 – 350 ms	C3, Cz, C4, CP3, CPz, CP4
CDA	450 – 650 ms	PO7/PO8, O1/O2

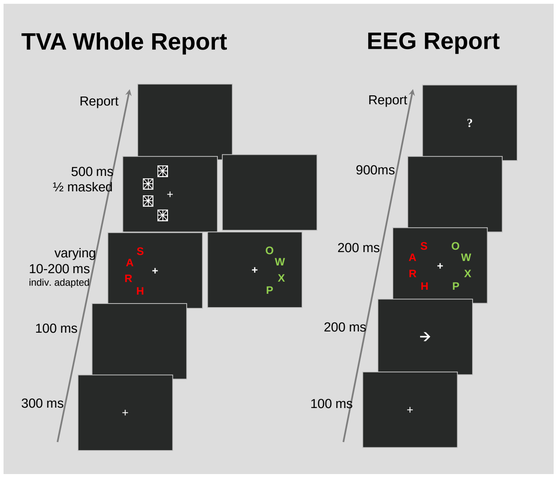
EEG Recording & Procesing

•64 Ag/AgCl electrodes (10/10 system)
•referenced to FCz, re-referenced to averaged mastoids
•Online filter: 0.1–250-Hz bandpass Offline filters: 0.5 Hz high-pass and 40 Hz low-pass
•ICA-based eye artifact correction
•Artifact rejection (max. ±60/±30µV at all electr./F9&F10, max. voltage step 50µV)
•Epochs: -400 – 1400 ms

TVA-based assessment permits the two abilities to be quantified for a particular individual in a mathematical independent manner.
The theory's neural interpretation further assumes that ***C*** and ***K*** are supported by distinct brain mechanisms (NTVA, Bundesen et al., 2005). Combining the methodological advantages of the model-based assessment with EEG offers a promising approach to identify and distinguish between neural underpinnings of inter-individual differences and age-specific decrements in these abilities

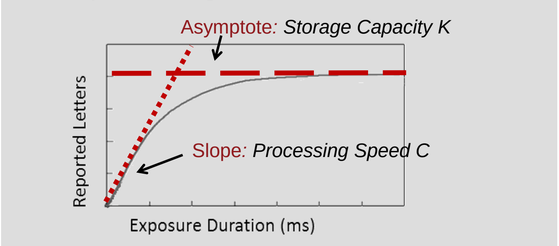
Hypotheses:
1. Age-related decline: Both parameters, *Processing Speed C* and *Storage Capacity K*, are reduced in the older group.
2. Independence: Distinct ERP components index
- inter-individual differences in *C* and *K*
- age-specific differences in *C* and *K*
3. These may comprise
- loss ⇨ $old_{low} \neq old_{high} = young$
- compensation ⇨ $old_{high} \neq old_{low} = young$

Experimental Procedures



Task: verbal letter report. 2 sessions:
1. TVA whole report, from which parameter estimates were derived (200 trials).
2. EEG report, adapted to be suitable for ERP analyses (240 trials).

Parameter Estimation



Individual parameter estimates were modeled based on the method described by Duncan et al. (1999, Appendix A; also see Dyrholm et al., 2011), and involved maximum likelihood estimation of the parameters defining the exemplary function above.

Contact: Iris Wiegand, PhD,
Center for Visual Cognition, University of Copenhagen
iris.wiegand@psy.ku.dk

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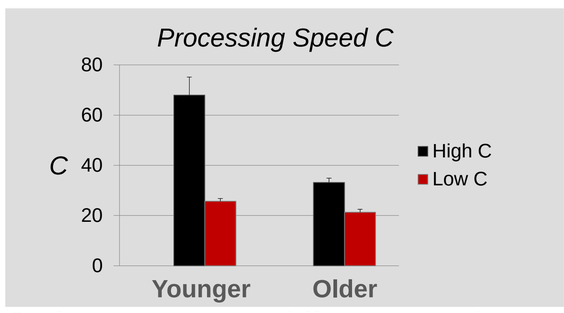
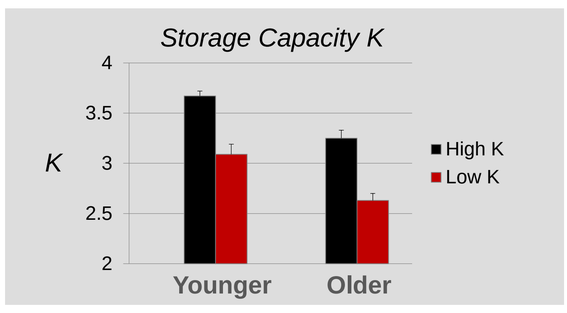
Results & Discussion

Behavioral Data



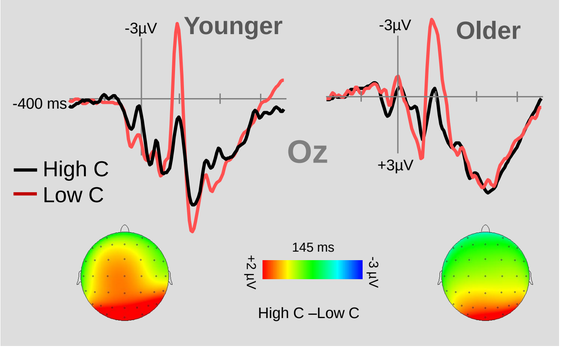
Performance group differences and age-related decline in *Processing Speed C* [ME Age, ME *C*-Level, both <.001]



Performance group differences and age-related decline in *Processing Speed C* [ME Age, ME *K*-Level, both <.001]

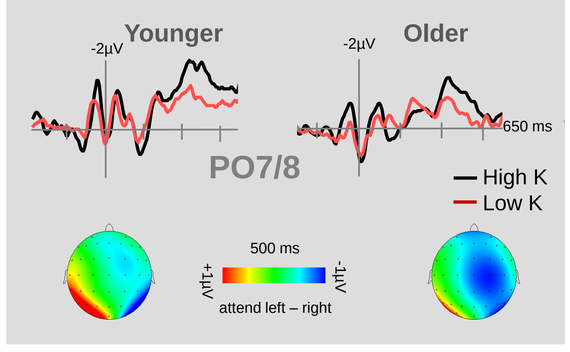
EEG Data

Posterior N1: Inter-individual differences in *Processing Speed C*



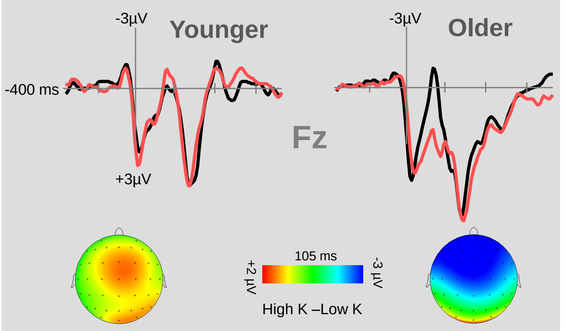
Lower Posterior N1 for faster compared to slower participants, across age groups [ME *C*-Level, p<.01]
⇨ indexes individual differences in the efficiency of object discrimination (e.g., Vogel & Luck, 2000)
⇨ presumably related to the quality of activated internal representations and/or signal-to-noise ratio

Contralateral Delay Activity: Inter-individual differences in *Storage Capacity K*



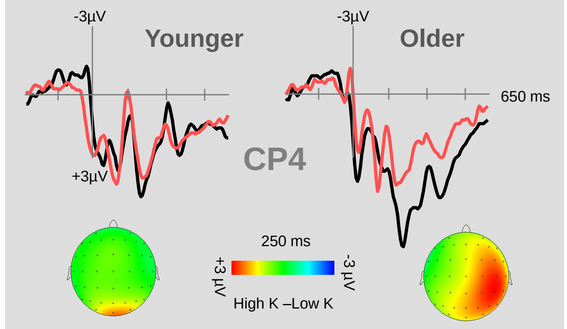
Higher CDA for younger compared to older participants, and for higher- compared to lower-capacity participants [ME *K*-Level, p<.01, ME Age, p<.05]
⇨ Indexes individual and age differences in sustained activation of internal representations (e.g., Vogel & Machizawa, 2004)
⇨ probably governed by thalamo-cortical feedback loops

Anterior N1: Age-dependent decline in *Processing Speed C*



Reduced Anterior N1 for slower- compared to faster older and all younger participants [Age* *C*-Level, p<.01]
⇨ may reflect a deficit in early control of attentional guidance (e.g., Töllner et al., 2009)

Right Central Positivity: Compensation of *Storage Capacity K* in older age



Enhanced RCP for higher- compared to lower-capacity older and all younger participants [Age**K*-Level, p<.05]
⇨ suggests compensatory recruitment of executive control for maintenance counteracting age-related sensory decline (e.g., Daffner et al., 2011)

Conclusions & Outlook

The findings support our main hypotheses and can be reconciled with assumptions of NTVA
1. Indepence of Processing Speed *C* and Storage Capacity *K*
⇨ Different neural processes support two limiting components of visual attention
2. Age-specific reorganization
⇨ Includes loss and preservation
⇨ The distinctiveness of neural processes underlying the two functions is maintained (or increased) in older age

The presented approach enables to link neural activity to performance in specified cognitive processes.

To further advance our understanding of the variance between age-related brain alterations and behavioral symptoms, future studies will aim at identifying
- predictors of decline and compensational abilities in older age
- neuro-cognitive indices of pathological aging (e.g. Alzheimer's disease)

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