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Age differences in N170 amplitude modulation by selective attention and working memory load

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Abstract

The ability to remain focused in the setting of both distracting and relevant information requires an orchestration of neural resources that are limited by working memory (WM) capacity. Recent evidence has indicated that perceptual load can eliminate distractor processing, whereas a high cognitive load increases distractor processing (1). Older adults have been found to have a selective deficit in processing irrelevant information. However, it is unclear how WM load impacts distractor processing in normal cognitive aging. To address this, electroencephalographic recordings in younger (aged 18-30 years) and older adults (aged 60-80 years) were collected to examine effects of WM load (0, 1, or 2 items) on attention to relevant faces and ignoring irrelevant faces using early visual ERPs. Participants viewed four sequential cue stimuli (two faces and two scenes), followed by a delay period and a probe stimulus. Instructions informed participants of the category (i.e. face or scene) and temporal position (1st, 2nd, 3rd, 4th) for the two stimuli to be attended. Results indicate a significant WM-load dependent modulation of N170 amplitude in young adults, such that increased WM load results in decreased evoked N170 amplitudes for both relevant and irrelevant stimuli. Further evaluation will be necessary to place this finding in the context of existing load theories. Neural recordings from older adults indicate an absence of N170 amplitude modulation by WM-load. We are exploring the potential that age-related deficits in WM capacity result in a generalized decrease in WM-load modulation of stimulus processing in cognitive aging.

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Background

*Both the magnitude of neural activity and the speed of neural processing are modulated by top-down influences (2).

*There is an instruction-dependant shift in the N170 peak latency (faster for attend and slower for ignore) relative to passive view (2).

*Older adults display enhancement for the N170 latency for relevant stimuli but do not show suppression for irrelevant stimuli (5).

*The extent to which irrelevant stimuli are excluded from perception occurs only when the processing load of a task engages full attention under conditions of high load (3).

*The N170 elicited by distracting faces demonstrates reduced amplitude during congruent versus incongruent working memory (4).

*N170 amplitude elicited by target faces decreases with load, and this N170 amplitude decrease levels off at load two, reflecting the behavioural working memory capacity of around two faces (6).

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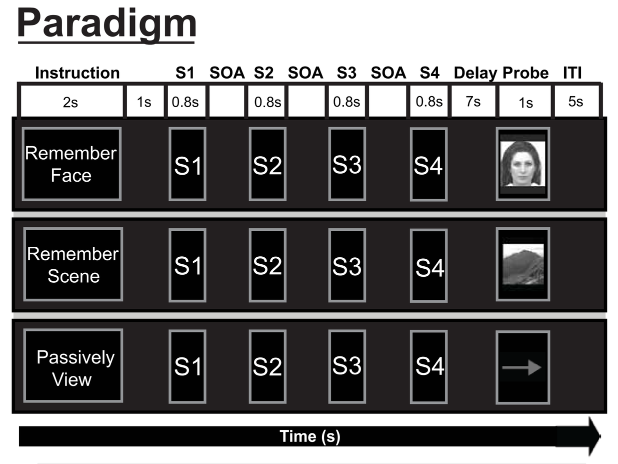
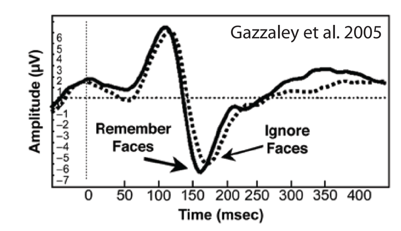
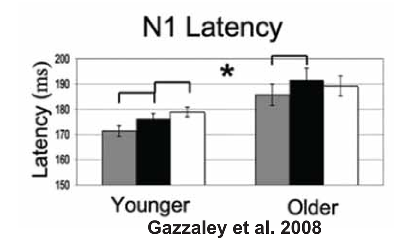
Paradigm



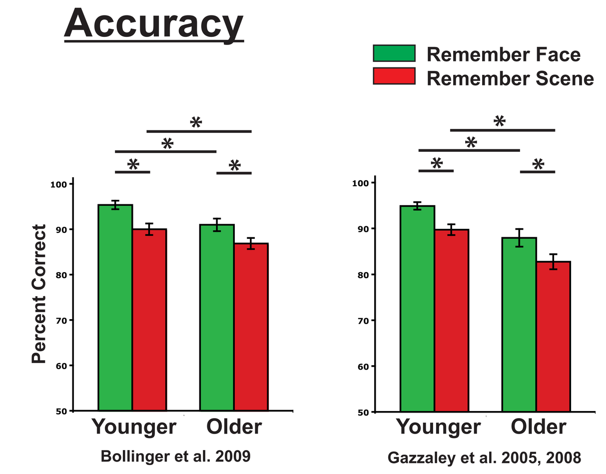
Experiment	Example Instruction	SOA
Gazzaley et al. 2005, 2008	Remember the Faces	0.2 sec
Bollinger et al. 2009	Remember the Faces 1, 3	1 sec

What is Suppression, Enhancement, and a Suppression Deficit?



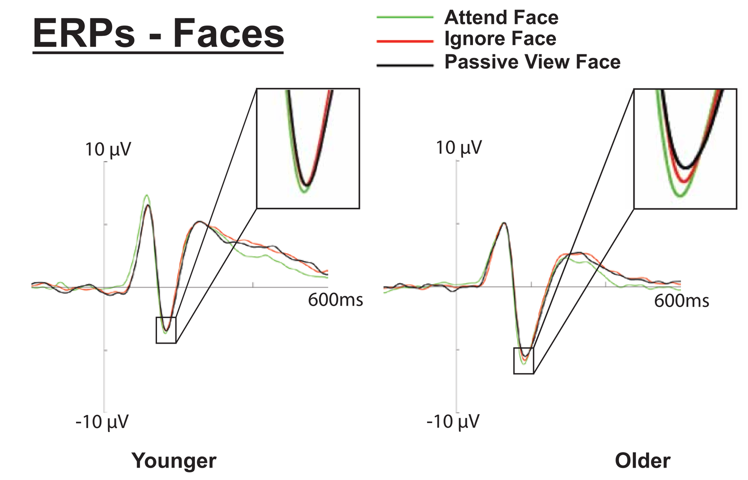


Accuracy



Main effects: Age: $F(1,38) = 6.67$; $p < 0.05$
Task: $F(1,38) = 26.37$; $p < .00001$
No Interaction; $p > 0.3$

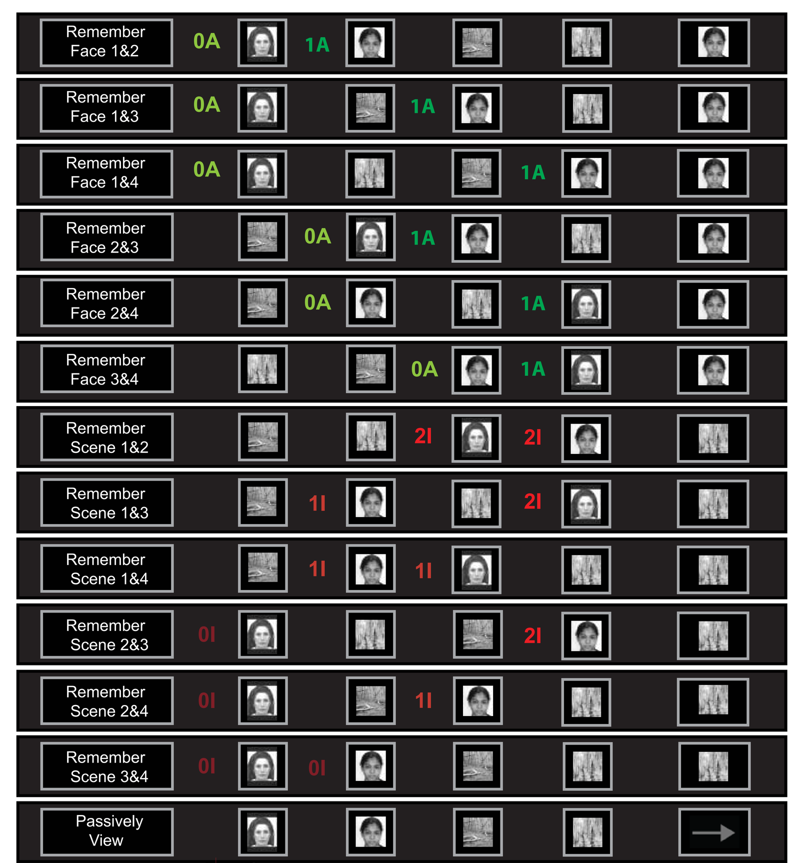
ERPs - Faces



* No significant attentional modulation at the N170 in younger or older adults.

* Pre-stimulus baseline (-200-0ms)

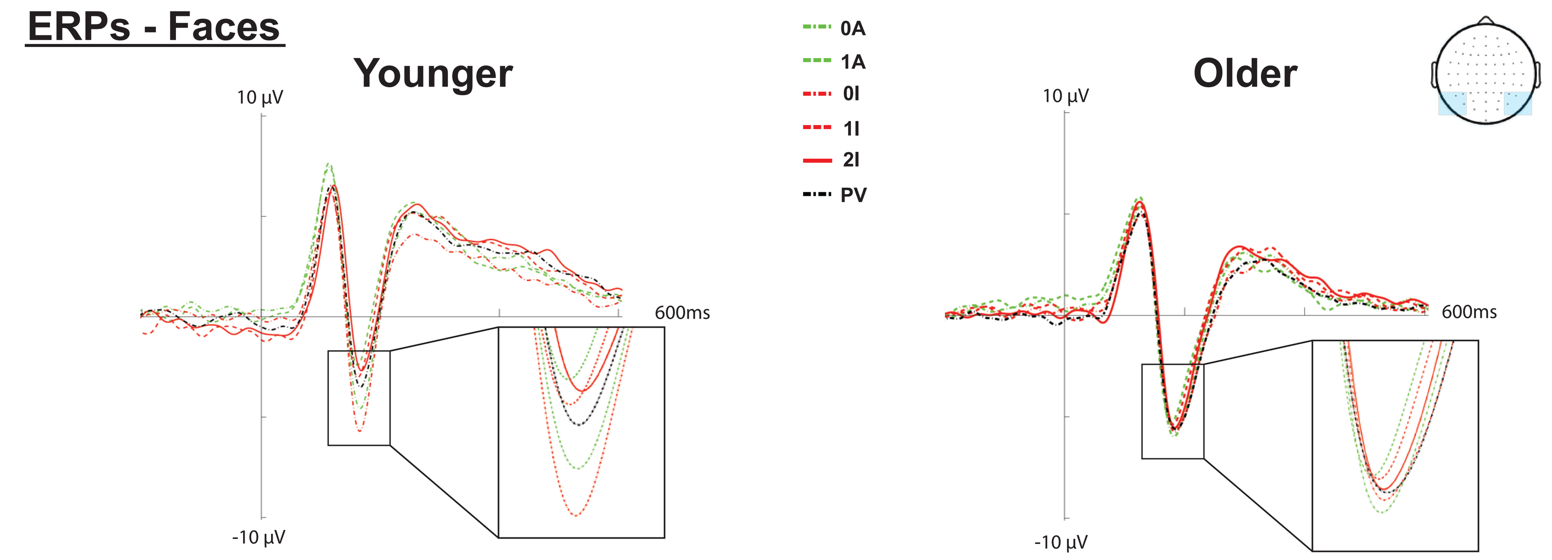
N170 Amplitude Modulation by WM Load



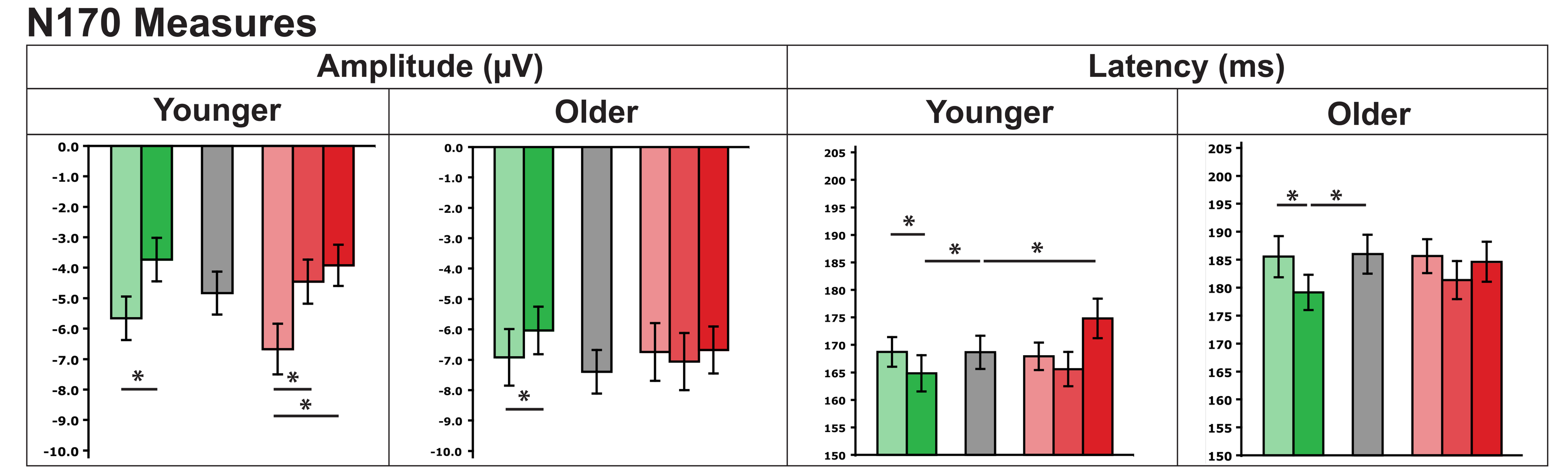
Baseline: 500 msec prior to the first stimulus

Symbol	WM load	Cognitive Operation
0A	0	Attend
1A	1	Attend
0I	0	Ignore
1I	1	Ignore
2I	2	Ignore

ERPs - Faces



N170 Measures



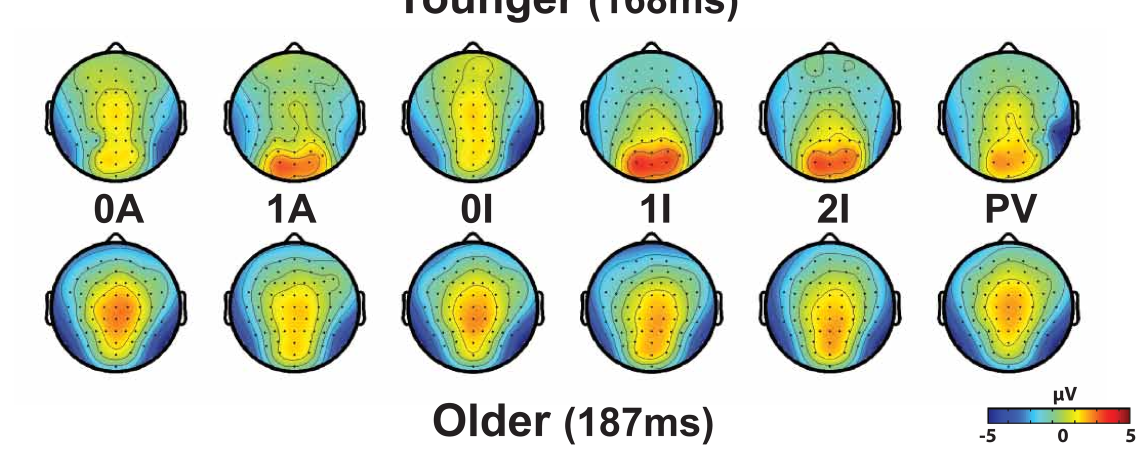
ANOVA (N170 amplitude):

Ignore (2X3): M.E. of WM load: $F(2,76) = 10.62$, $p < 0.0001$
Age X WM load interaction: $F(2,76) = 11.70$, $p < 0.0001$
Attend (2X2): M.E. of WM load: $F(2,38) = 26.07$, $p < 0.0001$
Modulation: M.E. of WM Modulation: $F(1,38) = 19.95$, $p < 0.0001$
Age X Modulation interaction: $F(2,76) = 3.56$, $p < 0.05$

Post-Hoc Analysis :

Younger: N170amp: 0I >1I, 2I ; 0A >1A
N170lat: 1A < PV < 2I
Older: N170amp: 0A >1A
N170lat: 1A < PV
Modulation: N170 amp: 0I-1I, 0I-2I
Younger>Older

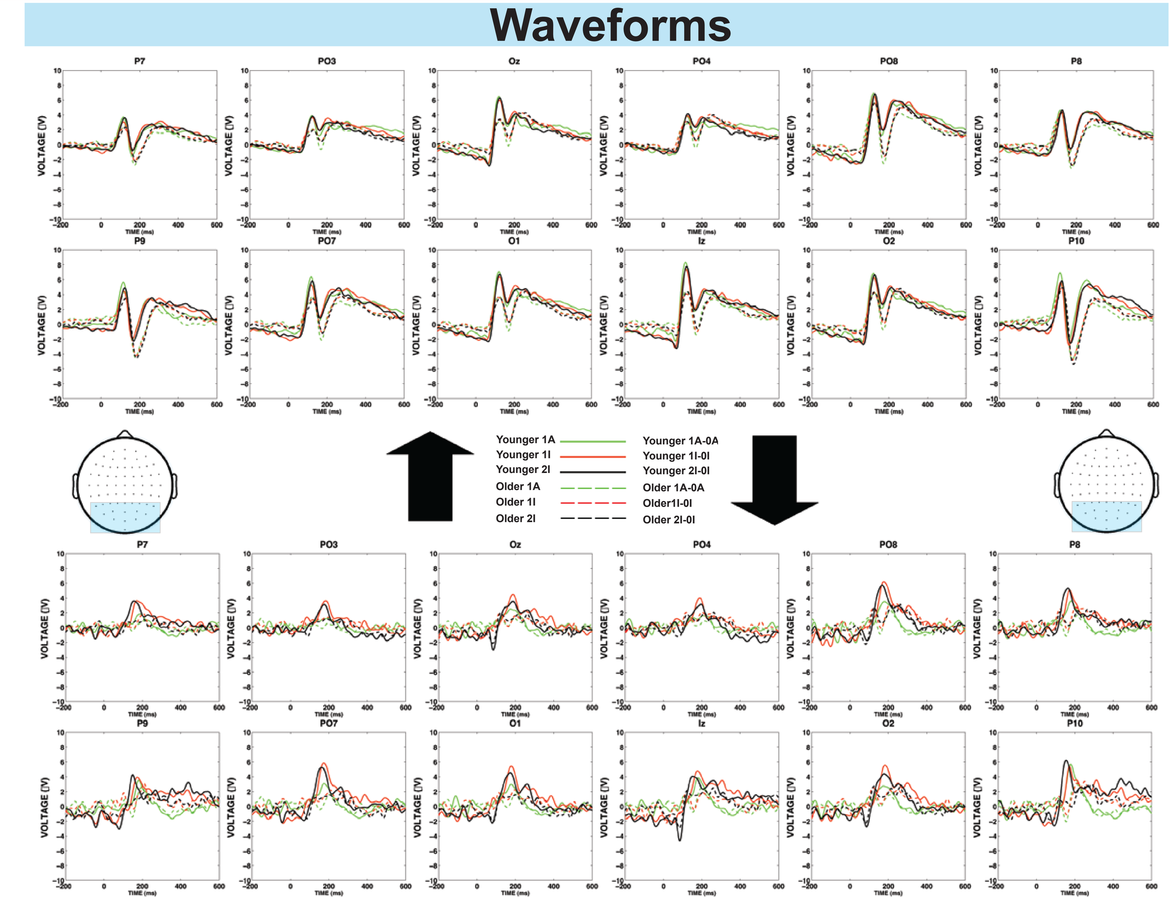
ERP Topographies



McCarthy-Wood Analysis

Group	Comparison	Electrode	Task	Interaction
Younger	0A-PV vs. 1A-PV	$F(12,456) = 1.84$; $p = 0.13$	$F(1, 38) = 12.99$; $p < 0.001$	**$F(12,456) = 4.44$; $p<0.01$**
	0I-PV vs. 1I-PV	$F(12,456) = 2.24$; $p = 0.07$	$F(1, 38) = 41.59$; $p < 0.00001$	**$F(12,456) = 3.52$; $p<0.01$**
	0I-PV vs. 2I-PV	$F(12,456) = 1.33$; $p = 0.20$	$F(1, 38) = 32.86$; $p < 0.00001$	**$F(12,456) = 3.24$; $p<0.05$**
Older	0A-PV vs. 1A-PV	$F(12,456) = 1.98$; $p = 0.11$	$F(1, 38) = 1.73$; $p = 0.20$	$F(12,456) = 1.43$; $p = 0.15$
	0I-PV vs. 1I-PV	$F(12,456) = 1.28$; $p = 0.23$	$F(1, 38) = 1.61$; $p = 0.21$	$F(12,456) = 0.27$; $p = 0.99$
	0I-PV vs. 2I-PV	$F(12,456) = 2.71$; $p < 0.05$	$F(1, 38) = 2.09$; $p = 0.16$	$F(12,456) = 0.35$; $p = 0.98$

Waveforms

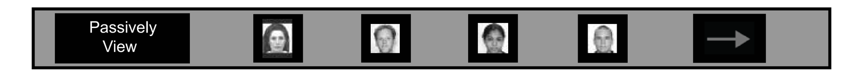


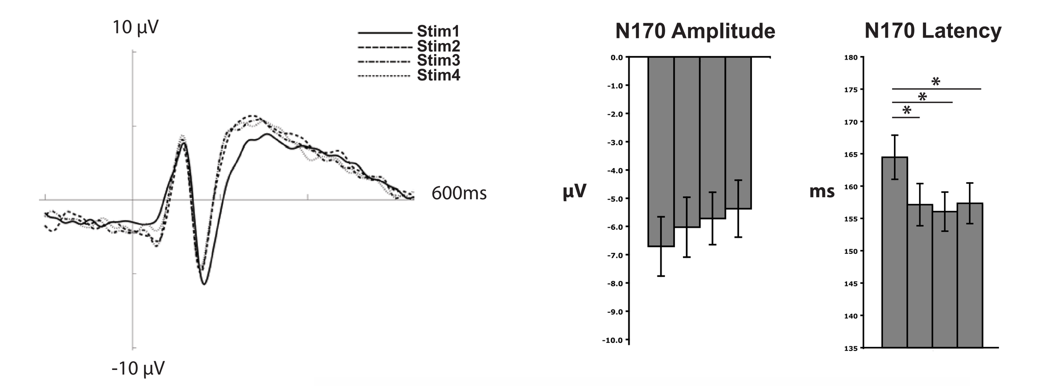
Difference Waves

Box 1: Control Experiment: Habituation

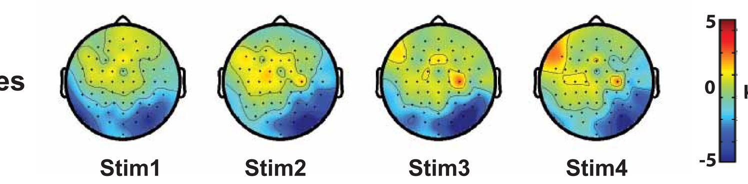
Previous experiments have demonstrated an absence of repetition suppression or habituation to sequential presentation of novel faces (7). In order to replicate these results and to strengthen our interpretation that the N170 effects described here are due to WM load and not to repetition suppression or habituation, 10 younger adults participated in an experiment designed to evaluate N170 amplitudes evoked by sequentially-presented novel faces .

Paradigm (76 trials)





ERP Topographies



These results suggest that although sequential presentation of novel faces may effect N170 latency, there is no significant effect on N170 amplitude under the same experimental conditions used here. This result confirms that habituation alone cannot account for our results and in turn bolsters our interpretation that WM-load is driving our observed modulation of N170 amplitude.

Conclusions

1) Younger adults display WM-load dependent modulation of N170 amplitude for both relevant and irrelevant face stimuli. According to current load theory, perceptual load (not cognitive load) effects account for our findings.

2) Older adults display WM-load related N170 amplitude modulation for relevant stimuli but not for irrelevant stimuli.

3) For this task, younger adults display enhancement and suppression of N170 latency only under conditions of high WM-load (although the observed latency enhancement may actaully be an effect of habituation).

4) Older adults display enhancement of N170 latency under conditions of high WM load (again the latency enhancement may be an effect of habituation), but display a deficit in N170 latency suppression.

5) Synchronous with the N170, a WM-load dependent difference wave was observed over several occipital electrode sites in younger adults.

6) Older adults do not display this widespread occipital ERP modulation by WM-load seen in younger adults.

Hypotheses:

=> We hypothesize that, in younger adults, the competition for limited resources between WM and attention drives the WM-load related modulation of the N170 amplitude. This competition occurs regardless of the cognitive operation involved (i.e. for attend *and* ignore).

=> These results also suggest that older adults may unintentionally 'drop' items from working memory when they ignore irrelevant information which may in turn result in often-observed WM deficits in older adults.

Methods

Stimuli. Stimuli consisted of grayscale images of natural scenes and faces. All face and scene images were novel across all conditions and across all blocks within an experiment. Images were 225 pixels wide and 300 pixels tall, (14x18 cm) and subtended 3 degrees (from center) of visual angle (participants were approximately 172 cm from the screen). The face stimuli consisted of a variety of neutral-expression male and female faces across a large age range. Each stimulus was used within one trial per experimental session.

Data Acquisition. Participants sat in an armchair in a dark, sound-attenuated room. EEG data was recorded during all 14 experimental blocks. The three conditions elicited 76 trials each. Electrophysiological signals were recorded with a BioSemi ActiveTwo 64-channel EEG acquisition system in conjunction with BioSemi ActiView software (CortechSolutions, LLC). Signals were amplified and digitized at 1024 Hz with a 24-bit resolution and collected unreferenced. All electrode offsets were maintained between +/- 20 mV.

Data Analysis. Pre-processing was conducted with Analyzer software (Brain Vision, LLC) and exported to MATLAB (The Mathworks, Inc.) for further analysis. To remove eyeblink and other electrical artifacts, data underwent ICA decomposition, eye movement components were removed, and epochs with excessive peak-to-peak deflections (exceeding ±100 µV), amplifier clipping or other artifacts were rejected. Data was then average-referenced, epoched and,unless otherwise noted, baselined to a period immediately preceding the first stimulus of each trial, time window (-500 to 0ms relative to stimulus onset). For ERP analyses, data was band-pass filtered 1-30Hz. A minimum threshold wasset for 40 artifact-free epochs per participant. These results include data from 20 younger (18-30 years) and 20 older(60-80 years) participants. All participants had normal or corrected-to-normal vision. Older adults underwent a battery of neuropsychological tests to ensure the absence of neurological disease.

Scalp distributions of ERP components in the difference waves were compared after normalizing their amplitudes prior to ANOVA according to the method described by McCarthy and Wood (1985). For the N170 component, comparisons were made over 13 occipital electrode sites. Differences in scalp distribution were reflected in significant stimulus condition by electrode interactions. For analysis of variance (ANOVA), Greenhouse-Geiser corrections were used when appropriate to correct for sphereicity. All paired and unpaired t tests were two-tailed and were subjected to False Discovery Rate (FDR) correction for multiple comparisons.