LOYOLA UNIVERSITY CHICAGO

Preparing people to lead extraordinary lives

Electrophysiology of Rule-Based Category Learning as a Function of Age

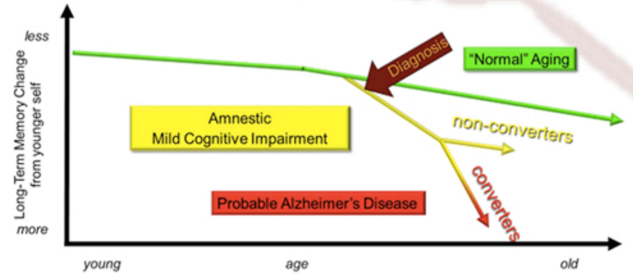
Krishna Bharani (1), Dietta Chihade (1), Kevin Nuechterlein (1), Sandra Weintraub (2), Ken A. Paller (2), Paul J. Reber (2), & Robert G. Morrison (1)

Loyola University Chicago (1) Northwestern University (2)

NORTHWESTERN UNIVERSITY

Introduction

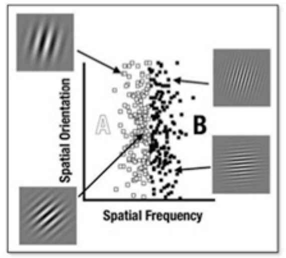
- A central challenge for translational cognitive neuroscience is to develop neurocognitive markers for normal and pathological aging.
- Previous fMRI studies have demonstrated the importance of prefrontal cortex and medial temporal lobe (Ashby & Maddox, 2005; Keri, 2003; Nomura et al., 2007; Nomura & Reber, 2008), two areas implicated in pathological aging including Alzheimer's disease (AD), as important for explicit rule-based category learning.
- Previous event-related potential (ERP) studies involving an incidental learning paradigm suggest that memory ERPs can predict the conversion of amnestic mild cognitive impairment (aMCI) to a probable AD diagnosis (Olichney et al., 2008).
- Neuropsychological studies have also found that aMCI patients are at increased risk for developing probable AD if their executive functions are compromised at the time of aMCI diagnosis (Albert et al., 2007).
- Thus, rule-based category learning may be sensitive to factors predicting subsequent pathology.

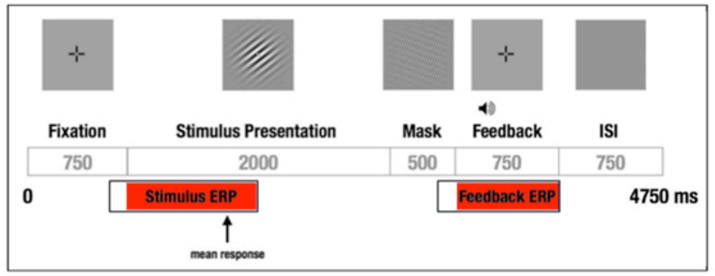


Methodology

Task

- We developed a rule-based category learning based on the methods of Maddox et al., (2003) and Normura et al., (2007)
- Participants categorized Gabor patches (320 trials) that varied in spatial frequency (i.e. how many stripes) and orientation (i.e. the angle of the lines in the patch).
- Two categories (A or B) were predetermined based on spatial frequency.
- Participants received feedback on each trial
- Participants also completed a second task in which they were given the category rule based on spatial frequency with figures at the near and far boundaries to test possible vision deficits.





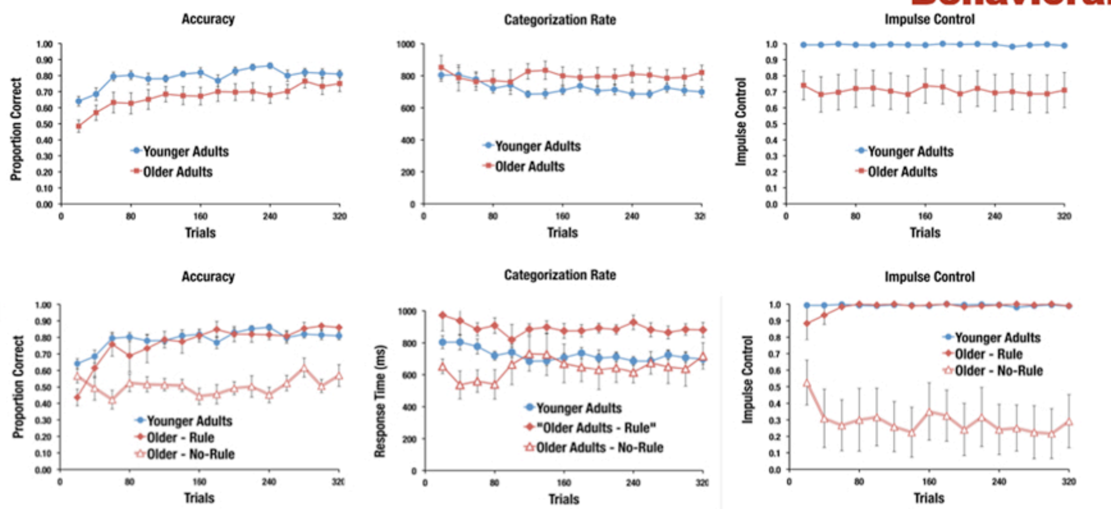
EEG

- EEG data was collected using a 38-channel Biosemi Active2 EEG system including two mastoid electrodes for digital re-referencing and four electrodes for monitoring eye movements.
- Data were filtered offline using a 0.01Hz high-pass filter and a 59-61Hz band-stop filter in EMSE (Source Signal Imaging) and all channels were corrected for ocular artifacts using EMSE's PCA-based algorithm.
- Stimulus- and Feedback-locked event-related potentials (ERPs) were calculated for correct and incorrect trials for all participants.

Participants

- We tested 21 younger adults (M = 19.86 , SD = 2.73) recruited from Loyola and Northwestern Universities and 16 older adults (M = 71.09 , SD = 2.91) recruited from the Northwestern Alzheimer's Disease Center Core.
- Older adults were within 1.5 SD of their age appropriate score on two measures of long-term memory

Behavioral Results



Accuracy

- Older adults showed lower accuracy younger adults, but there were two distinct subgroups based on accuracy.
- The Rule subgroup (n=10) learned slightly more slowly than younger adults, but showed equivalent asymptotic accuracy. The No-Rule subgroup (n=6) did not learn and showed near chance performance throughout the task.

Response Time

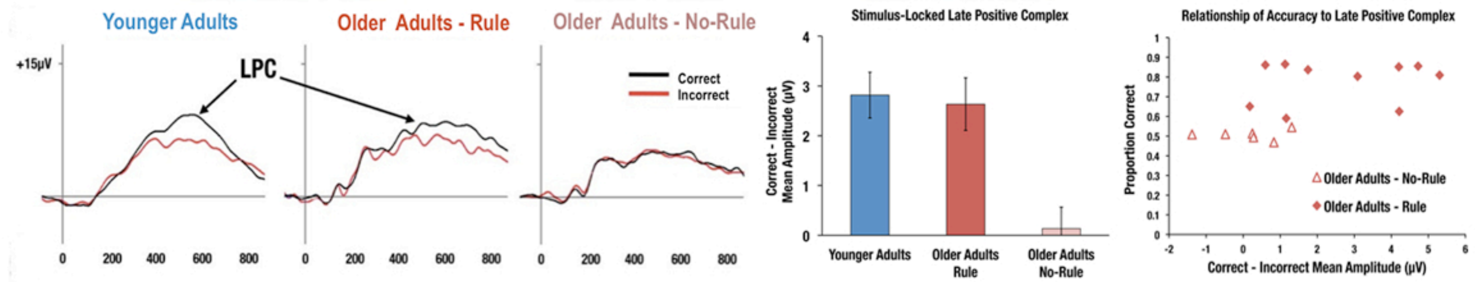
- The No-Rule subgroup and the young adults had similar response times that were lower than the Rule subgroup throughout the task.

Impulse Control

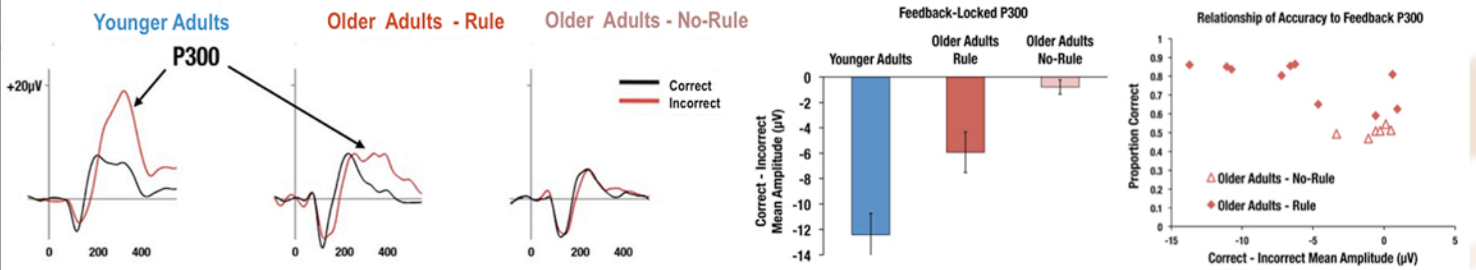
- Impulse control was determined by calculating the proportion of trials that participants answered more than once for a single stimulus (only the first response was used to determine accuracy).
- The No-Rule subgroup showed poor impulse control corresponding to their fast RTs suggesting a deficit in executive control may be important in understanding their task deficit.

Neuroimaging Results

- Younger adults showed similar patterns for the stimulus-locked Late Positive Complex (LPC) and feedback-locked P300 ERPs as we saw in our original study (Morrison, Reber, & Paller, 2009).



- Because of differences in peak latency between older and younger adults, stimulus-locked LPC ERPs were measured from 500 to 600ms for younger adults and from 600 to 750ms for older.
- Correct/incorrect LPC ERP subtractions of mean amplitude showed a reliable difference for younger and rule subgroup older adults, while the no-rule subgroup showed no difference.
- Based on many previous ERP studies involving memory we believe the LPC indexes long-term memory access and updating and thus appears to be abnormal in the no-rule subgroup.



- Correct/incorrect feedback-locked P300 ERP subtractions of mean amplitudes from 300 to 400ms shows a reliable difference for younger adults and rule subgroup older adults, while the no-rule subgroup showed no difference.
- Unlike the LPC, the P300 for the rule subgroup was reduced compared to that for younger adults in spite of equivalent accuracy suggesting decreased rule-learning confidence.
- The P300 ERP is widely believed to be an index of violations of expectancy and thus we interpret the correct/incorrect subtraction to reflect the degree to which a participant has developed confidence in an explicit rule for categorization.

Conclusion

- Compared to younger adults, older adults show increased variability in performance in a rule-based category learning task.
- Older adults showing deficits (no-rule subgroup) appear to have difficulties with both executive and memory functions as evidenced by behavioral and ERP results.
- While some older adults showed similar behavioral performance to younger adults (rule-subgroup), their ERPs show variable compromise, suggesting they may be appropriate predictors of further decline.
- Our results suggest that rule-based category learning with ERP analysis may be an excellent means to screen older adults for increased risk for pathological aging.

Acknowledgements

- Albert, M., Moss, M.B., Blacker, D., Tanzi, R., & McArdle, J.J. (2007). Longitudinal change in cognitive performance among individuals with mild cognitive impairment. *Neuropsychology, 21*, 158-169.
- Ashby, F.G., Maddox, W.T. (2005) Human category learning. *Annual Review of Psychology, 56,* 149-78
- Ashby, F. G., Ell, S. W., & Waldron, E. M. (2003). Procedural learning in perceptual categorization. *Memory & Cognition, 31,* 1114-1125
- Kéri, S. (2003). The cognitive neuroscience of category learning. *Brain Research Reviews, 43,* 85-109
- Nomura, E. M., Maddox, W. T., Filoteo, J. V., Ing, A. D., Gitelman, D. R., Parrish, T. B, Mesulam, M.-M. & Reber, P. J. (2007). Neural correlates of rule-based and information-integration visual category learning. *Cerebral Cortex, 17,* 37-43.
- Nomura, E. M., & Reber, P. J. (2008). A review of medial temporal lobe and caudate contributions to visual category learning. *Neuroscience & Biobehavioral Reviews, 32,* 279-291.
- Maddox, W. T., Ashby, F. G., & Bohil, C. J. (2003). Delayed feedback effects on rule-based and information-integration category learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29,* 650-662.
- Olichney, J.M., Taylor, J.R., Gatherwright, J., et al. (2008). Patients with MCI and N400 or P600 abnormalities are at very high risk for conversion to dementia. *Neurology, 70,* 1763-1770

CAN Lab
Cognitive & Affective Neuroscience
canlab.org

The authors would like to thank Susan Florczak, Brian Sweis, Janet Wingo, and Liz Tuminello for excellent technical support and the Illinois Department of Public Health's Alzheimer's Disease Research Fund and the Loyola Dean of Arts and Sciences for their generous support.