Implicit measures of receptive vocabulary knowledge in low-functioning individuals with autism

Emily Coderre[1], Mariya Chernenok[1], Laura Bosley[1], Jessica O'Grady[1], Barry Gordon[1,2], & Kerry Ledoux[1]

[1]Cognitive Neurology/Neuropsychology, Department of Neurology, The Johns Hopkins University School of Medicine, Baltimore, MD

[2]Department of Cognitive Science, The Johns Hopkins University, Baltimore, MD

Introduction

Assessments of the cognitive operations responsible for language are typically quantified using overt behaviors such as response time or verbal reports. However, such explicit measures assume an understanding of task goals and an ability to execute the required response. In certain populations, such as non- or minimally-verbal low-functioning individuals with autism (LFAs) in whom such measures might be difficult or impossible to obtain, implicit measures of cognitive abilities that do not require explicit understanding and cooperation are essential.

Eye movement monitoring (EM), pupillary dilation (PD), and event-related potentials (ERPs) can provide implicit measures of language processing (Odekar et al. 2009; Kuipers & Thierry, 2011; Connolly & D'Arcy, 2000). In recent work, we have shown that these measures can be used concurrently to estimate vocabulary knowledge in normal adults (Ledoux et al., 2015). In a visual world paradigm, EMs were faster and more accurate to pictures of high-frequency "known" words than to low-frequency "unknown" words. Changes in pupil dilation were greater in response to unknown words than to known words, reflecting greater cognitive demand. In a picture-word congruity paradigm, the amplitude of the N400 ERP component was reduced in response to matching picture-word pairs compared to mismatching pairs; however, this effect was only observed for known words, not for unknown words.

While these implicit measures hold great potential for cognitive assessment in the absence of behavioral responses, it is unknown whether these implicit measures can serve as reliable indices of vocabulary knowledge in low-functioning individuals with autism. The current study evaluates whether EM, PD, and ERPs can assess receptive vocabulary knowledge in LFAs, some of whom have no functional speech.

Methods

Participants

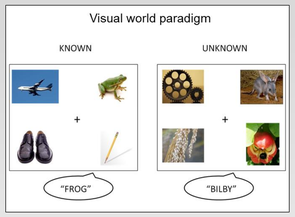
- Five LFAs; mean age 27 years (range 16-49); all males; 7 Caucasian, 2 Asian.
- All participants were enrolled in adult or educational programs specific to assisting individuals with autism and required direct 24-hour support staff and/or parental supervision.

Participant	ADOS					ADI-R	K-BIT		PPVT
	ADOS version	Module	Total	Classification	Symptom severity		verbal	non-verbal	
LFA01	1	1 (adapted)	20	autism	high‡	completed	N/A		N/A
LFA02	2	1 (adapted)	16	autism	high	N/A	N/A		N/A
LFA03	N/A					completed	N/A		20
LFA08	2	4 (adapted)	22	autism	--	N/A	45	79	58
LFA09	2	4	20	autism	--	N/A	40	60	43
LFA11	2	4	19	autism	--	N/A	93	131	94

‡ The ADOS-1 does not give symptom severity so total scores were compared with the ADOS-2 algorithm.

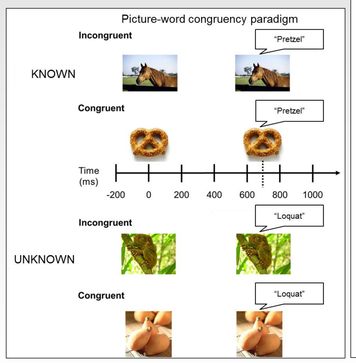
Eye Movement Monitoring and Pupillometry

- Visual world paradigm: four pictures presented, followed by a spoken word
- Applied Scientific Laboratories 504 Eye-Tracking System



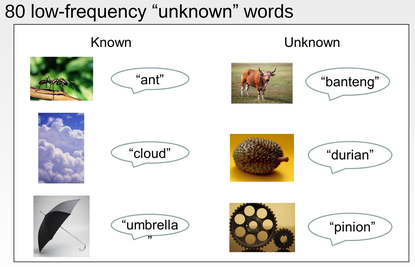
EEG Data Acquisition and Preprocessing

- Picture-word congruency paradigm: each picture presented twice, once with congruent and once with incongruent word pairing
- EEG recorded at 250 Hz using an Electrical Geodesics Inc. GES 300 EEG System with 256-channel Hydrocel Geodesic Sensor Nets and NetStation version 4.3
- Motion and eye movement artifacts corrected using ICA decomposition



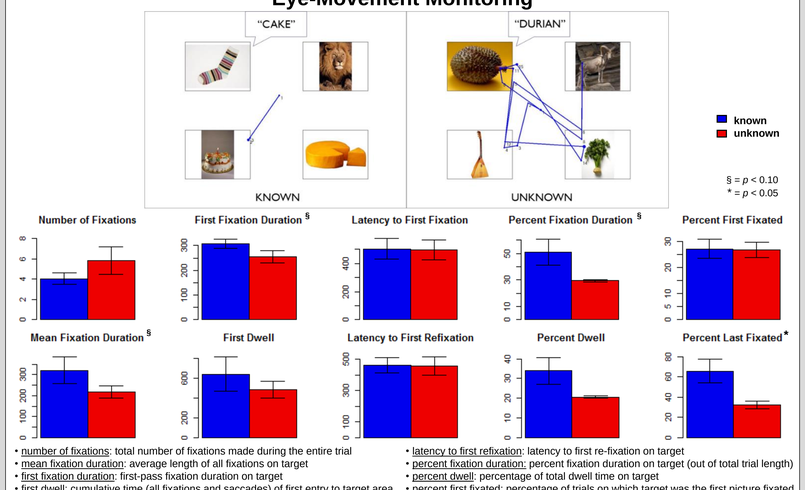
Stimuli

- 80 high-frequency "known" words
- 80 low-frequency "unknown" words



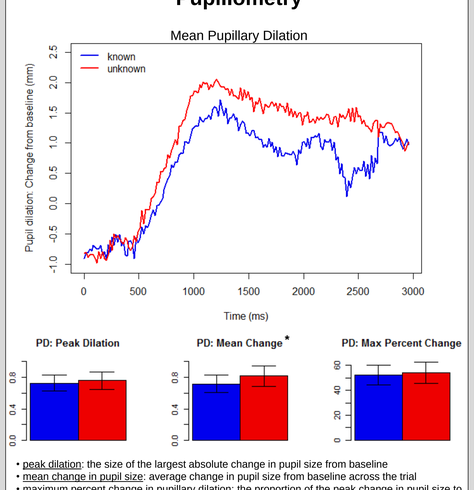
Results

Eye-Movement Monitoring



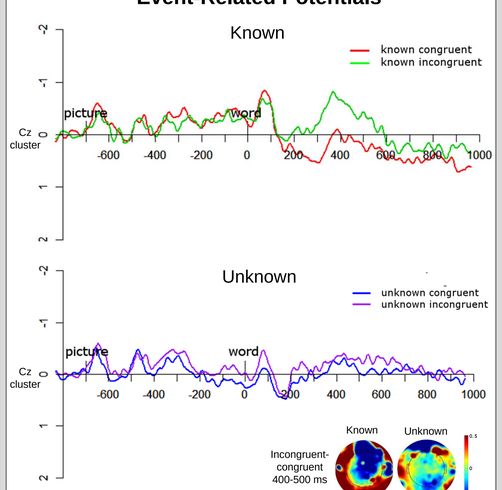
- number of fixations: total number of fixations made during the entire trial
- mean fixation duration: average length of all fixations on target
- first fixation duration: first-pass fixation duration on target
- first dwell: cumulative time (all fixations and saccades) of first entry to target area
- latency to first fixation: latency to first fixation on target
- latency to first refixation: latency to first re-fixation on target
- percent fixation duration: percent fixation duration on target (out of total trial length)
- percent dwell: percentage of total dwell time on target
- percent first fixated: percentage of trials on which target was the first picture fixated
- percent last fixated: percentage of trials on which target was the last picture fixated

Pupillometry

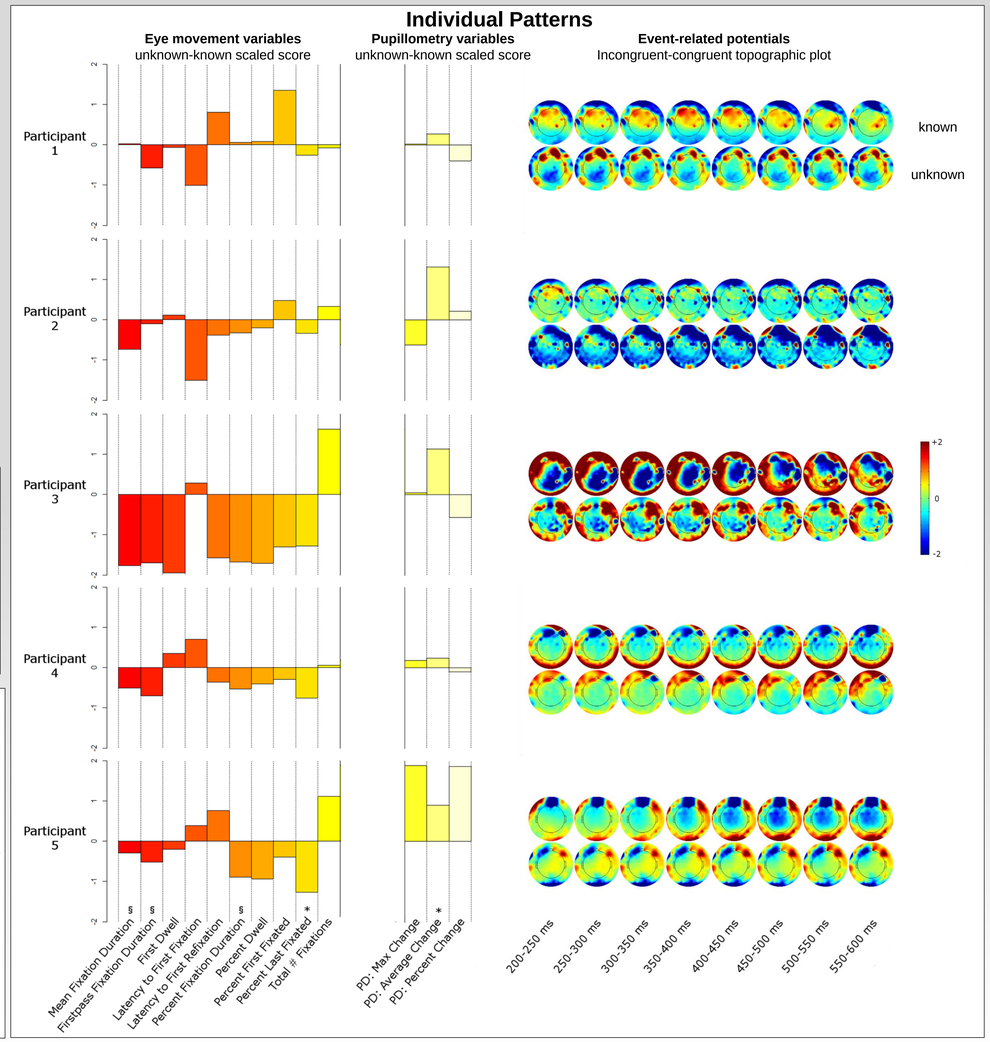


- peak dilation: the size of the largest absolute change in pupil size from baseline
- mean change in pupil size: average change in pupil size from baseline across the trial
- maximum percent change in pupillary dilation: the proportion of the peak change in pupil size to baseline pupil size

Event-Related Potentials



Individual Patterns



Discussion

In the EM data, known words showed longer average fixation durations and a greater proportion of fixation and dwell time on the target picture relative to unknown words, indicating that participants spent a greater amount of time looking at the target picture when the word was known. Known trials had fewer fixations compared to unknown trials, suggesting that participants' eyes moved more directly to the target picture in response to known words. These findings replicate those of normal adults (Ledoux et al., 2015).

In the PD data, the average change in PD was greater for unknown words compared to known words, suggesting greater recruitment of resources for unknown words.

In the ERP data, known trials elicited an N400 effect over centro-parietal scalp, whereas there was no such effect for unknown words.

As can be seen in the individual data, there was significant heterogeneity among the participants. Differences were observed in the strength of response of each measure and in which measures best distinguished between known and unknown words. This suggests that some of these implicit measures might be better suited for certain participants than others.

Conclusions

Overall, LFAs showed similar patterns of EM, PD, and ERPs responses to known and unknown vocabulary as did normal adults, although there was significant individual variation. Thus despite the inevitable heterogeneity in this population, these implicit measures can be used to assess receptive vocabulary knowledge in the absence of behavioral responses. These techniques hold great potential for assessment of linguistic and other cognitive capabilities in low-functioning populations.

References

Connolly, J.F., & D'Arcy, R.C.N. (2000). Innovations in neuropsychological assessment using event-related brain potentials. *International Journal of Psychophysiology, 37*, 31-47.

Kuipers, J.R., & Thierry, G. (2011). N400 amplitude reduction correlates with an increase in pupil size. *Frontiers in Human Neuroscience*, 5, 61.

Ledoux, K., Coderre, E.L., Bosley, L., Buz, E., Gangopadhyay, I., & Gordon, B. (2015). The Concurrent Use of Three Implicit Measures (Eye Movements, Pupillometry, and Event-Related Potentials) To Assess Receptive Vocabulary Knowledge in Normal Adults. *Behavior Research Methods*. doi 10.3758/s13428-015-0571-6.

Odekar, A., Hallowell, B., Kruse, H., Moates, D., & Lee, C.-Y. (2009). Validity of eye movement methods and indices for capturing semantic (associative) priming effects. *Journal of Speech, Language, & Hearing Research, 52*, 31-48.

Acknowledgements

We would like to thank the Linwood Center for their involvement as a research site and all of the participants and their families and/or caregivers. This research was supported by the Nancy Lurie Marks Foundation; the Department of Defense Autism Research Program AR093137; The Therapeutic Cognitive Neuroscience Fund; and the Benjamin and Adith Miller Family Endowment on Aging, Alzheimer's, and Autism Research.

Presented at the 2015 International Meeting for Autism Research, May 13-16, Salt Lake City, Utah