Advancing the Measurement of Receptive Language in Nonverbal Individuals with Autism

Laura V. Van Droof[1], Kerry Ledoux[1], Erin J. Pickett[1], Esteban Buz[1], Nia Billings[1], Barry Gordon[1,2]

[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

Background

Many individuals affected by autism fail to develop useful speech, and many of these individuals never learn to express themselves in any functional way. An important question about such individuals is whether this lack of expressive ability is accompanied, or perhaps even caused, by deficits in receptive language knowledge. However, because of the general problems that such individuals have with responding, this question has been difficult to address. Nonetheless, there is considerable (albeit usually anecdotal) evidence from families and therapists that such individuals may actually have greater receptive capabilities than is evidenced by traditional measures. We have used eye movements, pupillary dilation, and the N400 component of event-related potentials (ERPs) as measures of receptive vocabulary knowledge in three populations (normal adults, normally developing children, and high-functioning individuals with autism) in which self-report and behavioral accuracy served as measures of comparison (Ledoux et al., 2009).

Eye movement monitoring: Eye movements typically reflect current cognitive operations. For example, participants will look at objects in a display as they hear those objects named. Studies of normally developing children have suggested that such eye movements become more precise as children learn the meanings of words (Swingley & Fernald, 2002).

Pupillary dilation monitoring: Pupillary dilation has been shown to increase with task difficulty, and has been used as a measure of resource recruitment (Beatty & Lucero-Wagoner, 2000).

Event-related potentials (ERPs): A word or picture that is congruent with its preceding context (for example, the preceding sentence frame, or a previously presented picture) will elicit a smaller amplitude N400 than a word or picture that is incongruent with its context. This difference in the amplitude of the N400 has been called the N400 congruency effect (Connolly & D'Arcy, 1999).

Objective

Our aim was to test the hypothesis that eye movements, pupillary dilation, and the N400 component of ERPs could provide evidence of single-word comprehension in nonverbal individuals with autism, even in the absence of a behavioral response. We expect that eye movements will be faster to and fixate longer on pictures of known words, pupillary dilations will be greater when identifying unknown words, and an N400 congruency effect will be observed for known words, but not for unknown words.

Methods

Participants

- 3 low-verbal or nonverbal males diagnosed with autism
- 15 to 21 years of age
- Diagnoses were confirmed via administration of the Autism Diagnostic Interview Revised (ADI-R) and the Autism Diagnostic Observation Schedule (ADOS), and were in conformity with the clinical diagnoses.

Stimuli

Caregivers completed the MacArthur-Bates Communicative Development Inventory and other checklists. These sources were used to determine stimuli that were expected to be known receptively by the participants; unknown stimuli were drawn from a pool of items developed for other subject populations (Ledoux et al., 2009). High-resolution digital images were used to create the visual stimuli and digital audio recordings were then created of each image label.

Tasks

Training programs were implemented on an individual basis to acclimate the participants to our experimental tasks and equipment.

Forced Choice Task: Participants were asked to select one of four pictures (either all known or all unknown) presented simultaneously on a computer screen, along with an auditory token that named one of the objects/concepts pictured. Throughout this task eye movement and pupillary dilation data were collected

Congruity Task: Single pictures were presented on the computer screen, accompanied by the auditory presentation of a word that either matched (congruous condition) or did not match (incongruous condition) the name of the pictured item. The congruous and incongruous conditions were equally matched in number of known and unknown words. ERPs were recorded during this task.

Equipment

- Eye Movement and Pupillary Dilation: ASL Model 504 Eye-Tracking System
- ERP: Electrical Geodesics Inc. GES 300 EEG System with 256-channel Hydrocel Geodesic Sensor Nets

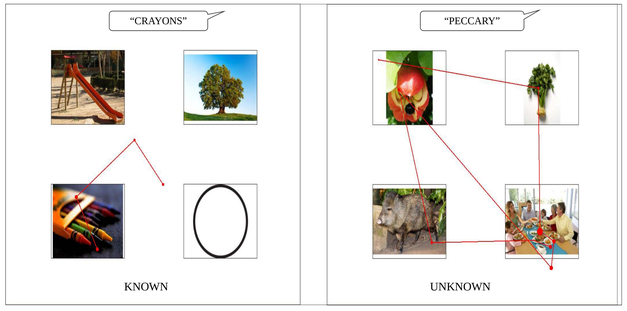


Figure 1. Eye movements and fixations during a known and unknown trial for an individual with autism

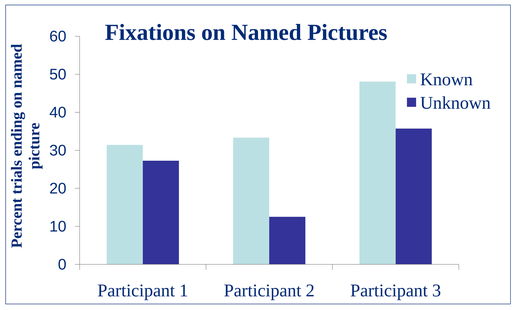


Figure 2. Average proportion of fixations that were on the named picture at the end of the trial, which was determined by either a mouse click or after 5 seconds.

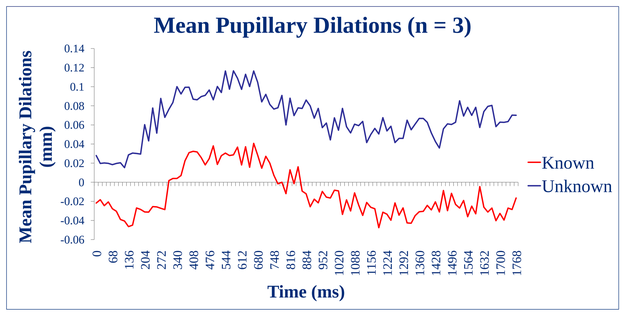


Figure 3. Average change in pupil dilation from baseline. Included are 93 Known and 83 Unknown trials from 3 participants with autism.

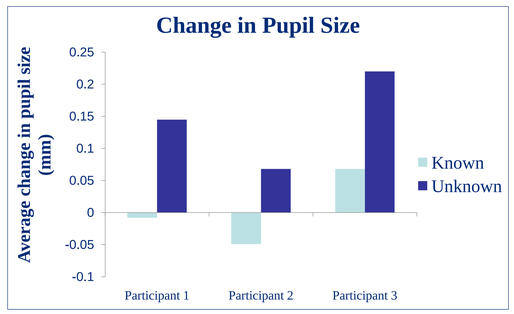


Figure 4. Average change in pupil size from the average pupil size of a previous slide with a fixation cross at the center.

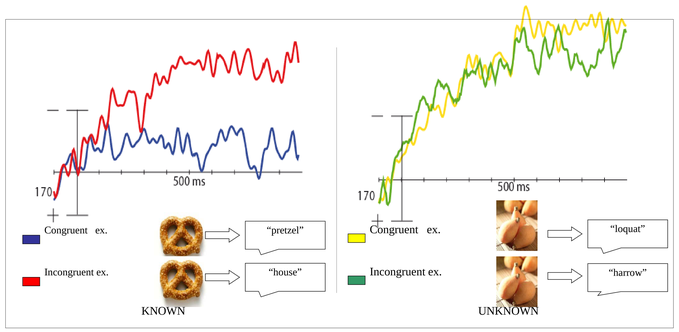
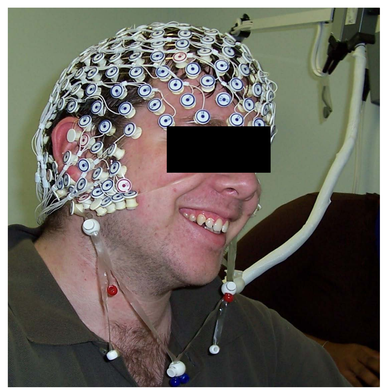


Figure 5. Shown are average waveforms for one participant across trials. (32 Known congruent, 31 known incongruent, 39 unknown congruent, and 30 unknown incongruent.) An N400 congruency effect was observed only for Known words.



Results

As predicted, differences were observed for all three measures between the known and unknown word conditions. Specifically, eye movements were faster to named pictures for known words (Figure 1), and fixations at the end of each trial were on the named picture more frequently for known words than unknown words (Figure 2). Pupillary dilation from baseline was greater in the unknown condition (Figure 3). The mean peak dilation was significantly greater for known words than unknown (p = .05). The average change in pupil size from baseline was significantly greater for the unknown items than for the known items (p = .007) (Figure 4). An N400 congruency effect (a reduction of the N400 to auditory tokens that matched the picture presented, relative to those that did not match) was observed, but only for words that were expected to be known to the individuals; no N400 congruency effect was observed for the unknown condition (Figure 5).

Conclusions

Eye movements, pupillary dilation, and the N400 component of ERPs differentiated known from unknown words, suggesting that these may be valid measures of single-word comprehension in low-verbal, variably responding, individuals with autism.

Our results demonstrate the ability to assess receptive language in nonverbal individuals with autism, a population that has been difficult to evaluate due to insufficient responding, poor motivation, and various other behavioral deficits. A better understanding of the abilities and potentials of these individuals could have significant theoretical as well as practical import. Even in the absence of overt expressive abilities, demonstration of some comprehension abilities would suggest the potential for developing expressive capabilities. Demonstration of this potential might motivate more intensive efforts at speech therapy, and attempts at using alternative routes of expressive and receptive communication (e.g., PECS). These measures may also provide useful indices of progress, supplementing or even substituting for more traditional behavioral methods that may be too insensitive or too unreliable in a non-verbal, non-responding population.

Our results suggest that the existence of covert comprehension abilities may be more widespread than previously believed in non-verbal, low-functioning individuals. We are in the process of continuing the studies of eye movements, pupillary responses, and ERPs in such individuals in order to test this hypothesis.

References

Beatty, J., & Lucero-Wagoner, B. (2000). The pupillary system. In J.T. Cacioppo, L.G. Tassinary, G.G. Berntson (Eds.), *Handbook of psychophysiology*, 2nd edition (pp. 142-162). New York, NY: Cambridge University Press.

Connolly, J., & D'Arcy, R. (1999). Innovations in neuropsychological assessment using event-related brain potentials. *International Journal of Psychophysiology, 37*, 31-47.

Ledoux, K., Pickett, E., Van Droof, L., Buz, E., Billings, N., Gordon, B. (2009). Receptive vocabulary knowledge in individuals with autism as assessed by eye movements, pupillary dilation, and event-related potentials. Poster presented at the 2009 Psychonomics Conference.

Swingley, D., & Fernald, A. (2002). Recognition of words referring to present and absent objects by 24-month-olds. *Journal of Memory and Language, 46*, 39-56.

Acknowledgments

Many thanks to our participants and their families for their participation and support. This work was supported by the Nancy Lurie Marks Family Foundation, The Therapeutic Cognitive Neuroscience Gift Fund, and by The Benjamin A. Miller and Family Endowment for Aging, Alzheimer's Disease, and Autism.

Conflict of Interest: None