**Modeling Implicit Measures of Receptive Vocabulary Knowledge in Normal Adults**

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**Introduction**

Implicit measures of language processing hold huge potential for assessing vocabulary knowledge in populations unable to give overt behavioral responses, such as low-functioning individuals with autism. We have previously used three types of implicit measures as indexes of receptive vocabulary knowledge in normal adults (Ledoux et al., in preparation).

**Eye movement monitoring (EM):** Eye movements typically reflect current cognitive operations: participants look at objects in a display as they hear those objects named. Such EMs become faster and more precise as normally-developing children learn the meanings of spoken words (Swingley & Fernald, 2002). EMs to pictures of known words are faster and end-of-trial fixations are more accurate compared to unknown words (Ledoux et al., in preparation).

**Pupillary dilation monitoring (PD):** Time-locked changes in pupil diameter are associated with attentional engagement and information processing. Pupillary dilation increases with task difficulty and has thus been taken as a measure of resource recruitment (Beatty & Lucero-Wagoner, 2000). Pupillary dilation (taken from eye-tracking data) is greater for unknown than known words (Ledoux et al., in preparation).

**ERP:** Results from N400 ERP event-related potentials (ERPs) showed that N400 amplitude is larger for known words than for unknown words (Ledoux et al., in preparation). ERP amplitude was significantly larger for spoken words than for pictures of words. This effect was present for both normal adults and adults with autism (Ledoux et al., in preparation).

**Pupil:** Pupil area was significantly larger for known than unknown words in normal adults but not in adults with autism (Ledoux et al., in preparation). Pupil dilation was larger for spoken words than for pictures of words (Ledoux et al., in preparation).

**Objectives**

**Aim 1:** Model the relationship between subjective knowledge ratings and implicit knowledge measures.

**Aim 2:** Use the model’s predicted knowledge ratings to more accurately code data as ‘known’ or ‘unknown’.

**Aim 3:** Predict knowledge ratings in populations that do not give over subjective rating scores.

**Methods**

**Participants:** 23 normal adults, right-handed native English speakers, 18-60 years of age.

**Equipment:**
- EM/ERP: Applied Scientific Laboratories 504 Eye-Tracking System
- ERP: Electrical Geodesics Inc. GES 300 EEG System with 256-channel HydroCel Geodesic Sensor Nets
- Subjective ratings observed using a scale of 1 to 5 (1 = known, 5 = unknown).
- Objective ratings observed using a scale of 1 to 5 (1 = known, 5 = unknown).

**Stimulus:**
- Words were presented in a visual display for a maximum of 2 seconds.
- EMs were measured using an event-related design with 2 conditions: known and unknown words.
- PD was measured using a time-locked design with 2 conditions: known and unknown words.
- ERPs were measured using a standard oddball paradigm with 2 conditions: known and unknown words.

**Modeling Procedure**

**Modeling:**
- Mixed logistic regression model fit in R using the lm4 package (Bates et al., 2013)
- Random effects: Subject
- Dependent variable: Subjective knowledge ratings: 0 = unknown, 1 = known
- Independent variables/ fixed effects:
  - EM measures:
    - N400/late ERP: mean latency of N400/late ERP (and amplitude difference between conditions)
    - PD measures:
    - PeakDwell: Maximum peak change in pupil dilation from baseline over the entire trial
    - Eye tracking: percentage of total time spent dwelling on the correct stimulus

**Model Testing (n=3)**

To simulate Aim 3, the final model was used to predict knowledge ratings on 3 normal adults who were the last to be tested. These subjects were not included in the training phase, so their subjective ratings did not contribute to the model’s predictions.

**Discussion**

The model was able to successfully predict known and unknown word status using a combination of ERP, PD, and EM implicit variables.

The model produced more accurate knowledge predictions for known than unknown words.

The modeling raised three important issues:
- Only trials which did not have any missing variables could be modeled, meaning that for some subjects with particularly messy data, there was a high amount of data lost.
- Subjective knowledge ratings were dichotomized from the original 10-point scale, so ratings of ‘unfamiliarity’ were not captured. The model’s predicted probabilities can be broken into multiple categories to capture these intermediate ratings.
- The degree of generalizability to different groups, especially clinical populations, is unclear.

Our results suggest that these implicit measures may be valuable methods for assessing single-word comprehension, particularly in populations that are minimally verbal or nonverbal. We are currently working on testing this model in typically-developing children and both high- and low-functioning adults with autism.

**References**


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