Understanding visual perception of words using an event-related potentials (ERP) megastudy

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Beyond Categories

Motivation

Humans are able to look at a variety of squiggly lines on all sorts of surfaces and extract meaning from them. This process is complex, and has several subprocesses it can be roughly broken down into:

- How do we identify meaningful symbols amidst noise and string them together to form valid, sensible sequences?
- How do we process these strings as a whole and associate some semantic entity with them?
- How does meaning persist in memory ?
- How does language work in the brain?

Here, we try to work towards answering one such question about the intermediate process between receiving a visual stimulus and understanding the meaning of a word: how do we visually perceive words?

Introduction

Electro-physiology. It is the measurement of electric current and voltage changes at the surfaces of tissues as a proxy measure for underlying activity. In the brain, the changes correspond to the action potentials of a group of neurons conducting electrochemical signals. EEG, short for electroencephalography, is an electro-physiological measure of brain activity collected at surface. The EEG signal has excellent temporal resolution (accurate to 1-10ms).

ERP. Event-related potentials are EEG brain activity measures observed directly after some event. In this case, ERPs are obtained immediately after presenting stimuli, and controlling for as many other events, such as muscular movement, hearing something strange, etc., as possible. When averaged across participants, they allow generating representative waveforms corresponding to specific stimuli.

The case for *megastudies* in psycholinguistics. Often, researchers choose a small set of stimuli just enough to satisfy the statistical needs of their *factorial* (hypothesis-specific) experiments. However, the stimuli can't be expected to represent natural language, which is arbitrarily larger. Further, the stimuli may introduce unforeseen confound [1]. In *megastudies*, researchers choose as many as several thousand stimuli, which can be expected to be representative to a much larger extent. *Megastudies* help build large datasets and enable retrospective data analyses.

Research questions

Past research. In the past, researchers have primarily used a lexical decision task. The participants must decide if the word they are seeing is valid or not. In one factorial study, researchers used about 300 stimuli in a lexical decision task [3]. In a *megastudy*, researchers presented about 1100 words, also in a lexical decision task [2] (see figure 1).

- **Task manipulation.** Would word processing be any different in a task other than lexical decision? What would happen if we activated phonological and semantic processing instead?
- **Individual differences.** How do personal characteristics such as anxiety, depression, language proficiency, literary exposure, traumatic experiences, etc. affect the processing of different words?

Method

- **Participants.** About 150 participants between ages 18 and 80 will be recruited from the college communities and surroundings.
- **Individual difference measures.** Participants will complete some preliminary tests asking about their past experiences, measuring cognitive baseline, reading speed, literary exposure, etc.
- **Stimuli.** Participants will be shown 1458 words as 100pt white-on-black text. Each stimulus will last 650ms followed by a randomized pause with duration between 300ms and 500ms so that participants don't get used to seeing the upcoming stimuli after the same pause. The entire list of stimuli will consist of blocks of 9 words, each containing 1 rhyming pair, 1 semantically related pair, 1 non-word, and 4 other non-special words. The list will be split into three sub-lists.
- **Experiment design.** The experiment will involve three tasks.
  1. **Lexical decision ("go/no-go" task).** Decide if a word is a valid word in English or not.
  2. **Phonological one-back decision.** Click a button every time a word rhymes with its immediate previous stimulus.
  3. **Semantic one-back decision.** Click a button every time a word is semantically related with its immediate previous stimulus.
- **Counterbalance.** Three blocks representing tasks will be counterbalanced to remove confound of task order in a cross design.

$$\left\{\begin{array}{c}\text{Phonological decision task}\\ \text{Semantic decision task}\\ \text{Lexical decision task}\end{array}\right\} \times \left\{\begin{array}{c}\text{Sub-list sequence } 1,2,3\\ \text{Sub-list sequence } 2,3,1\\ \text{Sub-list sequence } 3,1,2\end{array}\right\} = 9 \text{ orders}$$

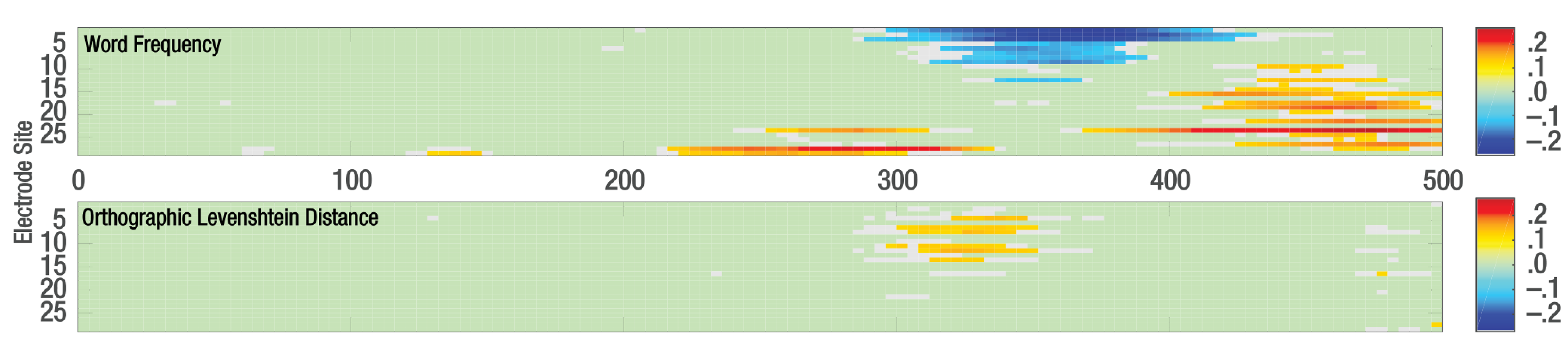

Figure 1: Partial correlations between event-related potential measures and two word features. Word frequency is a measure of how commonly a word occurs in some predefined corpus. Orthographic Levenshtein distance is its average orthographic similarity, defined as the number of edits needed to convert a word into another, with its 10 closest neighbors. Adapted from [2].

Example stimuli

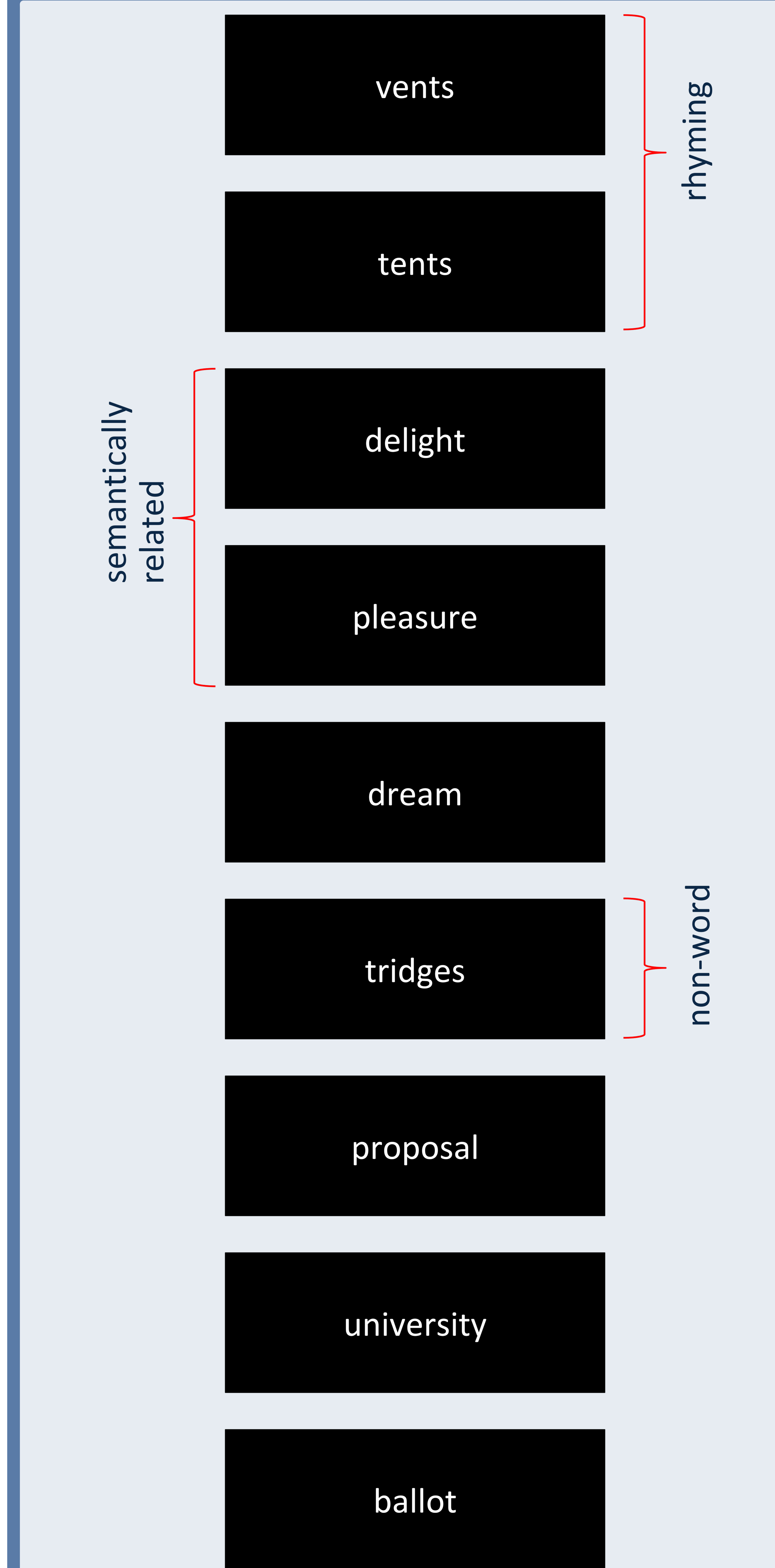

Figure 2: A typical block containing 9 stimuli. The block contains a non-word, one rhyming pair, one semantically related pair, and four other non-special stimuli. Three of these words elicit a response, and must be ignored from the data due to motor interference.

Equipment

Figure 3: A sample EEG cap to be placed on a participant during an experiment to collect real-time electro-physiological data.

Future exploration

- Stimulus-level partial correlation analyses of features to understand which features get processed first, which later.
- Partial semantic recreation of stimulus based on brain activity, or in other words, a computational model of word processing in the brain.

References

[1] David A Balota, Melvin J Yap, and Keith A Hutchison. Megastudies: What do millions (or so) of trials tell us about lexical processing? In *Visual Word Recognition Volume 1*, pages 104–129. Psychology Press, 2012.

[2] Stéphane Dufau, Jonathan Grainger, Katherine J. Midgley, and Phillip J. Holcomb. A thousand words are worth a picture: Snapshots of printed-word processing in an event-related potential megastudy. *Psychological Science*, 26(12):1887–1897, 2015.

[3] Olaf Hauk, Matthew H Davis, M Ford, Friedemann Pulvermüller, and William D Marslen-Wilson. The time course of visual word recognition as revealed by linear regression analysis of ERP data. *Neuroimage*, 30(4):1383–1400, 2006.

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