DIFFERENTIATING THE N3 AND N4 ELECTROPHYSIOLOGICAL SEMANTIC INCONGRUITY EFFECTS.

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Abstract

An event-related potential termed the N4 has been widely studied due to its sensitivity to semantic incongruity. A recent report (Nobre & McCarthy, 1994) indicates there is also an N3 component sensitive to semantic incongruity. To differentiate them, an existing dataset with 65 electrode sites, 78 subjects, and 120 sentences was examined. Instead of the usual procedure of averaging over the stimuli into distinct categories for each subject, a new approach was used by averaging over subjects. In this fashion, 120 sentence averages were produced. Correlational analyses indicate the N3 is sensitive to cloze probability. The N4 is more sensitive to sentential constraint than cloze probability; it is also sensitive to familiarity. The N3 appears to be responsive to semantic fit whereas the N4 appears to reflect semantic expectation (priming).

The N4 is a relative negativity that occurs about 400 ms in response to a word that violates the subject's semantic expectancy (Kutas & Hillyard, 1980). For example, the semantic context may be created by a sentence, such as, "I usually wake up early in the *lake*." It has recently been reported that another component, termed the N330, was observed to be larger to congruous endings (contrary to the N4) (Nobre & McCarthy, 1994). This paper will term it "N3" to avoid pinning it to a specific latency.

In order to try to delineate the functional differences between these two components, a novel analysis was applied to an existing dataset. The data were averaged over subjects, resulting in one average per stimulus. This arrangement has a number of advantages: 1) ability to use correlations which provide an easy to understand measure of effect size. 2) eliminates measurement problems due to individual differences in component topography. 3) facilitates analysis in cases where the independent variables are not available for all the stimuli since reaveraging for each comparison is not necessary.

Methods and Materials

Subjects and EEG Recording

Seventy-eight right-handed University of Oregon undergraduates, all native English speakers, were recruited from Psychology classes (37 males and 41 females; mean age 22). The data from twenty-three participants have already been presented in a previous report which can be consulted for more information about the experiment (Curran, Tucker, Kutas & Posner, 1993). Data was low-pass filtered at 30 Hz. Electroencephalographic (EEG) data were collected from 64 recording sites, plus a right mastoid reference sensor, with the Geodesic Sensor Net.

Procedure

Subjects were presented a series of sentences one word at a time. Each trial began with a central fixation mark (a plus sign) for 900 ms. Each word appeared for 105 ms and was immediately replaced by the fixation mark. After 900 ms the next word appeared. A period marked the end of each sentence. EEG collection began 184 ms before onset of the last word and was collected for a total of 2048 ms.

Subjects completed a block of 10 practice trials and then four blocks (30 trials each) of experimental trials. Each block was evenly divided between trials with congruous and incongruous sentence endings. Stimuli were sentences selected from those used by Kutas and Hillyard (1980). Congruous and incongruous words were matched in length and frequency of occurrence in the English language (Curran et al., 1993).

Factor Analysis

The principal component analyses (PCA) were conducted on the sentence averages. The dataset consisted of the voltage readings at each of the 65 sensors during 125 samples (160 ms pre-stimulus and 840 ms post-stimulus). For the PCAs, the time samples served as the 125 variables. The observations consisted of the 65 sensors for each of the 120 sentences. The relational matrix was the sum-of-squares-cross-products matrix. Promax rotation was used to rotate to simple structure (Dien, 1998). The factor scores were rescaled to microvolts by multiplying the scores by the factor loading and the standard deviation of the peak time point (Dien, 1998).

Norms

For the correlational analyses, four word-level characteristics and two sentence-level characteristics were examined. The word-level parameters were word length, frequency (Kucera & Francis, 1967), and familiarity (Coltheart, 1981). Cloze ratings (probability of word being chosen to complete sentence) and sentential constraint (number of endings chosen by at least 1% of the norming subjects) were also examined (Bloom & Fischler, 1980).

Results

Principal Components Analysis

The parallel test (Dien, 1998) indicated the retention of nine factors, accounting for 91% of the variance. For each factor, an index site was chosen to represent the factor. The index site was the one with the largest absolute mean factor score that was not either midline (to allow for laterality analyis) or periocular (to minimize residual eye artifacts). The N3 and N4 are illustrated in Figure 1. Note that the PCA characterizes the N4 effect as a P3 positivity in the congruous condition rather than an N4 negativity in the incongruous condition. Since these are mathematically equivalent, this paper will not take a position on which is a more accurate characterization.

Insert Figure 1 about here

ANOVA

An ANOVA was carried out on the index site factor scores for each of these putative components with one between group factor (congruous vs. incongruous endings) and one within group factor (left vs. right hemisphere homologous sites). The N3 is more negative to congruous stimuli (congruity, $F[1, 118]=16.632$, $p = .0001$) and is left-lateralized (hemisphere, $F[1, 118]=5.678$, $p = .0188$). The P3/N4 is more positive to congruous stimuli (congruity, F[1,

118]=100.996, p = .0001) and is left-lateralized (hemisphere, F[1, 118]=32.955, p = .0001). Note that the N3 effect cannot be due to misallocation of variance from the N4 (Wood & McCarthy, 1984) since it has a different scalp topography (c.f., Chapman & McCrary, 1995).

Correlations

In an effort to characterize these components (as described by these factors), the index sites were correlated against a number of measures of interest (using absolute amplitudes). For the full set of sentences, the N4 was negatively correlated with familiarity (r[80] = -.31; p = .0041). The sample size varies according to the number of stimuli rated on that parameter.

The N4 showed no correlations for incongruous stimuli at all. For congruous stimuli, the size of the N4 was negatively correlated with the cloze rating (r[54]=-.33; p = .013) and very correlated with sentential constraint (r[54]=.41; p = .0017).

For the incongruous stimuli only, the N3 was correlated with length (r[58]=.34; p = .0089). Whereas for the incongruous stimuli there was no correlation with sentential constraint (cloze ratings were not available), for the congruous stimuli, the N3 was correlated with cloze rating (r[54]=.37; p = .0051) and negatively correlated with sentential constraint (r[54]=-.38; p = .0044).

Discussion

The N4 is thought to reflect some aspect of semantic priming. This characterization is further supported by the current finding that it is also correlated with word familiarity, which could be thought of as context-independent priming. It is also intriguing that it is largest when the word is most constrained by the sentence context since a tightly constrained context strengthens the expectation (or priming) for a specific word.

The N3 also has an unknown function although its frontal left-lateralized scalp topography seems compatible with a source in Broca's area. It differs from the N4 in that it is no more

affected by sentential constraint than it is by cloze probability. Following the logic for the N4, this suggests that the N3 is reacting more to the semantic fit than to semantic priming. Thus, it does not matter as much if there are multiple potential endings for a sentence as long as the presented ending fits the sentence context. The suggestion that such sentence-level parameters are more important than word-level expectations is also supported by the observation that it is not affected by familiarity, unlike for the N4.

In conclusion, this study demonstrates the utility of averaging over stimuli rather than subjects. This approach permitted flexible, correlational analyses of stimulus parameters. Results suggest that the N3 may reflect semantic fit and hence sentence-level processing whereas the N4 may reflect semantic priming and hence word-level processing.

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Figure Captions

Figure 1. N3 and N4 waveforms and scalp topographies. Both grand average data and data accounted for by the respective factors are shown. Waveforms show time course from -160 to 840 msec. Grey lines are the congruous condition and black lines are the incongruous condition. Scalp plots are laid out roughly topographically with the top of the figure corresponding to the front of the head. Scalp plots show difference between responses to congruous and incongruous endings.