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Research report

The relationship between brain reaction and English reading tests for non-native English speakers

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ABSTRACT

This research analyzed the brain activity of non-native English speakers while engaged in English reading tests. The brain wave event-related potentials (ERPs) of participants were used to analyze the difference between making correct and incorrect choices on English reading test items. Three English reading tests of differing levels were designed and 20 participants, 10 males and 10 females whose ages ranged from 20 to 24, voluntarily participated in the experiment. Experimental results were analyzed by performing independent *t*-tests on the ERPs of participants for gender, difficulty level, and correct versus wrong options. Participants who chose incorrect options elicited a larger N600, verifying results found in the literature. Another interesting result was found: For incorrectly answered items, different areas of brain showing a significant difference in ERPs between the chosen and non-chosen options corresponded to gender differences; for males, this area was located in the right hemisphere whereas for females, it was located in the left. Experimental results imply that non-native English speaking males and females employ different areas of the brain to comprehend the meaning of difficult items.

1. Introduction

Brain activity occurring during memory processes can be observed by EEG (Cao et al., 2011). For example, test questions are, indeed, either understood or not by the learner undertaking an English reading test. In order to observe the variation in brain waves over a short time period and to find out the correlation between waveforms and events, Sutton, Braren, Zubin, and John first proposed an experimental method by using event-related potentials (ERPs) in 1965 (Sutton et al., 1965).

Over the past decade, ERPs have become a popular technology for observing brain activity and have been widely used in various areas of cognitive neuroscience. Many research results concerning semantic relatedness have been proposed (Davenport and Coulson, 2011; Hata et al., 2011). One specific component of ERPs, the N400, was first discovered by Kutas and Hillyard (1980a, 1980b) when they observed the responses to meaningful stimuli such as texts, sentences, and the combination of visual and auditory presentation of individual words (Kutas and Federmeier, 2000). When confronted with a semantically incorrect word (stimulus), a significant amplitude N400 is evoked in the ERPs (Kutas and Federmeier, 2000; Franklin et al., 2007; Rämä et al., 2010; Vigneau et al., 2011). N400 can therefore be used as an important indicator of semantic relatedness, to retrieve related messages, or integrate the meaning of the whole context (Brown and Hagoort, 1993; Farwell and Smith, 2001; Hata et al., 2011; Schumacher et al., 2012).

Following that discovery, Kolk et al. (2003) observed an effect for the P600 component, a late positive potential at about 600 ms after the onset of the target word. It is unlike the N400 effect caused by those semantic reversal anomalies. Some recent studies have proposed that the P600 may reflect a general process of resolving conflicts between separate meaning analysis systems and that it is, therefore, not limited to syntactic anomalies (Dien et al., 2010; Kuperberg, 2007; van Herten et al., 2006). Syntactic anomalies like “the fox hunted the poacher” or “cat dog eat” elicit the P600 effect (Klepousniotou et al., 2012). This difference between ungrammatical or complex sentences and grammatical or unambiguous sentences in the amplitude generated has been referred to as the P600 effect.

However, it was challenged when other studies found P600 effects without N400 effects triggered by semantic anomalies (Vissers et al., 2006). Both P600 and N400 are often used on word recognition tasks. Furthermore, sentences with semantic incongruities, semantic congruities, or syntactic anomalies are often used in comprehension tests, especially in tests of English ability, and can be applied to many fields.

In this research, we investigated the brain activity by presenting participants (non-native English speakers) with English reading test items on a computer screen. What differences can be observed in the EEG when a correct versus an incorrect answer is

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given in reply by a participant? Is there any significant difference between males and females? Is there any difference between participants with higher English ability and those with lower English ability? These are the questions explored in this research using the EEG system to examine the brain activity of non-native English speaking participants while taking an English reading test.

2. Results

Twenty participants, 10 males and 10 females between the ages of 20 and 24, participated in the English reading test voluntarily. Each participant completed three English reading tests in total. During each test, the EEG system recorded the participants' brainwaves and two significant features, N400 and N600, were analyzed.

We applied the independent *t*-test to analyze the significant difference between chosen options and non-chosen options under differing conditions. First, the options chosen by the participants were classified into correct or wrong answers. In all 180 items collected from the 20 participants, 53 items were replied to with wrong answers and 127 items were responded to with correct answers. We analyzed the targets (the chosen options) and non-targets (the non-chosen options) for these 180 items (Table 1). For wrong answers, a significant difference ($p < 0.05$) was noted at N600 on electrode F4 between targets (the chosen options) and non-targets (the non-chosen options) (Fig. 1). For correct answers, there was also a significant difference ($p < 0.05$) between the targets and non-targets, in this case, at N400 on electrode Fz (Fig. 2).

The responses to all items were then further divided into two groups, answers made by females and those made by males. The numbers of wrong answers made by females and males were 18 and 35, respectively. After running an independent *t*-test, results showed that N600 at the F3 electrode achieved a significant difference ($p < 0.05$) between chosen options and non-chosen options in the female group, and at the F4 electrode in the male group (Table 2). For correct answers, there was no significant difference between chosen options and non-chosen options in either the female or male group.

Finally, the responses to items were divided into three groups of similar size according to score—high, medium and low scores (Table 3). Results show that there was no significant difference between the target and non-target options of items in the medium and low score groups. Table 4 shows the statistical results of target and non-target options of items answered correctly and incorrectly in the high-score group. In this group, there were only 10 incorrect answers in total. We found that N600 at the F4 electrode achieved a significant difference ($p < 0.05$) between target and non-target options when answers were wrong (Table 4). In addition, results for the target and the non-target options reveal another significant difference ($p < 0.01$) in N400 at the Fz electrode for items answered correctly (Table 4).

Table 1
Statistical results of the wrong and correct answers.

Condition	Feature	Group	*N*	Mean	S.D.	*t*	Sig.
Wrong answers	***F4 N600***	***Target***	53	−5.13	5.57	−2.12	0.027*
		Non-target	53	−2.54	4.11		
Correct answers	***Fz N400***	***Target***	127	−2.10	6.43	2.35	0.018*
		Non-target	127	−4.16	4.05		

* p < .05

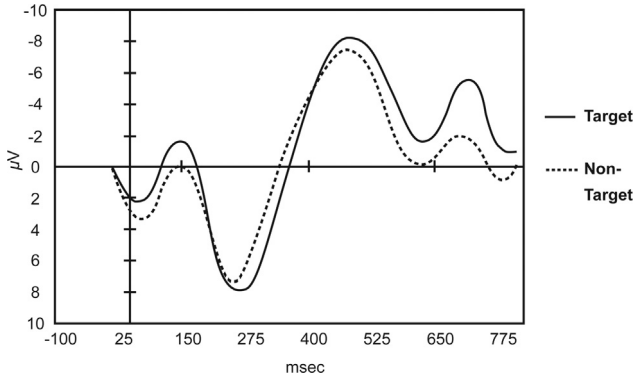

Fig. 1. A significant difference between the chosen option and the non-chosen options for wrong answers was observed in the value of N600 at F4.

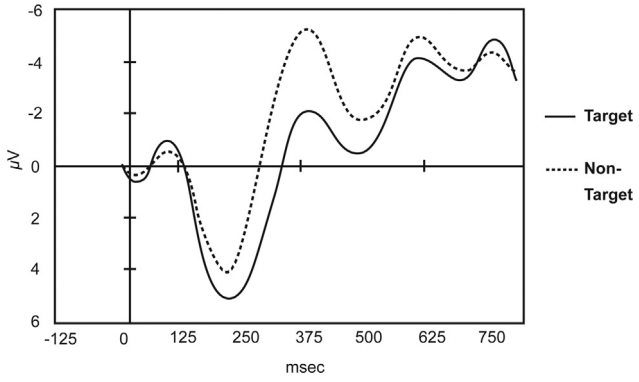

Fig. 2. A significant difference between the chosen option and the non-chosen options for correct answers was observed in the value of N400 at Fz.

Table 2
Statistical results of the wrong answers by females and males.

Condition	Feature	Group	*N*	Mean	S.D.	*t*	Sig.
Wrong responses by females	***F3 N600***	***Target***	18	−5.61	5.58	2.378	0.034*
		Non-target	18	−2.71	4.11		
Wrong responses by males	***F4 N600***	***Target***	35	−4.59	4.92	1.994	0.037*
		Non-target	35	−2.06	5.80		

* p < .05

Table 3
Statistical results of the high, medium, and low scoring groups.

Group	*N*	Mean	S.D.
High-scoring group	7	7.5	0.866
Medium-scoring group	7	6.5	0.500
Low-scoring group	6	5	1.118

3. Discussion

This paper has presented the brain potential variations of non-native English speakers while taking English reading tests. In this experiment, for correct answers, N400 brainwave reactions at electrode Fz (at the frontal lobe of the cortex) achieved a significant difference between targets (chosen options) and non-targets (non-chosen options). This finding is similar to that of Frishkoff et al. (2004). Frishkoff et al. contended that N400 effects