THE EFFECTS OF RESPONSE REQUIREMENTS AND LINGUISTIC CONTEXT ON AVERAGED ELECTROENCEPHALIC RESPONSES TO CLICKS
[English Version]

by
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ABSTRACT

AERs to clicks superimposed on sentences were used as physiological indicators of early speech perception activity under two different response methods; (1) marking the location of the superimposed click on a pretyped script of the stimulus sentence, or (2) writing out exactly the stimulus sentence before marking the perceived click location. Results from these experiements indicate that the AER technique was sensitive enough to discern signigicant differences in AER latency to clicks located after the major constituent break of the stimulus sentences only when the write-out response method was used. The data were interpreted as supporting the contention that different response requirements result in different perceptual strategies or sets. In addition, these experiments demonstrated the value of the AER technique as a supplement to behavioural data in speech perception studies.

INTRODUCTION

Seitz & Weber (1974) found that differences in response requirements significantly affected the reported location of clicks superimposed on sentences. When **Ss** had to write out the sentence before marking the click location, the click was perceived as migrating toward the major constituent break of the sentence, supporting the Fodor & Bever (1965) and Bever, Lackner & Kirk (1969) hypotheses that the major constituents form perceptual units which tend to resist interference from any extraneous noise. When **Ss** had only to mark pre-typed copies of the stimulus sentences,the click locations did not show the migration effect. However, both groups showed a tendency to mark the clicks as occurring pior to their actual location, confirming the findings of Ladefoged & Broadbent (1960) and Reber & Andersen (1970). These investigators interpreted their results in terms of Titchener's laws of prior entry (1908), which states that:

> "The stimulus for which we are predisposed requires less time than a like stimulus, for which we are uprepared, to produce its full conscious effect" (p.251)

While Seitz & Weber demonstrated that different response requirements resulted in different click location patterns, their behavioural paradigm was not able to reveal how the response requirement affected the actual perceptual process. It is of interest in speech perception research to determine whether the reported differential influences on click locations occurred in the early or the later stages of perceptual progressing of the click location tasks.

An estimate of the events occurring during the early stages of this process can be obtained in terms of averaged electroencephalic responses (AERs) to the clicks under the experimental reponse conditions discussed above. The characteristic AER to a series of discrete stimuli consists of a diphasic wave with the first major deflection, a negative wave often referred to a N1, occurring approximately 100 msec after the onset of the stimuli, and the second major deflection, a positive wave often referred to as P2, occurring about 200 msec after the onset of the stimuli. If the behaioural results of Seitz & Weber (1974) reflect differences in the early stage of processing, the latency of AERs to clicks may vary from one response method to the other, and in particular there may be latency differences occurring as a function of click positions within the sentences for one or both response methods.

The present paper reports the results of two experiments during which AERs to clicks were recorded under the write-out and script-marking response methods. The AERs in Experiment I, which were obtained concurrently with the behavioural measurements reported by Seitz & Weber (1974) (see also Seitz, 1972) were obtained only from the cerebral hemisphere contralateral to the ear receiving the click. One AER was obtained for each of the three click positions, resulting in three AERs per subject. Separate AERs for each response group were obtained.

The second experiment represented both a replication and extension of the first. In Experiment II, AERs were obtained from both cerebral hemispheres and analyzed with respect to response method and click position as in Experiment I, and also with respect to cerebral hemispheres, ear receiving the click, and presence or absence of sentence accompanying the click. Only the results directly related to response methods and click positions are reported here, while the other results from Experiment II are reported elsewhere (Mononen & Seitz, in press 1975).

EXPERIMENT I
METHOD

Subjects

Ss were 24 right-handed adults between the ages of 18 and 35, with hearing levels of 20 dB ISO or better in both ears at .5, 1, and 2 kHz. Hand preference was predetermined by questionnaire an only **Ss** with strong right-side dominance were allowed to participate.

Materials

Stimulus strings were 1 practice sentence and 24 experimental sentences with specified major constituent breaks (Bever, Lackner & Kirk, 1969). A click or approximately 30 msec duration was located at one of three positions within each sentence. The three click locations, as seen in the example below were (a) two syllables prior to the major constituent break; (b) at the major constituent break; and (c) two syllables after the major contituent break.

(a) (b) (c)
WHEN HE STOOD UP + MY SONS BOOK FELL FROM THE LOW TABLE

Three alternate stimulus tapes were prepared, with each click position appearing one time on each sentence on one of the three stimulus tapes. A strip of foil for triggering a click generator was pasted on the back of the recording tape in one of three click positions on each sentence, with the foil positioned at each of three locations on 8 of the 24 stimulus sentences on each tape. The order of click positions was randomized within each stimulus tape.

Stimulus Presentation

The **Ss** were assigned to one of two groups of 12 for each click location method, and matched in pairs as a function of age, sex, stimulus tape heard and ear receiving click (Siegel, 1956). Each **S** listened to one of the three stimulus tapes while seated by a table in a sound-treated room. Stimulus material was presented through a matched pair of TDH-39 earphones at 70 dB ISO. The sentences were presented through one earphone and the clicks through the other earphone. To control for possible ear effects (Fodor & Bever, 1965), one half of the **Ss** in each group heard the clicks in the right ear and the sentences in the left ear, and the other half heard the clicks in the left ear and the sentences in the right ear.

The 30 msec click was generated by a home made click generator and delivered directly to the earphone during the experiment. Each click location on the sentence was previously confirmed by a graphic recording.

Instructions

The **Ss** in the group required to mark prepared scripts were instructed that they were going to hear a series of sentences on which a click was superimposed. After listening to each sentence with its accompanying superimposed click, the tape recorder would be stopped and the **Ss** were to turn a page in their booklet and mark the location of the click by placing an arrow over the exact spot (letter or space between words) on the typed copy of the stimulus sentence where the click was perceived as occurring. The **Ss** in the group required to write out the sentences before marking the click location were given similar instructions, except that they were told to turn a page in their booklet and, on the blank page supplied, to write out the stimulus sentence exactly, then mark the location of the perceived click to the nearest letter or space between the words on their handwritten copy of the stimulus sentence. After completing their respective tasks on each trial, the **Ss** in both groups were instructed to push a button to indicate readiness for the next trial.

AER Technique

Ongoing EEG activity was [illegible] and recorded during the presentation of the stimulus sentences via th[illegible] silver-chloride surface electrodes attached to the scalp of each subject. One e[illegible] was attached to the vertex (Cz on the International 10-20 System), the other ele[illegible] the mastoid (a more neutral neurological position) and the ground electrode was attached to the forehead.

The EEG signal[illegible] stimulus sentences, and the clicks were all recorded on magnetic tape so that signa[illegible] averaging could be conducted off line, a necessity resulting from the randomization procedure used on each of the three stimulus tapes. Each **S's** ongoing EEG signal was amplified by two high gain pre-amplifiers of a Hewlett-Packard 7712 Polygraph Recorder.

The amplified EEG signal was then routed through an oscilloscope for on line monitoring and then into a Vetter 2D FM recording adaptor which converted the changes in voltage of the EEG signal into modulations in frequency that could be recorded on an AM tape recorder. The EEG signals, the stimulus sentences and the clicks were then simultaneously recorded on three separate channels of a Sony TC 654-4 quadraphonic tape recorder (See Seitz, 1972, for a more detailed description of the equipment).

Data Analysis

Results of a preliminary study had indicated that high quality AERs could be obtained with as few as 8 summations when the subjects took an acitve part in the experiments. Hence this study was designed to obtain the AERs by summing all the sentences with the same click position presented to an individual subject, 8 for click position a, 8 for click positon b and 8 for click position c. The EEG responses to the superimposed clicks were determined by directing the recorded EEG signal through the recording adaptor, returning the variations in frequency that were stored on the tape to changes in voltage. The reconverted signal was then routed to the Fabri-Tek 1010 digital signal averager.

Each click coming from the click channel of the storage tape recorder triggered 1000 msec of EEG activity. The sentence channel of the stored tape of each **S** was monitored by earphone to be certain that only the 8 sentences containing the same objective click locations were used in obtaining an AER. The resulting AER was then fed to a Hewlett-Packard 7035B X-Y plotter and a permanent graphic display of the AER was produced. The graphic display was used to determine the latency measurement for analysis. Thus, three AERs were obtained for each of the 24 **Ss**; one for each of the three objective click locations used in this experiment. The graphic displays were judged to be AERs if the first major negative peak (N1) appeared between 75 and 150 msec and the following major positive wave (P2) occurred no sooner than 30 msec after the onset of the N1,usually somewhere between 150 and 250 msec (Derbyshire and McCandless, 1964). All measurements met these requirements. Measurement of AER latencies were made from the onset of the click to the peak of N1.

RESULTS AND DISCUSSION

Each experimental group yielded a total of 36 AERs, 12 for each click position. The results of a Wilcoxon matched pair, signed ranks test (Siegel, 1956) indicated no significant difference ($p > .05$) in AER latency between the two groups (see Figure 1). Apparently whatever was occurring in the perceptual process which resulted in different behavioral click location responses was not being reflected in overall latency o` response to clicks.

While there was no significant difference in the overall latency between the two groups, an analysis of click positions within each group revealed a significant difference between click positions for the write-out group, with click position "c" having a significantly shorter ($p < .05$) AER latency than click position "a" or "b". There was no significant difference found between click positons in the marking response group (See Figure 1).

The shorter latency of click position "c" in the write-out group corroborates reaction time data previously reported by Abrams & Bever (1969) using write-out response method and the same stimulus sentences used in Experiment I. Abrams & Bever found that reaction time to click objectively located after the major constituent break were faster than reaction time to clicks located before or in the break. The occurrence of faster post break click responses seems to be a direct effect of the response requirement of writing out the stimulus sentence before marking the perceived click location. The lack of difference in AER latency among click positions for the marking group agrees with the results of Scholes et al. (1969) who used both AER and reaction time techniques with the marking response method, did not find any difference in either AER or reation time between pre- and post-break click positions.

While the results of this study were very interesting, initial equipment limitations made extrapolation from the resulting data somewhat difficult. For example, the procedures for balancing the loudness of click and sentence was not entirely satisfactory. Another limitation was the fact that only one hemishpere at a time could be monitored in Experiment I. In addition, a control condition in which the click was presented monaurally was not run. Had such a control condition been included in the first experiment a comparison of the conditions might have revealed changes in AERs that result from changes in the tasks themselves. That is, an AER resulting from a passive listening experience might be significantly different from an AER resulting from the active listening required by these kinds of experiments. To correct for the above limitations in the intial experimental design, Experiment II was undertaken.

EXPERIMENT II
METHOD

Subjects

Twelve right-handed English-speaking students between the ages of 20 and 35 years served as **Ss**. All had hearing levels of 20 dB ISO or better at .5, 1, and 2 kHz.

Materials

Stimulus material was the same as that used in Experiment I.

Stimulus Presentation

Ss were randomly assigned to one of the two groups, with 6 in each group. All other procedures were the same as in Experiment I except that the click was 20 msec rather than 30 msec in duration, and was recorded on tape at an intensity equal to the speech envelope of the sentence channel to ensure clear reception of the click relative to the sentence. In addition the stimulus material was presented to the subjects through TDH 39 earphones at 50 dB ISO.

Both cerebral hemishperes were monitored in Experiment II. Silver-silver chloride electrodes of higher quality than those of Experiment I were used with the two cortical electrodes placed at C3 and C4 (re-International 10-20 System), 20% off the vertex on the interaural line. This change was made so that readings from the two hemispheres would be more independent and to ensure that the two electrodes would not interfere with each other. Two other electrodes were attached to the two mastoids of the skull and a common ground electrode was attached to the forehead.

In Experiment II latency differences to N1 were analyzed as a function of the two methods of response, the two hemishperes receiving the click stimulus, the three click positions and the linguistic task versus the monaural control task.

RESULTS AND DISCUSSION

Each **S** generated 12 AERs, 3 for each hemisphere in the click-in-sentence condition and 3 for each hemishere in the click-in-isolation condition. See Figure 2 for an example of the resulting AER from Experiment II. Results of analysis of variance revealed, as in Experiment I, that there was no significant differency in overall latency between the write-out response method group and the marking response method group ($p > .05$), but there was a significant interaction between response methods, response conditions and click positions [F (2,16) = 6.579, p<.01]. Further analysis of this interaction by the Newman-Keuls Test revealed that for the click position "c" the mean latency of the write-out group was significantly faster than the other click position latencies under the linguistic task condition (p<.01), but not significantly different from any of the click position latencies of the control condition (see Figure 3). This finding of Experiment II confirms the linguistic results of Experiment I. Other relevant results were that the contra-lateral hemishpere AERs were significantly faster to N1 than ipsilateral hemisphere AERs [F (1,8) = 8.642, p<.025] in the dichotic linguistic condition, while there was no difference between ipsilateral and contralateral hemispheres in the monaural control condition. These results corroborate the contralateral AER data of Experiment I. The final result from the analysis of variance was that the monaural control condition had significantly faster overall AER latencies than the linguistic, click-in-sentnece condition [F (1,8) = 11.28, p<.01].

The fact that the passive listening control condition AERs were significantly faster than the linguistic condition was somewhat unexpected. It was anticipated that if Titchener's Law applied to the early portions of the perceptual process the linguistic condition AERs would be faster. It appears however, that the clicks in linguistic context require more time to process than those in the control condition. Furthermore, a number of different comparisons and correlations were made between the AER data and the click location responses from both experiments and no correlation of any kind was found. These results strongly indicate that the behavioral click locations activity is a different part of the perceptual process, perhaps reflecting a decision process, and may not even be part of the perceptual process at all. If this speculation is true, then the prior entry effect might not be the results of differential perceptual processing but rather some form of response decision criterion that occurs much later in the process of fulfilling the experimental requirements. While more study is needed to determine the merit of the above speculation, the lack of correlation between the AER data and behavioral click location data does indicate that the prior entry phenomenon is not reflected in the early phases of the perceptua' process.

The data from Experiment II also suggested that the AER latencies might be significantly faster than those found in Experiment I. A test for independent sample (Ferguson, 1966) indicated that the contralateral hemisphere AER latencies in the linguistic condition of Experiment II were, indeed, signigicantly faster than the comparable AER latencies for Experiment I (t34 - 3.60, p < .01).

This difference in AER latency between the two experiments could be the result of difference in click duration, click loudness balancing and AER recording equipment. In Experiment II, the pre-amplifiers differed from those used in Experiment I in that they had common mode rejection that decreased the noise in the EEG considerably. The result was sharper AERs with shorter latencies in Experiment II.

Finally, the behavioral data from Experiment II were analyzed by the methods used by Seitz & Weber (1974). The result replicated their findings, with the analysis of variance revealing that the write-out response method resulted in significant movement toward the major contituent break while the marking response method revealed no such trend [F 1,10 = 6.8067, p<.05].

In summary, results from both Experiment I and II demonstrate a more rapid AER response to clicks located after the major constituent break when **Ss** were required to write out the stimulus sentence, but no significant difference was found between click position latencies when the **Ss** had only to mark the prepared scripts.

This supports the behavioral evidence in Seitz & Weber (1974) that the major constituent break serves as a closure point in the perceptual processing of sentence material under the write-out response method.

CONCLUSION

Two experiments utilizing averaged electroencephalic responses to clicks in sentences revealed that AER latencies to clicks located after the major constituent break were significantly faster when **Ss** had to write out the sentence before marking the location of the click on the written sentence. This faster response to post-break clicks was not evident when **Ss** had only to locate the clicks on pre-typed copies of the stimulus sentence. These data were interpreted as supporting the contention that different resonse requirements result in different perceptual strategies or sets. The results for the write-out groups in these experiments are in accordance with reaction time data of Abrams & Bever (1969), while results from the marking response groups in the present experiments are in accordance with the results of Scholes et al (1969) for AERs and reaction time with the marking response method. Significantly faster control condition AER latencies and lack of correlation between behavioral data and AER latencies strongly suggest that the prior entry effect does not occur in the early portion of the perceptual process that is monitored by the AER technique. These experiments have demonstrated the value of the AER technique in providing a non-motor, non-volitional, real-time indicator of activity to supplement behavioral data in speech perception studies.

Fig.1

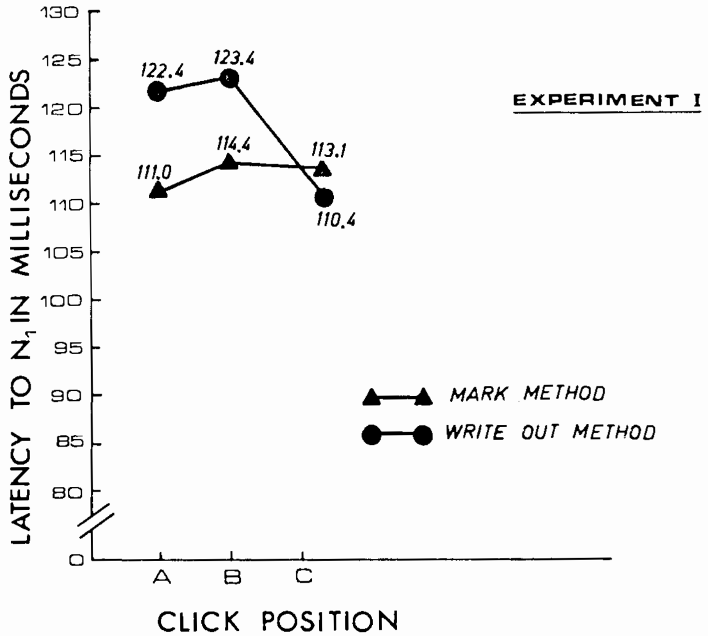


Figure 1. Mean AER latency to N1 (in milliseconds) for each response method and objective click position in Experiment 1.

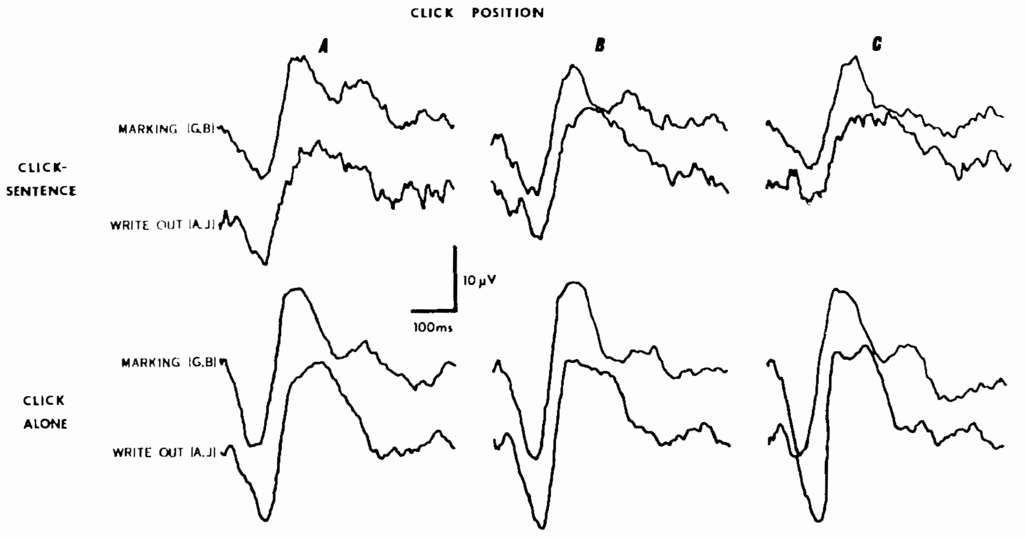
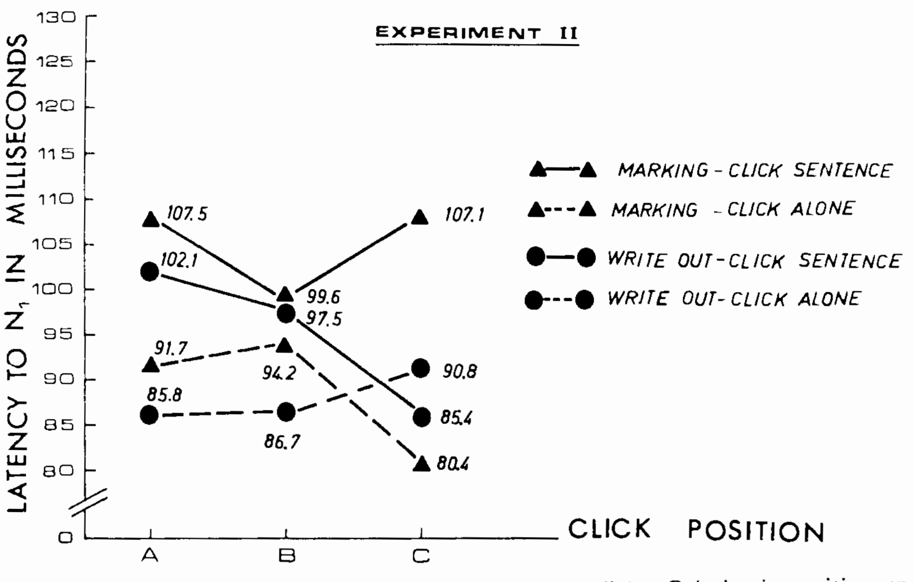


Figure 2. Representative Contralateral AERs (C4) to clicks presented to the left ear for subjects G.B. and A.J. Polarity is positive up.



Each AER is the average of 8 individual responses to clicks. Polarity is positive up.

Figure 3. Mean AER latency to N1 (in milliseconds) for listening conditions, response methods and click positions in Experiment II

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