Speech elicited mismatch negativity in patients with aphasia

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ABSTRACT

Thirty four aphasic patients were included in this study. They were classified into three subgroups; expressive, receptive and mixed. The control group included also 34 subjects with matched age and gender. Event-related potential (Mismatch Negativity test) was elicited using Arabic speech stimuli. Results showed that speech processing at cortical levels was impaired in aphasics. Furthermore, aphasic patients of different types differed significantly from the control group in all the parameters of the MMN test. The results pointed to the importance of using speech elicited MMN in the follow up of aphasic patients. (Egypt J. Neurol. Psychiat. Neurosurg., 2004, 41(2): 521-530).

INTRODUCTION

Aphasia is the condition in which an individual has difficulty expressing thoughts and understanding what is said or written by others¹. It is essentially a language disorder, which results from damage to the portion of the brain that is dominant for language. For most people, this is the left hemisphere². Aphasia might result from direct head trauma³, brain tumors⁴, or brain infection⁵ and most frequently stroke⁶.

Different aspects of language can be affected in aphasia to varying degrees depending on the location and severity of the damage. Aphasia can be so severe as to make communication with the patient almost impossible, or it can be very mild. It may affect mainly a single aspect of language use, such as the ability to retrieve the names of objects, or the ability to put words together into sentences, or the ability to read. More commonly, however, multiple aspects of communication are impaired, while some channels remain accessible for a limited exchange of information⁷.

Brain lesions in aphasia usually involve the central auditory processing areas⁸. How central auditory processing influences the speech-language impairment in aphasics has not been studied comprehensively. It is still controversial whether the speech-language impairment in aphasia patients is due to linguistic deficit⁹,¹⁰, or to central auditory processing deficit that impairs linguistic perception¹¹,¹².

Central auditory processing is a basic mechanism for linguistic perception. It projects information to many areas of higher cognitive functions in the brain including speech and language. Presence of speech-language impairment in some patients with evident temporo-parietal lesions was partially attributed to central processing deficits¹³.

Mismatch negativity test (MMN) which is an electrophysiological test, has been shown to reflect the preattentive central auditory processing mechanisms¹⁴. It has been also shown to reflect acoustic signal processing at cortical levels. MMN provides a unique window to the central auditory stimulus representation in the brain. It enables the measurement of the accuracy of sensory information represented without requiring the subject's attention or response¹⁵,¹⁶,¹⁷. MMN is an objective measure for the permanent auditory memory traces e.g. speech sound memory traces¹⁸.
The aim of this work is to study the cortical response to speech stimuli in different types of aphasia. This is going to be achieved by using MMN test elicited by Arabic speech stimuli. By this work we hope to use this simple, easy and objective test (MMN) as a prognostic tool for aphasic patients of different types.

SUBJECTS AND METHODS

Study group: composed of 41 right-handed aphasic patients. They were 21 males and 20 females. Their age ranged from 45 to 55 years. They all suffered from a left-hemispheric cerebrovascular infarction in the territory of middle cerebral artery. Although all the aphasics exhibited very different lesions of the dominant hemisphere, yet the size and site of lesions were different. All aphasic patients were diagnosed by complete neurological examination and confirmed by imaging techniques. Either CT scan or MRI was done for every patient (Figs. A & B are examples of CT scan and MRI). They were chosen to represent the main diagnostic categories of aphasia, that is Broca's, Wernicke's and mixed aphasia.

All subjects were selected to have no previous history of any hearing loss or any form of ear troubles, no history of noise exposure, any medical disorder that is known to cause hearing loss. Moreover, they all had no history of neurological disorder before the presence illness. Subjects were then classified into three subgroups: subgroup 1 (included 11 patients with Receptive aphasia), subgroup 2 (included 11 patients with Expressive aphasia) and subgroup 3 (included 19 patients with mixed aphasia). Two patients were excluded as they refused to perform the mismatch negativity test (one receptive aphasic and one expressive aphasic patient).

Control group: 34 normal hearing subjects were selected to match the study group in age and gender. They all had no history of ear problems, noise exposure, neurological or medical disorder known to affect hearing.

Fig. (A): Plain CT scan showing non-hemorrhagic infarction in the territory of middle cerebral artery involving the left temporoparietal region.
Fig. (B): MRI brain ($T_1W_1$) showing non-hemorrhagic infarction affecting the left middle cerebral artery.

**Methods:**

All subjects included in this study were submitted to:

- Otological examination and full audiological history.
- Impittance test as an objective test; including tympanometry and acoustic reflex. Patients who did not have type A tympanogram and acoustic reflex sensitivity within normal range in both ears were excluded from this study.
- Mismatch Negativity test: the test procedure was explained to each subject then he/she was seated down reading his or her selected magazine or newspaper. Arabic CV syllables were presented in an oddball paradigm. The syllables were pronounced by a native Arabic adult male, recorded and then sent to the Intelligent Hearing Company to be digitized and calibrated. The syllables used were /ga/ (standard) and /da/ (deviant), as they are known to be processed by the auditory cortex only with no thalamic contribution. These two syllables were frequency contrast, i.e. they were differing in their onset frequency of their third formant.

The stimuli were presented at 65dB SPL monaurally in a repetition rate of 1/sec with a probability of 15% for deviant stimulus presentation. Monaural stimulation was chosen according to the Bellis et al. who reported that both monaural and binaural stimulation by speech signals are processed in the left hemisphere.

Two blocks were collected, each contained 2 averaged sweeps or traces. The first trace was for the deviant stimulus which contained 200 averaged stimuli, while the second trace contained 900-1100 averaged standard stimuli according to the random presentation of the deviant stimulus during testing. The presence of the N1 response on both the standards and deviants was visually inspected before computing MMN wave. The difference curve was computed by subtracting the
Standards from deviants. For qualitative analysis of MMN peak amplitude, latency, and duration were measured on the individual responses.

## RESULTS

Study group included only 34 aphasic patients as two patients refused to perform the test, and five cases showed no response (no MMN). They were 4 patients of the mixed group and one patient from the receptive group. The included patients were 16 males and 18 females. Their age ranged from 45 years to 55 years with the mean of 48.9 years and standard deviation of ±2.1 years. While the control group consisted of 34 subjects 16 males and 18 females. Their age ranged from 44 to 56 years with the mean of 49.1 years and the standard deviation of ±1.9 years.

Comparison of the three parameters of the MMN test (latency, duration and amplitude) was done between the control group and all the aphasic patients (Table 1). Aphasics as one group showed shorter latency, duration and smaller amplitude than the control group. However, there was no significant difference between the two groups regarding the peak latency of MMN wave. While, there was a highly significant difference regarding the other two parameters (duration and amplitude).

Analysis of Variance (ANOVA) test was applied in order to compare the MMN parameters in the three subgroups of aphasia with the control group. Furthermore, each two subgroups of aphasia were compared (Table 2) and the Scheffe test was then applied in order to identify the significant cell. Results showed that the three subgroups were significantly different from the control group in all the parameters of the MMN test. Moreover, results of Scheffe test showed the following:

- As regards the latency: control group was significantly different from the three subgroups. Moreover, each subgroup differed significantly from the others (Fig. 1). The expressive aphasics showed the longest latency among all the subgroups, while the receptive aphasics showed the shortest latency. On the other hand, the mixed aphasics showed latency range within the normal values although significantly different from the control group.

- As regards duration: only expressive and mixed aphasics were significantly different from the control group. Furthermore, there was no significant difference between the expressive and mixed aphasics regarding the duration, while the receptive aphasics differed significantly from both the expressive and the mixed aphasics (Fig. 2).

- As regards the amplitude: expressive aphasics did not differ significantly from controls, while both receptive and mixed aphasics were significantly different from controls. Furthermore, each two subgroups of aphasia were significantly different from each other (Fig. 3).

### Table 1. Comparison of MMN parameters (latency, amplitude and duration) in control and study group.

<table>
<thead>
<tr>
<th>MMN Variables</th>
<th>Control (No. =34)</th>
<th>Aphasics (No.=34)</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency</td>
<td>207.8 (13.3)</td>
<td>197.5 (32.8)</td>
<td>1.329</td>
<td>0.190</td>
</tr>
<tr>
<td>Duration</td>
<td>101.3 (6.5)</td>
<td>57.7 (27.3)</td>
<td>7.003</td>
<td>0.0005*</td>
</tr>
<tr>
<td>Amplitude</td>
<td>1.53 (0.23)</td>
<td>0.74 (0.54)</td>
<td>6.199</td>
<td>0.0005*</td>
</tr>
</tbody>
</table>

* = P < 0.05
Table 2. Comparison of latency, amplitude and duration among studied cases and control.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Aphasics (n=10)</th>
<th>Control (n=34)</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Receptive (n=10)</td>
<td>Mixed (n=13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>148.8-167.3</td>
<td>185.6-197.2</td>
<td>180.5-230.2</td>
<td>138.76</td>
</tr>
<tr>
<td>Mean</td>
<td>160.7</td>
<td>189.7</td>
<td>207.8</td>
<td>13.3</td>
</tr>
<tr>
<td>S.D.</td>
<td>5.4</td>
<td>3.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>69.30-107.2</td>
<td>22.40-49.49</td>
<td>94.0-113.53</td>
<td>172.76</td>
</tr>
<tr>
<td>Mean</td>
<td>95.9</td>
<td>38.2</td>
<td>101.3</td>
<td>6.5</td>
</tr>
<tr>
<td>S.D.</td>
<td>14.2</td>
<td>9.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.59-0.93</td>
<td>0.03-1.06</td>
<td>1.25-1.89</td>
<td>96.42</td>
</tr>
<tr>
<td>Mean</td>
<td>0.82</td>
<td>0.18</td>
<td>1.53</td>
<td></td>
</tr>
<tr>
<td>S.D.</td>
<td>0.11</td>
<td>0.27</td>
<td>0.23</td>
<td></td>
</tr>
</tbody>
</table>

*Significant

![MMN Peak Latency in Different Groups](image_url)

**Fig. (1):** Peak latency of MMN in all studied groups.
Fig. (2): Duration of MMN wave (in msec.) in all studied groups.

Fig. (3): Amplitude of MMN wave (in µV) in all studied groups.
DISCUSSION

Language is the most common way of communication between humans. Because language is affected in aphasia, speech stimuli were chosen to study the language processing deficits in those patients. MMN was chosen as it is expected that aphasics and normal subjects may differ in cortical processing of speech.

It is well documented that damage to the left but not the right hemisphere destroys language function. It is also known that many functions related to various subsystems of language processing have been located in the left hemisphere, in fronto-temporal (Broca) and in temporoparietal (Wernicke) areas. Therefore, aphasics with left hemisphere affection of varying degrees were selected to constitute the study group of this work.

Fig. (4): Examples of Mismatch negativity traces from each subgroup of aphasia.
Three types of aphasia only were included in this study; Broca's, Wernicke's and mixed aphasia. Broca's aphasia is characterized by non-fluent speech and preserved comprehension (expressive aphasia). In this type the lesion is circumscribed to Broca's area. While Wernicke's aphasics have fluent speech output with poor auditory comprehension. In this type the lesion usually involves left superior temporal region. These patients are usually unaware of the receptive deficit they have (receptive aphasia). On the other hand, the mixed type of aphasia is considered to be the most severe clinical form of disturbance in all cases of aphasia.

The MMN latency of all the aphasic patients together was within the normal range and did not differ significantly from that of the control group. This agrees with the results of Auther et al.\textsuperscript{23}. While, the latency response of each subgroup differed significantly from that of the control group and differed from each other. The expressive type of aphasia showed the longest latency among aphasics, followed by the mixed and lastly the receptive type of aphasia, which showed the shortest latency (Fig. 1). This may be related to the function of the affected area in the receptive type of aphasia, which is the Broca's area.

The duration parameter of MMN was shorter in aphasics than in control (Fig. 2). Moreover, the amplitude parameter was smaller in aphasics than in control group (Fig. 3). Furthermore, when the aphasic group was divided into the three subgroups, each subgroup differed significantly from the control and the other two subgroups. These results agree with those of Auther et al.\textsuperscript{23}, Auther et al.\textsuperscript{24} and Csepe et al.\textsuperscript{26}. Auther et al.\textsuperscript{24} used da-ga stimuli (frequency contrast) in order to examine the relationship of MMN in aphasic patients to their site of lesion, and severity of their aphasia. Furthermore, in another work the same authors\textsuperscript{23} investigated the relationship between the MMN and improvement in aphasia. Their results suggested a trend of changes in duration and amplitude of MMN with improvement of aphasia. The results of our work agree with those, as in our work both the duration and amplitude of MMN were significantly less in aphasics. This means that using both duration and amplitude parameters of MMN will help in follow up of aphasic patients.

The largest duration of MMN response among the three subgroups of aphasia was noticed in the receptive aphasics, although their MMN peak latency was the shortest (Table 2 & Figs. 2 & 3). This means a shallow response wave and this could be also related to the affected area or the site of lesion in this type of aphasia. It could also mean that the brain in this type of aphasia takes a longer time to discriminate the difference between the two presented stimuli.

The result of Broca's aphasia in this work showed the largest amplitude among the three aphasic subgroups (1.32\(\mu\)V \(\pm\) 0.27), while the latency was longer than control (Table 2 & Figs. 3 & 1). This result agrees with those of Csepe et al.\textsuperscript{26} who reported that in these patients MMN appeared to have large amplitude.

The MMN response in the mixed subgroup were the least identifiable among the three subgroups of aphasics (Figs. 1, 2 & 3). This could be related to the size of the lesion as well as the severity of aphasia. Lesions in patients of the mixed group are considered to be the largest in size. This is also supported by the fact that four of the five cases with absent MMN were of the mixed group. Furthermore, Wertz et al.\textsuperscript{25} reported that the short duration of MMN in aphasics was significantly related to severity of aphasia on the western aphasia battery, which agrees with the result of our work. This was also confirmed by their imaging techniques including CT scan and MRI. However, this point should be studied on a larger sample of patients.

It has been suggested that the spared regions in the left hemisphere normally act to prevent the expression of latent language functions within the undamaged right hemisphere\textsuperscript{21}. Thus, only after the intact right hemisphere has been released from the disruptive and suppressive influence of the damaged left hemisphere by sectioning of corpus callosum, can its own residual function become
effective. It is also reported that language specific impairment resulting from left hemispheric lesion might be compensated by secondary capacities of the right hemisphere. The likelihood that language ability improves after stroke is high, yet the degree of recovery is very variable. Recovery depends on many factors that should be considered. Besides the size, site and severity of the lesion, recovery can be related to neuroplasticity. The mechanisms of neuroplasticity responsible for cognitive recovery after cortical damage are still controversial. These mechanisms include synaptic sprouting, synaptogenesis, restoration of lateral inhibitory connections, which apparently are crucial for the functioning of cortical networks, and the unmasking of latent connections.

Finally it can be concluded that speech processing at the cortical levels is impaired in aphasics. Aphasics showed significantly different MMN response than normal subjects. However, only duration and amplitude parameters are considered important when comparing the aphasics as one group. On the other hand, comparing the three subgroups tested in this study revealed significant difference than the normal subjects in all MMN parameters. It can be concluded then that MMN test can be used for monitoring the improvement in aphasics as it is easy, noninvasive, and not time consuming.

REFERENCES


المخلص العربي

موجة عدم التوافق السلبية للكلام في مرضى الحبسة الكلامية

أربعة و ثلاثين مريضاً مصاباً بالحبسة تم الكشف عليهم. تم تقسيمهم إلى ثلاثة مجموعات حسب نوع الحبسة: حبسة تعريبية، حبسة استقبالية، وحبسة مختلطة. كما تم الكشف على عدد سائل من الأشخاص الطبيعيين كمجموعة ضابطة. تم استخدام اختبار موجة عدم التوافق السلبي باستخدام اللغة العربية. وقد أظهرت النتائج أن تحليل الكلام عند مستوى التكرار المحيط أقل في مرضى الحبسة. كما أظهرت النتائج أن أنواع الحبسة المختلفة تختلف اختلافاً ذو دلالة إحصائية عن الأشخاص الطبيعيين في كل معلوم لاختبار موجة عدم التوافق السلبي. وهذا يثبت أهمية استخدام موجة عدم التوافق السلبي في متابعة مرضى الحبسة الكلامية.