N1-P2 Evoked Response as a Measure for Short-Term Visual Memory

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Abstract

We investigate the relationship of N1-P2 evoked response (peak-to-peak amplitude and time interval) with short-term visual memory in humans. Visual evoked responses obtained from 20 subjects (10 non-amnesic alcoholics and 10 non-alcoholics) are extracted from channel P8 referenced to channel Cz during the presentation of modified delayed matching-to-sample visual task using Snodgrass and Vanderwart picture set. Our results indicate that N1-P2 amplitudes are higher for non-matching (novel) stimuli as compared to matching stimuli for all the subjects. N1-P2 time interval is also shorter for the case of matching stimuli. This indicates that information processing is increased for the non-matching stimuli as compared to matching stimuli. These results are quite consistent with a number of related studies and we conclude that N1-P2 is related to short-term visual memory involved during object recognition. The results also indicate that N1-P2 amplitude is higher for non-alcoholics as compared to alcoholics, which indicates that some form of memory impairment exist in alcoholics.

1. Introduction

The general mechanism underlying the neuronal behavior that relates vision and memory is yet to be fully understood [1]. However, low frequency component analyses have identified the occipito-temporal cortex to be involved in memory process of humans [1, 11]. These studies use Visual Evoked Potential (VEP) extracted from subjects performing a modified delayed matching-to-sample task and the results indicate that a positive component around 170 to 240 ms [11] and 220 to 260 ms [1] after stimulus onset can serve as a visual memory potential. Higher frequency analysis (>20 Hz) has shown that occipitotemporal and frontal electrodes are involved in the memory process [10].

In this paper, VEP is extracted from alcoholic and non-alcoholic subjects while performing modified delayed matching-to-sample paradigm using Snodgrass and Vanderwart [9] picture set. We investigate the possibility of using N1-P2 peak-to-peak amplitude and time interval as a measure for short-term visual memory in humans during object recognition. The evoked response is extracted from channel P8 following studies by Begleiter et. al. [1] and Zhang et. al. [11].

In our analysis, N1 is the first negative peak evoked around 180 ms (±20 ms) after stimulus onset, while P2 is the positive peak immediately following N1. N1 latency to auditory response has been shown to be around 100 ms while for the flash evoked potential, it is around 130 ms [3]. Longer response time of N1 in our case is most likely due to the different stimulus i.e. visual object in our case.

Although positive component similar to P2 has been suggested as a measure of short-term memory potential [1,11], the inclusion of N1 is preferable for the following reason. N1 can be thought as the start of the stimulus response. Therefore, the time interval and amplitude difference between N1-P2 peaks will be a better representative of the short-term memory.

The analysis of N1-P2 response is extended to study the short-term memory impairment in alcoholics.

2. Method

Twenty subjects, 10 non-amnesic alcoholics and 10 non-alcoholics participated in the experimental study. The alcoholics tested have been abstinent for a minimum period of one month and are also off all medications for the same period of time. The non-alcoholics are not alcohol or substance abusers. The

subject was seated in a reclining chair located in a sound attenuated RF shielded room. Measurements are taken from channel P8 (10/20 International montage [4]) placed on the subject's scalp, which are sampled at 256 Hz. Position Cz is used as reference. This channel setup is chosen based on earlier studies [1,11].

The VEP signals are recorded from subjects while being exposed to two stimuli, which are pictures of objects chosen from Snodgrass and Vanderwart picture set [9]. These pictures are common black and white line drawings like airplane, banana, ball, etc. executed according to a set of rules that provide consistency of pictorial representation. The pictures have been standardized on variables of central relevance to memory and cognitive processing. Figure 1 shows some of these pictures.

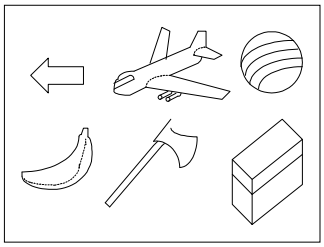


Figure 1: Some objects from Snodgrass and Vanderwart picture set

The second stimulus (S2) is shown in either matching (S2M) or non-matching condition (S2N) to the first sample stimulus (S1). Matching denotes that S1 is repeated as S2M. Care is taken to ensure that the S2N is different from S1 not only in visual form but also in terms of semantic. Stimulus duration of each picture is 300 ms and inter-stimulus interval is 1.6 s with an inter-trial interval of 3.2 s. The presentations of matching and non-matching trials are random. The stimuli are shown using a computer display unit located 1 meter away from the subject's eyes. The subjects are asked to decide whether S2 is the same or different as compared to S1. They are asked to press a mouse key in one hand if S2 matched S1 and to press a mouse key in the other hand if S2 differed from S1, after the presentation of S2 on each trial. The designation of the hand indicating match or non-match is alternated for all subjects. Response accuracy and speed are stressed equally. One-second measurements after each stimulus onset are stored. For further details of the data collection process, refer to Zhang et. al. [11].

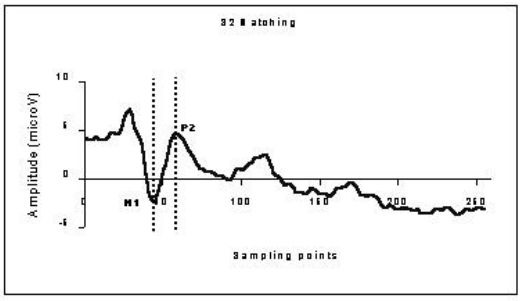
In this study, VEP signals with eye blink artifact contamination are removed using a computer program written to detect VEP signals with magnitudes above 100 μV. These VEP signals detected with eye blinks are then discarded from the experimental study and additional trials are conducted as replacements. The threshold value of 100 μV is used since blinking produces 100-200 μV potential lasting 250 milliseconds [5].

Low pass digital filtering with 3 dB cut-off at 20 Hz is applied since N1 and P2 frequency responses are in this range [2]. A 9th order forward and reverse Butterworth digital filter is used for this purpose. Order 9 is used since it is sufficient to give a minimum attenuation of 30 dB in the stop band with a transition band from 20 to 30 Hz. Forward and reverse filtering are performed to achieve zero phase response i.e. to avoid any phase distortion.

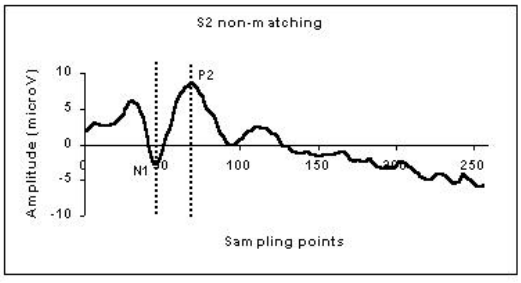
A total of 20 S2M and 20 S2N artifact free trials for each subject are used in the experiment. Mean from the data are removed. This is to set the pre-stimulus baseline to zero [8]. Averaging based on each type of stimulus, for each subject is performed to remove background electroencephalogram.

3. Results

Figure 2 shows the grand averaged VEP for all the non-alcoholic subjects for both the S2M and S2N stimuli types. Also shown in the figure are the N1 and P2 responses. Figure 3 shows the grand averaged VEP for alcoholics.

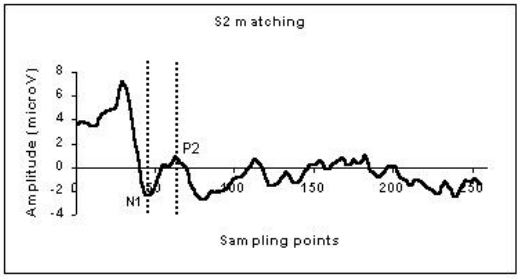


(a)

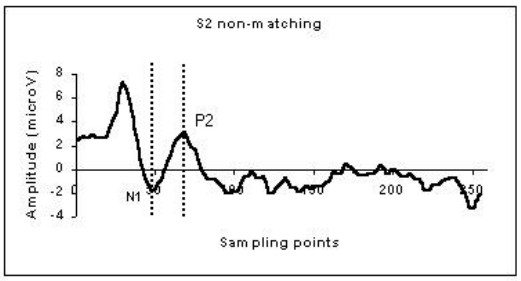


(b)

Figure 2: Grand averaged VEP for non-alcoholic subjects for (a) S2M (b) S2N



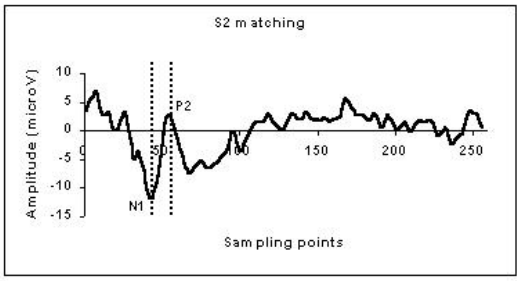
(a)



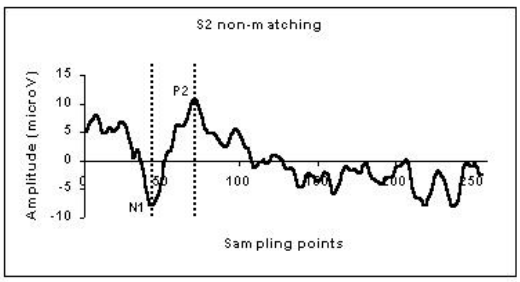
(b)

Figure 3: Grand averaged VEP for alcoholic subjects for (a) S2M (b) S2N

Figure 4 and 5 show averaged VEP for two subjects, a non-alcoholic and an alcoholic, respectively. Due to constraints in space, results for other subjects are not shown.

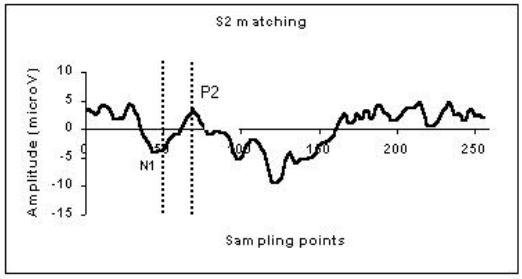


(a)

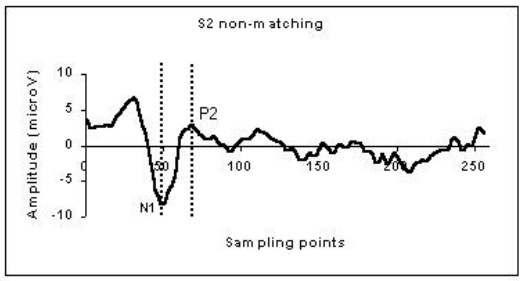


(b)

Figure 4: Averaged VEP for a non-alcoholic subject (a) S2M (b) S2N



(a)



(b)

Figure 5: Averaged VEP for an alcoholic subject (a) S2M (b) S2N

Table 1 gives the N1-P2 peak-to-peak time interval and amplitude for the grand averaged VEP.

Table 1: N1-P2 peak-to-peak time interval and amplitude for the grand averaged VEP

	S2M		S2N	
Subjects	**Time (ms)**	**Amplitude (μV)**	**Time (ms)**	**Amplitude (μV)**
Non-alcoholic	54.6	6.77	76.8	11.32
Alcoholic	66.3	3.10	69.0	4.63

4. Discussion

In this paper, it is proposed that N1-P2 peak-to-peak amplitude and time interval could be used as a measure of short-term visual memory processes involved during object recognition. Previous studies [1,11] have shown that higher latency and larger response for S2N stimuli as compared to S2M stimuli using a peak component similar to P2. The N1-P2 peak-to-peak amplitude response investigated in this paper also gives higher response to S2N as compared to S2M for all the alcoholic and non-alcoholic subjects. This fact is also in line with neural network models of memory [6].

The N1-P2 peak-to-peak time interval is also longer for S2N as compared to S2M. Again, this is true for all the alcoholics and non-alcoholics subjects. This indicates that more information processing is involved in a non-matching condition as compared to a matching condition.

Grand averaged response shows that N1-P2 amplitude is higher for non-alcoholics as compared to alcoholics. This is true for both S2 matching and S2 non-matching stimuli. This shows that non-alcoholics are able to access more short-term visual memory as compared to alcoholics.

The N1-P2 time interval is shorter for non-alcoholics as compared to alcoholics for S2 matching stimuli, which shows that alcoholics respond slower than non-alcoholics.

However, the N1-P2 time interval is similar for S2M and S2N for alcoholics. This shows that alcoholics respond somewhat equally to matching and non-matching stimuli i.e. they have difficulty in distinguishing between matched and non-matched stimuli. The non-alcoholics do not exhibit this behavior, i.e. their N1-P2 time interval is longer for S2N as compared to S2M, which is as anticipated since S2N process is more complex than S2M.

These results indicate that some form of memory impairment exist in alcoholics. However, it is difficult to correlate N1-P2 response between alcoholics and non-alcoholics on the individual scale, which is most likely due to the difference in age, gender and socioeconomic status of the tested subjects. Further normalization across subjects taking into account of these parameters was not possible due to lack of information of these parameters.

Acknowledgement

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References

[1] Begleiter, H., Porjesz, B., and Wang, W., "A Neurophysiologic Correlate of Visual Short-term Memory in Humans," *Electroencephalography and Clinical Neurophysiology*, pp. 46-53, vol. 87, 1993.

[2] Brandt, M.E., Jansen, B.H., and Carbonari, J.P., "Pre-stimulus Spectral EEG Patterns and The Visual Evoked Response", *Electroencephalographic and Clinical Neurophysiology*, pp.16-20, vol. 80, 1991.

[3] Cooper R., Osselton, J.W., and Shaw, J.C., *EEG Technology*, Butterworths & Company Publishers, 1980.

[4] Jasper, H., "The ten twenty electrode system of the international federation," *Electroencephalographic and Clinical Neurophysiology*, pp.371-375, vol. 10, 1958.

[5] Kriss, A., "Recording Technique," *in Evoked Potentials in Clinical Testing*, edited by Halliday, A.M., Churchill Livingstone, 1993.

[6] McClelland, J., and Rumelhart, D., *Parallel Distributed Processing*, vols. 1 and 2, MIT Press, Cambridge, MA.

[7] Palaniappan, R. and Raveendran, P., "Single Trial VEP Extraction Using Digital Filter," *Proceedings of IEEE 11th Workshop on Statistical Signal Processing*, pp. 249-252, 6-8 August 2001, Singapore.

[8] Polich, J., "P300 in Clinical Applications: Meaning, Method and Measurement," *American Journal of EEG Technology*, pp. 201-231, vol. 31, 1991.

[9] Snodgrass, J.G. and Vanderwart, M., "A Standardized Set of 260 Pictures: Norms for Name Agreement, Image Agreement, Familiarity, and Visual Complexity," *Journal of Experimental Psychology: Human Learning and Memory*, pp. 174-215, vol. 6, No.2, 1980.

[10] Tallon-Baudry, C., Bertrand, O., Peronnet, F., and Pernier, J., "Induced λ-Band Activity during the delay of a Visual Short-Term Memory Task in Humans," *Journal of Neuroscience*, pp. 4244-4254, vol. 18, no. 11, 1998.

[11] Zhang, X.L., Begleiter, H., Porjesz, B., Wang, W. and Litke, A., "Event Related Potentials During Object Recognition Tasks," *Brain Research Bulletin*, pp. 531-538, vol. 38, no. 6, 1995.