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Identification of Nicotine Effect on Working Memory via Electroencephalogram

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ABSTRACT
The effect of nicotine on the working memory of smokers has not been carried out using Electroencephalogram (EEG) alone, a non-invasive technique that can detect brain activities via electrodes placed on the scalp. This paper describes the effects of nicotine on short-term memory and working memory of non-smoker and smoker through Electroencephalogram (EEG) obtained during two working memory tasks. The EEG signals were filtered to remove interferences and to acquire the working memory information. The signals were analysed using Fast Fourier Transform (FFT) and Power Spectral Density (PSD) to obtain the frequency and power spectrum of EEG signals during the working memory trials. It was found that EEG signal strength at frontal area, particularly Fz and F3 was lower before smoking than after smoking. However, it could not reach the level of cognitive performance of non-smokers. The results show that EEG is suitable for monitoring the working memory performance through cognitive tasks.

Key words:brain signals, power spectrum, nicotine effect, working memory, short-term memory.

1. INTRODUCTION
Addiction to smoking is caused by nicotine in the cigarette that is sedative and stimulant. Nicotine can make the mind and body more active due to the release of adrenaline from adrenal glands stimulation. It also allows the release of brain chemical called dopamine which makes the smoker brain change. Studies have shown that cognitive performance and concentration can be improved and enhanced after consuming nicotine [1, 2]. However, in the absence of nicotine for 12 hours, the attention and cognitive abilities of nicotine-dependant persons will be impaired [3].

A few studies have investigated the effect of nicotine on brain function and performance [1]-[7]. Ernt et al [3] used statistical analysis to examine the effect of abstinence from smoking on working memory through two cognitive tasks namely two-letter search and logical reasoning. Warbrick et al [2] compared the conventional analysis and simultaneous electroencephalogram (EEG)-functional Magnetic Resonance Imaging (fMRI) analysis to detect nicotine effect on brain function. fMRI is bulky and requires the injection of radioactive to produce brain images which is not comfortable to the patients. None of the studies used EEG as a single modality to examine the effect of nicotine on working memory.

EEG is an electrophysiological monitoring method that detects electrical activity in human brain via electrodes attached to scalp. EEG has been used in researches to detect drowsiness [8], monitor concentration in the classroom [9], diagnose sleep disorder [10], recognise familiar faces [11] and others. Some researchers have employed EEG to monitor alertness and memory performance [12], [13] with the exclusion of nicotine. Chris Berka, et al [13] proposed real-time analysis of EEG to monitor status of alertness, cognition, and memory. Klimesch et al. [9] reported that EEG alpha and theta oscillations could reflect cognitive and memory performance. A study carried out by B. Schack, et al [14] have found that theta-gamma EEG rhythms could indicate short-term memory processing, using the Sternberg task with random figures and number words.

Working memory is responsible for the short-term storage and manipulation of information necessary for higher cognitive functions, such as language, planning and problem solving. There are two types of processes involve in working memory; executive control and activate maintenance. The executive control includes manipulation of encoding and information retrieval in working memory whereas activate maintenance keeps information available. According to Cohen et al [15], the prefrontal and parietal cortex play a role in active maintenance. The working memory storage uses the mechanisms that underlie perception which are the parietal and temporal lobes [16].

This paper describes the effects of nicotine on short term and working memory identified through EEG. EEG signals were recorded from smokers and non-smokers and the analysis was carried out using Fast Fourier Transform (FFT) and Power Spectral Density (PSD).

2. METHODOLOGY

The research was conducted in four stages which include Protocol Design of EEG Signal Recording, Data Acquisition, Signal Processing and Signal Analysis. Twelve subjects; smokers and non-smokers aged between 22-25 years were participated in this study. The subjects are healthy and have normal colour vision. Consent form was given to the subject and the recording protocol was explained in detail before the signal acquisition was carried out.

2.1 Protocol Design of EEG Signal Recording

The room for recording the EEG signal must have normal interior lighting and with minimal obstruction between the speaker and subject. Before the recording was performed, the subject was asked to sit comfortably on a chair in front of a notebook which displays the questions designed using Microsoft PowerPoint. There were two tasks for the subject to be performed; shape sequence task and 2-back task. For each task, the subject has to answer a few questions and the total questions are thirty. Two different sets of questions are prepared for the smokers to answer before and after smoking. The smokers are asked not to smoke for 2 hours before the trial to study the effect of abstinence [17]. During the execution of these tasks, the subject must be in silent mode, meaning that they are not allowed to talk. The signal recording commenced once the first task was executed.

In the first task, the subject was asked to relax for 3 minutes before answering the questions. The instructions for each task were first displayed on the screen and read by the subjects. Then, the trials commenced. The subject was given 1 minute to relax between each trial as shown in Table 1. The questions in task 1 were designed to examine working memory and cognitive performance and developed by referring to Cognifit website [18].

Table 1: Tasks and Activities

Trial	Task	Activity
1	1. Remember shape sequence	i. Relax for 3 minutes ii. Read the instruction displayed on the notebook screen. iii. Answer the question. iv. Repeat step (ii) & (iii) until all questions are answered.
2	2. Two-back test	i. Relax for 1 minute ii. Read the instruction displayed on the notebook screen. iii. Answer the question. iv. Repeat step (ii) & (iii) until all questions are answered.

As the trial starts, the subject was presented with three common shapes in sequence. A sample of shape sequence in the question in task 1 is shown in Figure 1. Each shape sequence was shown for 4 seconds [19]. The shape sequence was selected to test memory response immediately because the effect of memory may occur in less than 1 second when a person views a picture or reading a sentence [20]. Then, the subject was allowed to choose the answer from the multiple choices presented on a slide (see Figure 2) for 5 seconds. There are ten questions in trial 1.

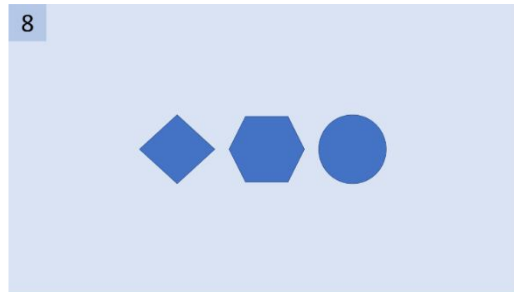


Figure 1: A sample of shape sequence in the Task1 question

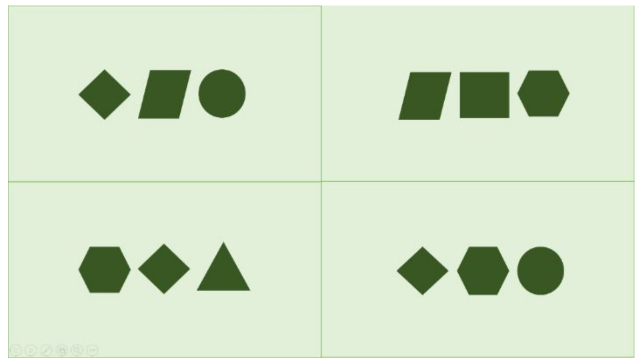


Figure 2: A sample of multiple-choice answer.

The second task questions were developed to test short-term memory. The questions were designed based on [17] with minor modifications. As the first task, the instruction is displayed on the first slide. A block will appear randomly on one of the slots of 3x3 grid with a fixed empty slot at the centre. The interval between the appearance and disappearance of the block is at interval of 1.4 seconds. The subject has to remember the previous 2 position of the block and then select the correct position from the multiple choices given. If there are 4 transitions in the question, the correct answer will be the 2nd transition. Figure 3 shows a sample of the question for this task. This task includes twenty questions.

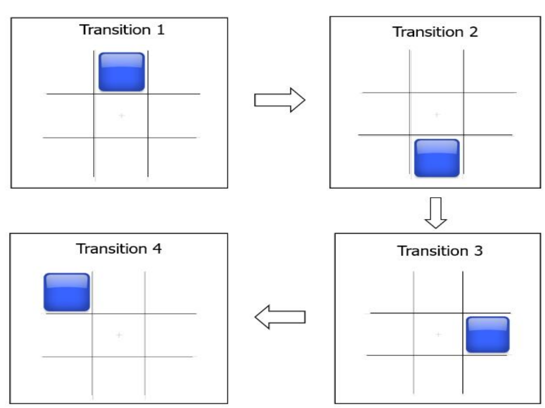


Figure 3: A sample of block appearance in the Task 2 question.

2.2 Data Acquisition

EEG signals were recorded using EnobioNeuroelectrics Instrument Controller (NIC) with dry electrodes located at 32-placements. The dry electrodes, integrated into the EEG cap, were located on the scalp according to the international 10-20 system [18] at locations Fp1, Fp2, AF3, AF4, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, PO3, PO4, O1, Oz, O2 as shown in Figure 4. The selected channels for example F3, F4 were for short-term memory, channel Fz is for working memory, P3 and P4 was for spatial memory, Pz for cognitive processing, and O1, O2 for visual memory. The sampling frequency used was 500 Hz.

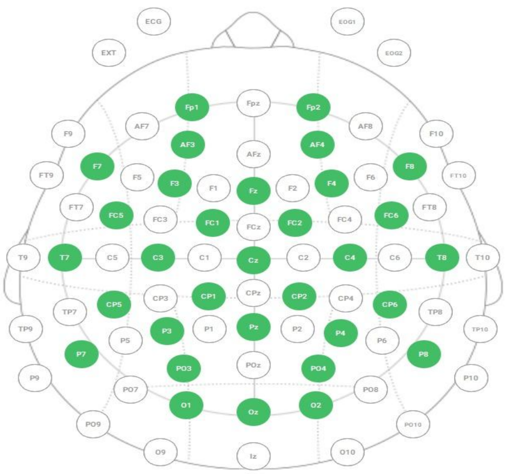


Figure 4: The locations of electrode used to record the EEG signals.

2.3. EEG Signal Processing and Analysis

The recorded EEG signals contains artifacts such as baseline drift [21], power line interference and signals from other part of the body that need to be removed. High pass filter was used to remove the baseline drift bandpass filter with the bandpass frequency range of 4-12 Hz was used to extract the signals that contain information on the working memory activities. To analyse the frequency content of the raw and filtered signal, spectral analysis was carried out using Fast Fourier Transform (FFT). The FFT was computed using (1).

$$X(k) = \sum_{n=0}^{N-1} x(n).W_N^{nk} \qquad (1)$$

where X*(k)* is the coefficients that lie in the range of $0 \leq k \leq (N-1)$, x(n) is the signaland W_N^{nk} is a periodic function.

The energy and signal strength of the signals were identified by computing the Power Spectral Density (PSD) using (2). Using PSD, the information on the frequency points that have strong and weak frequency variations can be extracted [22].

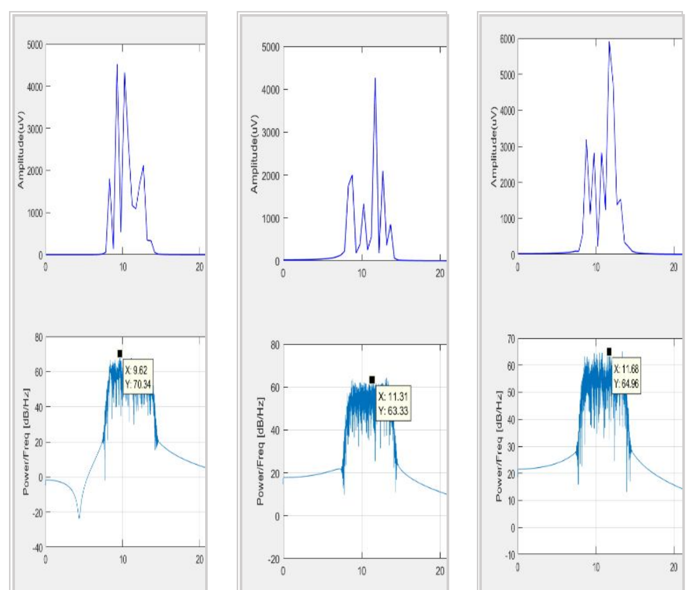
$$P(X_k) = \frac{1}{N^2}[|X_k|^2 + |X_{N-k}|^2] \qquad (2)$$

where k= 1, 2, ……..$(\frac{N}{2} - 1)$

3. RESULTS AND DISCUSSION

Figure 5 shows a sample of the frequency and power spectrum of the non-smoker, smoker before smoking and smoker after smoking obtained at F3 during relax. The frequency of EEG signals of non-smokers and smokers is in the range of 9 to 12 Hz. The amplitude of power spectrum of the non-smokers (68 to 71 dB/Hz) is higher than those of smokers during relax. Before smoking, the strength of the EEG signals is lower than that of after smoking. This indicates the nicotine has an effect on the memory even during relax. This result is confirmed by the average PSD taken from 12 subjects (non-smokers and smokers) as shown in Table 2. The average PSD after smoking is higher than that before smoking but it cannot exceed the average PSD of non-smoker.

Table 3 shows the average PSD of EEG signals of non-smokers and smokers during working memory trial of task1 and task 2 obtained from seven channels; F3, F4, Fz, P3, P4, O1 and O2. Comparing the average PSD from the channels, it can be seen that channel F3 and Fz produce the same trend where the average PSD of non-smokers is higher than that of smokers during performing both tasks and taking nicotine increases the PSD of the smokers. The channels could show the effect on the nicotine on the short-term memory and working memory and demonstrate how active the memory of the non-smokers and smokers is. Channels P3, P4, O1 and O2 do not show similar trend in the results. The channels are associated with spatial memory and visual memory.



(a) (b) (c)

Figure 5: The frequency and power spectrum of (a) non-smoker, (b) smoker before smoking and (c) smoker after smoking at F3 during relax.

Table 2: Average PSD during relax and working memory trial

Subjects	Average PSD (dB/Hz)	
	Relax (F3 channel)	Working Memory Trial (Fz Channel)
Non-smoker	70.34	68.09
Smoker (before smoking)	63.33	64.39
Smoker (after smoking)	64.96	66.33

Table 3: Average PSD at various channels during working memory trials

Electrode Positions	Average PSD (dB/Hz)					
	Task 1			Task 2		
	Non-smoker	Smoker before Smoking	Smoker after Smoking	Non-smoker	Smoker before Smoking	Smoker after Smoking
F3	67.84	64.34	64.66	66.45	61.72	66.08
F4	64.75	63.11	64.30	64.57	62.17	65.00
Fz	66.89	64.64	66.78	68.09	64.39	66.33
P3	62.24	65.27	63.37	64.74	61.67	65.30
P4	62.70	65.36	61.34	64.23	61.86	63.80
O1	61.09	63.39	62.57	65.29	63.07	64.02
O2	64.24	65.68	65.96	65.71	63.12	64.53

5. CONCLUSION

The nicotine effects on working memory using EEG signals of non-smoker and smoker before and after smoking have been described in this paper. The effect of nicotine on short term memory was tested by conducting two trials, the shape sequence task and 2-back task. PSD was employed to determine the signal strength and detect the working memory status with the absence and presence of nicotine. It was shown that F3 and Fz produce the highest PSD when conducting working memory trials for both non-smokers and smokers and reveal that the cognitive performance of a smoker is improved after consummation of nicotine, but it is below than that of non-smoker. This shows that EEG is a suitable tool for monitoring the working memory status and the nicotine effects on the working memory.

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REFERENCES

1. A. S. Gershon, M. A Campitelli, S. Hawken, C. Victor, B. A. Sproule, P. Kurdyak, P. Selby, **Cardiovascular and neuropsychiatric events after varenicline use for smoking cessation,***Am. J. Respir. Crit. Care Med.*, vol. 197, no. 7,pp. 913–922, Dec.2017. https://doi.org/10.1164/rccm.201706-1204OC
2. T. Warbrick, A. Mobashar, J. Brinkmeyer, F. musso, T. Stoeker, N.J. Shah, G. R. Fink, G. Winterer, **Nicotine effects on brain function during a visual oddball task: A comparison between conventional and EEG-informed fMRI analysis**,*J.Cogn. Neurosci.*, vol. 24, no. 8, pp. 1682–1694, Aug.2012.
3. M. Ernst, **Smoking history and nicotine effects on cognitive performance**, *Neuropsychopharmacology*, vol. 25, no. 3, pp. 313–319, March 2001.
4. J. E. Lisman and M. A. P. Idiart, **Storage of 7 ± 2 short-term memories in oscillatory subcycles**, *Science (80).*, vol. 267, no. 5203, pp. 1512–1515, March 1995.
5. Z. Dai, J. Souza, J. Lim, P. M. Ho, Y. Chen, J. Li, N. Thakor, A. Bezerianos, Y. Sun, **EEG cortical connectivity analysis of working memory reveals topological reorganization in theta and alpha bands**, *Front. Hum. Neurosci.*, vol. 11,pp 1-13, May 2017. https://doi.org/10.3389/fnhum.2017.00237
6. A. Mendrek, J. Monterosso, S. L. Simon, M. Jarvik, A. Brody, R. Olmstead, C. P. Domier, M. S. Cohen, M. Ernst, E. D. London, **Working memory in cigarette smokers: Comparison to non-smokers and effects of abstinence**, *Addict Behav*, vol 31, no. 5, pp 833-44, May 2006.
7. R. J. Moran, P. Campo, F. Maestu, R. B. Reilly, R. J. Dolan, and B. A. Strange, **Peak frequency in the theta and alpha bands correlates with human working memory capacity**, *Front. Hum. Neurosci.*, vol. 4, pp 1-11, Nov. 2010.
8. J. N. Mindoro, C. D.Casuat,A. S. Alon, M. A.Malbog, **Drowsy or not?Early drowsiness detection utilizing arduino based on electroencephalogram (EEG) neuro-signal**", International Journal of Advanced Trends in Computer Science and Engineering, vol 9, no. 2, pp 2221-2226, April 2020. https://doi.org/10.30534/ijatcse/2020/200922020
9. Z. Azavitra,S. I. Safie, M. I. Yusof, M. Aimullah, N. H. Ja'far, **Study of students' concentration in the classroom with quranic recitation background using electroencephalogram**, *International Journal of Advanced Trends in Computer Science and Engineering*, vol 1, pp 158-165, Feb. 2020. https://doi.org/10.30534/ijatcse/2020/2991.12020
10. S. Tiwari, D.Arora, P. Sharma, B. Bhardwaj, **Sleep disorder diagnosis through frequency based EEG energy level patterns**, *International Journal of Advanced Trends in Computer Science and Engineering*, Vol 9, Issue 2, pp 2036-2042, April 2020. https://doi.org/10.30534/ijatcse/2020/175922020
11. A. Alsufyani, R. Alroobaea, K. A. Ahmed, **Detection of single-trial EEG of the neural correlates of familiar faces recognition using machine-learning algorithms**,*International Journal of Advanced Trends in Computer Science and Engineering*, vol 8, issue 6, pp 2855-2860, Dec. 2019. https://doi.org/10.30534/ijatcse/2019/28862019

12. C.Berka, D. J. Levendowski,M. M. Cvetinovic,Miroslav M. Petrovic,Gene Davis,**Real-time analysis of EEG indexes of alertness, cognition, and memory acquired with a wireless EEG headset**, *Int. J. Hum. Comput. Interact.*, vol. 17, no. 2 **,**pp. 151–170, Jun 2010.
13. W. Klimesch, **EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis**, *Brain Res. Rev.*, vol. 29, no. 2–3, pp. 169–195, April 1999**.**
14. B. Schack, N. Vath, H. Petsche, H. G. Geissler, and E. Möller, **Phase-coupling of theta-gamma EEG rhythms during short-term memory processing**, *Int. J. Psychophysiol.*, vol. 44, no. 2, pp. 143–163, May 2002**.**
15. J. D. Cohen., W. M. Perlstein, T. S. Braver, L. E. Nystrom, D. C. Noll, J. Jonides, E. E. Smith, **Temporal dynamics of brain activation during a working memory task**, *Nature*, vol. 386, no. 6625, pp. 604–608, May 1997**.**
16. J. Jonides, S. C. Lacey, and D. E. Nee, **Processes of Working Memory in Mind and Brain**, *Curr. Dir. Psychol. Sci.*, vol. 14, no. 1, pp. 2–5, Feb. 2005**.**
17. N. Sribuathong, P. Sittiprapaporn, **Changes of brainwaves in Thai smokers indexed by the lightweight electroencephalography**, in *2nd Joint International Conference on Digital Arts, Media and Technology 2017: Digital Economy for Sustainable Growth*,Chiang Mai,2017**,** pp. 374–377.
18. J. E. Capó-Aponte, L. A. Temme, H. Lee Task, A. R. Pinkus, M. E. Kalich, A. J. Pantle, **Visual perception and cognitive performance,** in*Helmet-mounted displays: Sensation, Perception* and Cognition issues, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL, 2009, pp 335–390.
19. E. Clarence, S. Rash, Z. Abdullah and N. M. Ali, **Using moving and static rsvp presentation modes on children's digital flashcard**,in *Proceedings of International Conference on User Science and Engineering, i-USEr*,ShahAlam, 2011**,** pp. 95–99.
20. M. C. Potter, **Very short-term conceptual memory**, *Mem. Cognition*, vol. 21, no. 2, pp. 156–161, March 1993**.**
21. B. Kundu, D. W. Sutterer, S. M. Emrich, and B. R. Postle, **Strengthened effective connectivity underlies transfer of working memory training to tests of short-term memory and attention**, *J. Neurosci.*, vol. 33, no. 20, pp. 8705–8715, May 2013.
22. L. Marzetti, D. Mantini, S. Cugini, G. L. Romani, and C. del Gratta, ***High-resolution spatio-temporal neuronal activation in the visual oddball task: a simultaneous EEG/fMRI study***, in *2007 Joint Meeting of the 6th International Symposium on Noninvasive Functional Source Imaging of the Brain and Heart and the International Conference on Functional Biomedical Imaging*, Hangzhou, 2007, pp. 59–62. https://doi.org/10.1109/NFSI-ICFBI.2007.4387687
23. A. G. Reddy, S. Narava, **Artifact removal from EEG signals**, *Int. J. Comput. Appl.*, vol. 77, no. 13,pp. 17–19, Sept. 2013**.**