

**FRAGRANCE – EVOKE NEURAL DYNAMICS OF CALMNESS
AND WORKING MEMORY ASSESSED USING QUANTITATIVE
ELECTROENCEPHALOGRAPHY**

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MASTER OF SCIENCE

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AUTHOR DECLARATION

I affirm that all the work presented in this thesis is my original effort, except where references to quotations and summaries have been appropriately cited.

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ABSTRACT

This research explores the neurophysiological and cognitive effects of commercial fragrances by examining their chemical composition and their influence on calmness and working memory. Despite the widespread use of fragrances in daily life, their underlying neurological impacts remain underexplored, particularly those associated with changes in electroencephalographic (EEG) signals and cognitive performance. Twenty-four healthy male participants, with a mean age of 21.75 ± 2.15 years, were selected based on defined inclusion criteria and randomly assigned to four groups: Fragrance A, Fragrance B, Fragrance C, and a placebo. EEG recordings were taken before and after fragrance exposure using the Unicorn Hybrid 8-channel EEG system, with a focus on alpha and theta wave activity across key electrodes (Fz, Pz, PO7, PO8) to assess calmness-related neural responses. In parallel, cognitive effects were evaluated using the CogniFit digital platform, which tested non-verbal and visual short-term memory performance through accuracy scores and reaction times. Fragrance compositions were analysed using gas chromatography-mass spectrometry (GC-MS), allowing identification of key volatile compounds in each sample. Each fragrance demonstrated a unique chemical profile. Statistical analysis showed significant differences in EEG changes (mean difference = $+5.34\mu\text{V}^2/\text{Hz}$, $p = 0.008$, Cohen's $d = 1.70$) and memory score ($+2.67\%$, $p = 0.021$, Cohen's $d = 1.70$) across fragrance groups, specifically for Fragrance B. The findings suggest that specific chemical compounds, especially those with musky, floral, and sweet aromatic profiles, may enhance calmness and cognitive function via olfactory-neural pathways. This research contributes scientific evidence on how specific fragrance compounds influence brain activity and memory function. The findings have practical implications for the development of evidence-based aromatherapeutic products to enhance emotional regulation and cognitive performance, although the small sample size and male-only sample.

Keywords: Electroencephalography (EEG), GC-MS Analysis, Working Memory, Calmness, Alpha and Theta Waves.

ABSTRAK

Kajian ini meneroka kesan neurofisiologi dan kognitif daripada pendedahan kepada wangian komersial dengan menilai komposisi kimia dan pengaruhnya terhadap ketenangan serta prestasi memori. Meskipun wangian sering digunakan dalam kehidupan seharian, impak neurologi yang mendasarinya, terutamanya berkaitan perubahan gelombang EEG dan prestasi kognitif masih kurang diterokai secara saintifik. Dua puluh empat peserta lelaki sihat dengan purata umur 21.75 ± 2.15 tahun yang dipilih berdasarkan kriteria yang digariskan dan dibahagikan secara rawak kepada empat Kumpulan: Wangian A, Wangian B, Wangian C, dan kumpulan plasebo. Rakaman EEG telah dijalankan sebelum dan selepas pendedahan kepada wangian menggunakan sistem EEG Unicorn Hybrid 8-saluran, dengan fokus kepada aktiviti gelombang alpha dan theta pada elektrod utama (Fz, Pz, PO7, PO8). Pada masa yang sama, prestasi kognitif diukur melalui platform digital CogniFit yang menilai memori bukan lisan dan memori jangka pendek visual berdasarkan ketepatan dan masa tindak balas. Komposisi setiap wangian telah dianalisis menggunakan kaedah kromatografi gas-pemisahan jisim (GC-MS) untuk mengenal pasti sebatian kimia meruap utama. Setiap wangian menunjukkan profil kimia yang unik. Analisis statistik menunjukkan perbezaan dalam skor memori (+2.67%, $p = 0.021$, Cohen's $d = 1.70$), dan perubahan EEG (perbezaan min = $+5.34\mu V^2/Hz$, $p = 0.008$, Cohen's $d = 1.70$) antara kumpulan wangian, secara khususnya untuk Wangian B. Kajian ini menyumbang bukti saintifik mengenai bagaimana sebatian wangian tertentu mempengaruhi aktiviti otak dan fungsi memori. Dapatan kajian ini mempunyai implikasi praktikal dalam pembangunan produk aromaterapi berasaskan bukti untuk meningkatkan pengawalan emosi dan prestasi kognitif walaupun saiz sampel yang kecil dan tertumpu untuk subjek lelaki sahaja.

Kata Kunci: Elektroensefalografi (EEG), Analisis GC-MS, Ingatan Kerja, Ketenangan, Gelombang Alfa dan Teta.

الملخص

تستكشف هذه الدراسة التأثيرات العصبية-الفسولوجية والمعرفية للطور التجارية من خلال تحليل تركيبها الكيميائي وتأثيرها في مستوى الهدوء والذاكرة العاملة، إذ على الرغم من الانتشار الواسع لاستخدام العطور في الحياة اليومية، فإن تأثيراتها العصبية الكامنة لا تزال غير مستكشفة بصورة كافية، ولا سيما ما يرتبط بالتغيرات في إشارات تخطيط كهربية الدماغ (EEG) والأداء المعرفي. شملت الدراسة أربعة وعشرين مشاركاً من الذكور الأصحاء بمتوسط عمر بلغ 21.75 ± 2.15 سنة، تم اختيارهم وفق معايير إدراج محددة وتوزيعهم عشوائياً إلى أربع مجموعات: العطر (أ)، العطر (ب)، العطر (ج)، ومجموعة ضابطة (دواء وهمي). وتم تسجيل إشارات تخطيط كهربية الدماغ قبل التعرض للعطر وبعده باستخدام نظام Unicorn Hybrid ذي الثماني قنوات، مع التركيز على نشاط موجات ألفا وثيتا عبر الأقطاب الرئيسة Fz، Pz، PO7، PO8 لتقييم الاستجابات العصبية المرتبطة بالهدوء، كما تم تقييم التأثيرات المعرفية باستخدام المنصة الرقمية CogniFit لاختبار أداء الذاكرة غير اللفظية والذاكرة البصرية قصيرة المدى من خلال درجات الدقة وأزمنة الاستجابة، إضافةً إلى تحليل التركيب الكيميائي للعطور باستخدام تقنية الكروماتوغرافيا الغازية المقترنة بمطياف الكتلة (GC-MS) لتحديد المركبات المتطايرة الرئيسة في كل عينة، حيث أظهر كل عطر بصمة كيميائية مميزة. وأظهرت التحليلات الإحصائية فروقاً دالة في التغيرات المسجلة في تخطيط كهربية الدماغ) متوسط الفرق $+5.34 \mu V^2/Hz$ ، $p = 0.008$ ، $Cohen's d = 1.70$ وفي درجات الذاكرة $+2.67\%$ ، $p = 0.021$ ، $Cohen's d = 1.70$ بين مجموعات العطور، وبشكل خاص لصالح العطر (ب)، مما يشير إلى أن بعض المركبات الكيميائية المحددة، ولا سيما ذات الطابع العطري المسكي والزهري والحلو، قد تسهم في تعزيز الهدوء والوظيفة المعرفية عبر المسارات العصبية الشمية. وتقدم هذه الدراسة دليلاً علمياً على تأثير مركبات عطرية محددة في نشاط الدماغ ووظائف الذاكرة، مع دلالات تطبيقية لتطوير منتجات علاج عطري قائمة على الأدلة لتعزيز تنظيم الانفعالات والأداء المعرفي، رغم محدودية حجم العينة واقتصارها على الذكور.

الكلمات المفتاحية: تخطيط كهربية الدماغ (EEG)، تحليل GC-MS، الذاكرة العاملة، الهدوء، موجات ألفا وثيتا.

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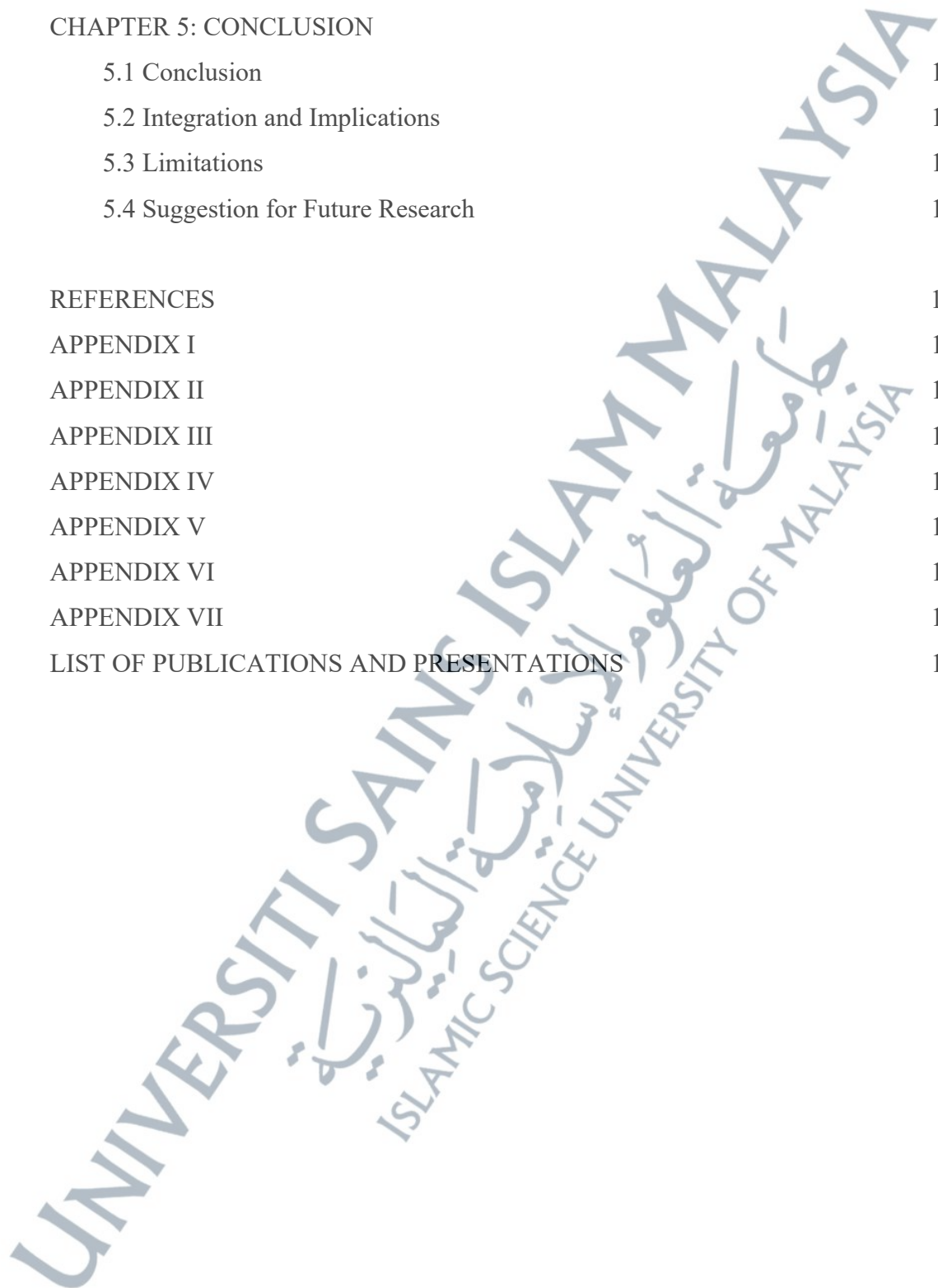
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1.1	$X(k) = \sum_{n=0}^{N-1} x(n) e^{-j2\pi kn/N}, k = 0, 1, \dots, N - 1$	61
1.2	$d_i = \text{Before}_i - \text{After}_i$	65
1.3	$\bar{d} = \frac{1}{n} \sum_{i=1}^n d_i$	66
1.4	$s_d = \sqrt{\frac{\sum (d_i - \bar{d})^2}{n - 1}}$	66
1.5	$SE = \frac{s_d}{\sqrt{n}}$	66
1.6	$t = \frac{\bar{d}}{SE}$	66
1.7	$d = \frac{\bar{d}}{s_d}$	66
1.8	$d = \frac{t}{\sqrt{n}}$	66

LIST OF ABBREVIATIONS

EEG	Electroencephalographic
GC-MS	Gas Chromatography-Mass Spectrometry
USIM	Universiti Sains Islam Malaysia
MMQ	Multifactorial Memory Questionnaire
FFT	Fast Fourier Transform
PPM	Parts Per Million
mg/m ³	Milligrams Per Cubic Meter
ACGIH	The American Conference of Governmental Industrial Hygienists
TLVs	Threshold Limit Values
IFRA	International Fragrance Association
PSD	Power Spectral Density
Hz	Hertz
μV ² /Hz	Microvolt Squared Per Hertz
Fz	Frontal Midline
Pz	Parietal Midline
PO7	Parieto-Occipital Left Hemisphere
PO8	Parieto-Occipital Right Hemisphere
ROI	Region of Interest