EFFECTS OF MENTAL FATIGUE AND RECOVERY THROUGH MUSIC ON STROKE PERFORMANCE AMONG TABLE TENNIS PLAYERS IN UNIVERSITY

By

DING CONG

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

March 2025

FPP 2025 4

DEDICATION

Dedicated With Love

To

My Beloved Wife,
My Angelic Daughter.
My Dear Parents, Sisters, and Brothers

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

EFFECTS OF MENTAL FATIGUE AND RECOVERY THROUGH MUSIC ON STROKE PERFORMANCE AMONG TABLE TENNIS PLAYERS IN UNIVERSITY

By

DING CONG

March 2025

Chairman : Professor Soh Kim Geok, PhD
Faculty : Educational Studies

Mental fatigue (MF) is a psychobiological state induced by prolonged cognitive tasks. MF is known to affect athletes' performance in both cognitive and physical domains; however, its effects on table tennis stroke performance and psychological factors, as well as the effects of music recovery in mitigating these effects, remain unexplored. Thus, the aim of this study is to examine the effects of MF and music recovery on these variables. This study employed a pre-and post-test design using cluster randomised controlled trials. A total of 64 university table tennis players (n = 16 per group), aged 18 to 24 years, were recruited into four groups: fatigue music group (FMG), fatigue no music group (FNMG), fatigue control music group (FCMG), and fatigue control no music group (FCNMG). Table tennis stroke performance test and psychological factors measurements were employed in the four groups at baseline test, post-test 1 and post-test 2. In the first intervention, an incongruent Stroop task was administered to FMG and FNMG, while a congruent Stroop task was used in FCMG and FCNMG. In the second intervention, FMG and FCMG listened to the "Dreaming"

music piece, looped twice for 8.48 minutes, with a black screen displayed. Meanwhile, FNMG and FCNMG were instructed to sit and relax with a black screen.

The results from the Generalised Estimation Equations (GEE) indicated that the Stroop task significantly induced MF feeling (MD=-4.338, P<0.001). MF affected psychological factors such as negative emotion (MD=0.688, P<0.05); attention focusing (MD=2.500, P<0.001); attention shifting (MD=2.250, P<0.05); scope of attention (MD=1.750, P<0.001); thought-action repertoire (M=1.563, P<0.05); rate of perceived exertion (RPE) (MD=-1.375, P<0.001), and motivation (MD=1.163, P<0.001). Additionally, MF affected stroke performance in terms of stroke accuracy (MD=3.500, P<0.05), fault numbers (MD=-2.563, P<0.001), and total scores (MD=6.063, P<0.001). However, MF did not significantly affect positive emotion (MD=0.625, P=0.104) or stroke performance in speed (MD=0.663, P=0.412). On the other hand, music recovery mental fatigue by counteracting the MF feeling (MD=2.313, P<0.001), psychological factors of positive emotion (MD=-2.750, P<0.001); negative emotion (MD=0.938, P<0.001); attention-focusing (MD=-1.375, P<0.05); attention shifting (MD=-1.938, P<0.001); scope of attention (MD=-1.063, P<0.05), thought-action repertoire (MD=-1.375, P<0.05), RPE (MD=-1.813, P<0.001) and motivation (MD=-0.769, P <0.001). Meanwhile, music counteracted the stroke performance decrement in stroke accuracy (MD=-4.188, P<0.001), the fault numbers (MD=3.375, P<0.001), and the total score decrement (MD=-7.563, P<0.001). However, music did not significantly affect ball speed (MD=1.113, P=0.088).

These findings were aligned with theories of the Strength Model of Self-Regulation, the improved Psychobiological Model of Endurance Performance and Broaden Effects.

Table tennis players' stroke accuracy, including accuracy numbers, fault numbers, total scores, and psychological factors, was affected by mental fatigue. Meanwhile, music may serve as an effective recovery strategy by counteracting the adverse effects of mental fatigue on stroke performance and underlying psychological factors. The coaches and table tennis players should avoid prolonged cognitive task exposure (e.g. smartphone use before the competition) under MF conditions. On the other hand, if MF occurred, music could be an effective recovery method to counteract the stroke performance decrements.

Keywords: Mental fatigue, music, table tennis, stroke performance, theories

SDG: GOAL 3: Good Health and Well-Being

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN KELETIHAN MENTAL DAN PEMULIHAN MUZIK TERHADAP PRESTASI PUKULAN DI KALANGAN PEMAIN TENIS MEJA UNIVERSITI

Oleh

DING CONG

Mac 2025

Pengerusi : Profesor Soh Kim Geok, PhD
Fakulti : Pengajian Pendidikan

Keletihan mental (MF) adalah keadaan psikobiologi yang disebabkan oleh tugas kognitif yang berpanjangan. MF diketahui mempengaruhi prestasi atlet dalam domain kognitif dan fizikal; namun, kesannya terhadap prestasi pukulan dalam permainan pingpong dan faktor psikologi, serta kesan pemulihan melalui muzik dalam mengurangkan kesan tersebut, masih belum diterokai. Oleh itu, tujuan kajian ini adalah untuk mengkaji kesan MF dan pemulihan melalui muzik terhadap pembolehubah-pembolehubah ini. Kajian ini menggunakan reka bentuk pra dan pasca ujian dengan ujian terkawal rawak berkelompok. Seramai 64 pemain ping pong universiti (n = 16 setiap kumpulan), berumur 18 hingga 24 tahun, telah direkrut ke dalam empat kumpulan: kumpulan muzik keletihan (FMG), kumpulan tanpa muzik keletihan (FNMG), kumpulan muzik kawalan keletihan (FCMG), dan kumpulan tanpa muzik kawalan keletihan (FCNMG). Ujian prestasi pukulan ping pong dan ukuran faktor teori telah dijalankan ke atas empat kumpulan pada ujian asas, ujian pasca 1 dan ujian pasca 2. Dalam intervensi pertama, tugas *Stroop* tidak sepadan diberikan

kepada FMG dan FNMG, manakala tugas *Stroop* sepadan digunakan pada FCMG dan FCNMG. Dalam intervensi kedua, FMG dan FCMG mendengar muzik "Dreaming", yang dimainkan dua kali selama 8.48 minit dengan paparan skrin hitam. Sementara itu, FNMG dan FCNMG diarahkan untuk duduk dan berehat dengan paparan skrin hitam.

Hasil dapatan daripada Persamaan Anggaran Umum (GEE) menunjukkan bahawa tugas *Stroop* secara signifikan menginduksi perasaan MF (MD=-4.338, P<0.001). MF memberi kesan kepada faktor teori seperti emosi negatif (MD=0.688, P<0.05); tumpuan perhatian (MD=2.500, P<0.001); pengalihan perhatian (MD=2.250, P<0.05); skop perhatian (MD=1.750, P<0.001); repertoir pemikiran-tindakan (M=1.563, P<0.05); kadar usaha yang dirasakan (RPE) (MD=-1.375, P<0.001), dan motivasi (MD=1.163, P<0.001). Selain itu, MF mempengaruhi prestasi pukulan dari segi ketepatan pukulan (MD=3.500, P<0.05), bilangan kesilapan (MD=-2.563, P<0.001), dan jumlah skor (MD=6.063, P<0.001). Walau bagaimanapun, MF tidak memberi kesan yang signifikan terhadap emosi positif (MD=0.625, P=0.104) atau prestasi pukulan dari segi kelajuan (MD=0.663, P=0.412). Sebaliknya, muzik mengurangkan keletihan mental dengan menentang perasaan MF (MD=2.313, P<0.001), faktor psikologi seperti emosi positif (MD=-2.750, P<0.001); emosi negatif (MD=0.938, P<0.001); tumpuan perhatian (MD=-1.375, P<0.05); pengalihan perhatian (MD=-1.938, P<0.001); skop perhatian (MD=-1.063, P<0.05); repertoir pemikiran-tindakan (MD=-1.375, P<0.05), RPE (MD=-1.813, P<0.001) dan motivasi (MD=-0.769, P<0.001). Sementara itu, muzik menentang penurunan prestasi pukulan dari segi ketepatan pukulan (MD=-4.188, P<0.001), bilangan kesilapan (MD=3.375, P<0.001), dan penurunan jumlah skor (MD=-7.563, P<0.001). Walau bagaimanapun, muzik

tidak memberi kesan yang signifikan terhadap kelajuan pukulan (MD=1.113, P=0.088).

Prestasi pukulan ping pong dari segi ketepatan, bilangan kesilapan, jumlah skor, dan faktor teori yang mendasarinya dalam kalangan pemain universiti dipengaruhi oleh keletihan mental. Sementara itu, muzik boleh menjadi strategi pemulihan yang berkesan untuk mengatasi kesan buruk keletihan mental terhadap prestasi pukulan dan faktor teori yang mendasarinya. Jurulatih dan pemain ping pong seharusnya mengelakkan pendedahan kepada tugas kognitif yang berpanjangan (seperti penggunaan telefon pintar sebelum pertandingan) dalam keadaan MF. Sebaliknya, jika MF berlaku, muzik boleh menjadi kaedah pemulihan yang berkesan untuk menentang penurunan prestasi pukulan.

Kata Kunci: Keletihan mental, muzik, pingpong, prestasi pukulan, teori-teori

SDG: MATLAMAT 3: Kesihatan yang Baik dan Sejahtera

ACKNOWLEDGEMENTS

My PhD journey has been an extraordinary chapter of my life, filled with invaluable lessons and discoveries. I am immensely grateful to the university for providing a nurturing platform where my dreams could take flight.

I sincerely thank my supervisor, Professor Dr. Soh Kim Geok, whose guidance was a beacon of light throughout this journey. Her patience, positivity, and insightful feedback refined my work and encouraged me always to chase my dreams. Working under her supervision has been one of the great honors of my life. I also sincerely thank Professor Dr. Samsilah Binti Roslan, whose expertise and advice have greatly enriched my work. Additionally, a special mention to my brother, Dr. Sun He, for introducing me to the fascinating world of sports psychology and for his unwavering support in times of challenge.

To my wife, daughter, parents, brothers, and sisters - thank you for being my steadfast lighthouses. Your unwavering faith and love have illuminated my path through the most challenging times. Lastly, I am grateful to all my friends, colleagues, and participants whose enthusiasm and support have been crucial in this pursuit. Your contributions have left a lasting imprint on my heart. Thank you all for being part of this unforgettable journey. Here’s to chasing dreams and making them a reality.

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Soh Kim Geok, PhD
Professor
Faculty of Educational Studies
Universiti Putra Malaysia
(Chairman)

Samsilah binti Roslan, PhD
Professor
Faculty of Educational Studies
Universiti Putra Malaysia
(Member)

____

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 8 May 2025

TABLE OF CONTENTS

	Page
ABSTRACT	i
ABSTRAK	iv
ACKNOWLEDGEMENTS	vii
APPROVAL	viii
DECLARATION	x
LIST OF TABLES	xv
LIST OF FIGURES	xviii
LIST OF APPENDICES	xx
LIST OF ABBREVIATIONS	xxi

CHAPTER

1	**INTRODUCTION**			1
	1.1	Background		1
		1.1.1	Psychobiological State of Mental Fatigue and Sports Performance	4
		1.1.2	Music and Its' Benefits on Sports Performance	6
	1.2	Problem Statement		10
	1.3	Objective of the Study		14
		1.3.1	General Objectives	14
		1.3.2	Specific Objectives	15
	1.4	Hypothesis		15
		1.4.1	General Hypothesis	15
		1.4.2	Specific Hypothesis	16
	1.5	Significance of the Study		18
		1.5.1	Theoretical Significance	18
		1.5.2	Practical Significance	20
	1.6	Delimitation of Study		21
		1.6.1	Population Delimitation	21
		1.6.2	Measurement Delimitation	21
		1.6.3	Intervention Delimitation	22
	1.7	Limitations of Study		23
		1.7.1	Limitation of the First Intervention	23
		1.7.2	Limitation of the Second Intervention	25
	1.8	Definition of Terms		26
		1.8.1	Mental Fatigue	27
		1.8.2	Music	27
		1.8.3	Stroke Performance	28
		1.8.4	Table Tennis Players	29
2	**LITERATURE REVIEW**			30
	2.1	Terminology of Mental Fatigue		30
	2.2	The Effects of Mental Fatigue		31
		2.2.1	Effects of Mental Fatigue on Physical Performance	31

	2.2.2	Effects of Mental Fatigue on Cognitive Performance	33
	2.2.3	Effects of Mental Fatigue on Performance of Racket Sports Based on a Systematic Review	35
2.3		The Inducement of Mental Fatigue	37
2.4		The Manifestations of Mental Fatigue	39
2.5		The Strategies to Counteract Mental Fatigue	40
	2.5.1	Physiological Strategies Counteract Mental Fatigue	40
	2.5.2	Psychological Strategies Counteract Mental Fatigue	42
	2.5.3	Behavioural Strategies Counteract Mental Fatigue	43
	2.5.4	Music Counteracts Mental Fatigue Based on Systematic Review	45
2.6		Theoretical Framework	48
	2.6.1	The Introduction of Three Theories	48
	2.6.2	Framework Establishment	53
2.7		Conceptual Framework	55

3	**METHODOLOGY**			57
	3.1	Overview		57
	3.2	Study Design		57
	3.3	Subjects		58
		3.3.1	Population and Sampling	58
		3.3.2	Sample Size	60
		3.3.3	Inclusion and Exclusion Criteria	64
	3.4	Research Instruments		65
		3.4.1	Measurement of Dependent Variables	67
		3.4.2	Measurement of Control Variables	71
	3.5	Developed the Intervention		73
		3.5.1	First Intervention for Inducing Mental Fatigue	74
		3.5.2	Second Intervention: Listening to Music Recovery from Mental Fatigue	75
	3.6	Control the Covariant		78
	3.7	Validation for the Protocol		79
		3.7.1	Validity of the Intervention	79
		3.7.2	Validity of the Measurements	80
	3.8	Pilot Study		81
		3.8.1	Testing the Reliability of the Instruments	82
		3.8.2	Testing the Feasibility of Experimental	82
	3.9	Data Collection Procedures		83
		3.9.1	Data Collection Permission by the Ethics Committee	83
		3.9.2	Data Collection Permission by Participants	84
		3.9.3	Data Collection Procedure in Real Experimental	84
		3.9.4	Measurement Procedures	85
	3.10	Statistical Analyses		87
4	**RESULTS**			89
	4.1	Introduction		89
	4.2	Test of Assumptions		89

4.2.1 Normality Test 90
4.2.2 Homogeneity Test of Variances 91
4.2.3 Equality of Groups at Baseline 97
4.3 Inferential Statistics 101
4.3.1 First Objective of Mental Fatigue Feelings 101
4.3.2 Second Objective of Positive and Negative Emotion 107
4.3.3 Third Objective of Attention Control 117
4.3.4 Fourth Objective of the Scope of Attention 126
4.3.5 Fifth Objective of Thought-Action Repertoire 131
4.3.6 Sixth Objective of Stroke Accuracy 137
4.3.7 Seventh Objective of Ball Speed 150
4.3.8 Checking Secondary Outcome of RPE and Motivation 155
4.4 Summary of the Result 165

5 DISCUSSION, CONCLUSION, IMPLICATION, AND RECOMMENDATION FOR FUTURE STUDY 166
5.1 Introduction 166
5.2 Discussion 166
5.2.1 Discussion on Mental Fatigue Feeling 167
5.2.2 Discussion on Positive and Negative Emotions 169
5.2.3 Discussion on Attention Control of Attention Focusing and Attention Shifting 171
5.2.4 Discussion on the Scope of Attention 173
5.2.5 Discussion on Thought-Action Repertoire 174
5.2.6 Discussion on Stroke Accuracy 176
5.2.7 Discussion on Ball Speed 178
5.3 Conclusion 180
5.4 Implications 180
5.4.1 Theoretical Implication 181
5.4.2 Practical Implication 182
5.5 Recommendations for Future Study 183

REFERENCES 185
APPENDICES 203
BIODATA OF STUDENT 240
LIST OF PUBLICATIONS 241

LIST OF TABLES

Table		Page
3.1	Effect Size Calculation for the Variables of This Study	61
3.2	Summary of Research Instrument	66
3.3	Interventions among Four Groups in the Two Phased	74
3.4	Top 5 Music Lists	76
3.5	Scoring of Emotion Induced by Music	76
3.6	List of Panels of Experts	79
3.7	Results of Reliability	83
3.8	Data Collection Procedures	84
3.9	The Statistical Analysis for Each Hypothesis	88
4.1	Normality Test of the Demographic Characteristics, Confounding Variables and Dependent Variables	92
4.2	Mean Comparison among Groups for the Demographic Information, Confounding and Dependent Variables at Baseline Test	100
4.3	Descriptive Statistics (Mean, SE) for MF Feelings	102
4.4	Results of GEE on MF Feeling	103
4.5	Pairwise Comparison of MF Feeling (within group)	105
4.6	Pairwise Comparison of MF Feeling (between groups)	106
4.7	Descriptive Statistics (Mean, SE) for Positive and Negative Emotion Scores	108
4.8	Results of GEE on Positive and Negative Emotion Score	109
4.9	Pairwise Comparison of Positive and Negative Emotion (within group)	111
4.10	Pairwise Comparison of Positive and Negative Emotion (between groups)	114
4.11	Descriptive Statistics (Mean, SE) for Attention Focusing and Attention Shifting	117
4.12	Results of GEE on Attention Focusing, and Attention Shifting	119

4.13	Pairwise Comparison of Attention Focusing and Attention Shifting Score (within group)	121
4.14	Pairwise Comparison of Attention Focusing and Attention Shifting Score (between groups)	123
4.15	Descriptive Statistics (Mean, SE) for Scope of Attention	127
4.16	Results of GEE on the Scope of Attention Score	128
4.17	Pairwise Comparison of Scope of Attention (within group)	129
4.18	Pairwise Comparison of Scope of Attention (between groups)	130
4.19	Descriptive Statistics (Mean, SE) for Thought-Action Repertoire	132
4.20	Results of GEE on Thought-Action Repertoire Score	133
4.21	Pairwise Comparison of Thought-Action Repertoire (within group)	134
4.22	Pairwise Comparison of Thought-Action Repertoire (between groups)	135
4.23	Descriptive Statistics (Mean, SE) for Stroke Accuracy Numbers, Faults Numbers and Total Score	138
4.24	Results of GEE on Accuracy Numbers, Fault Numbers and Total Score	139
4.25	Pairwise Comparison of Accuracy Numbers, Faults Numbers and Total Score (within group)	142
4.26	Pairwise Comparison of Accuracy Numbers, Faults Numbers and Total Numbers (between Groups)	146
4.27	Descriptive Statistics (Mean, SE) for Ball Speed	151
4.28	Results of GEE on Table Tennis Players' Ball Speed	152
4.29	Pairwise Comparison of Ball Speed (within Group)	153
4.30	Pairwise Comparison of Ball Speed (between Groups)	154
4.31	Descriptive Statistics (Mean, SE) for RPE Score	156
4.32	Results of GEE on RPE Score	156
4.33	Pairwise Comparison of RPE (within Group)	158
4.34	Pairwise Comparison of RPE (between Groups)	159
4.35	Descriptive Statistics (Mean, SE) for Motivation	160
4.36	Results of GEE on Motivation	161

4.37 Pairwise Comparison of Motivation (within group) 162

4.38 Pairwise Comparison of Motivation (between groups) 164

LIST OF FIGURES

Figure		Page
2.1	The Strength Model of Self-Regulation	50
2.2	Psychobiological Model of Endurance Performance	52
2.3	The Broaden Effect of Broaden-and-Build Theory	53
2.4	Theoretical Framework of This Study	55
2.5	The Conceptual Framework of this Study	56
3.1	Sample Size Calculation Based on the Repeated Measure within-between Interaction	62
3.2	Example Item of Global-Local Visual Processing task	69
3.3	Scoring of Emotion Induced by Music	77
4.1	The Mean Scores Changes of Mental Fatigue Feelings across the Times among Groups	107
4.2	The Mean Scores Changes of Positive Emotion across the Times among Groups	116
4.3	The Mean Scores Changes of Negative Emotion across the Times among Groups	116
4.4	The Mean Scores Changes of Attention Focusing across the Times among Groups	125
4.5	The Mean Scores Changes of Attention Shifting across the Times among Groups	126
4.6	The Mean Scores Changes of Scope of Attention across the Times among Groups	131
4.7	The Mean Scores Changes of Thought-Action Repertoire across the Times among Groups	136
4.8	The Mean Scores Changes of Accuracy Numbers across the Times among Groups	149
4.9	The Mean Scores Changes of Fault Numbers across the Times among Groups	149
4.10	The Mean Scores Changes of Total Scores across the Times among Groups	150

4.11 The Mean Scores Changes of Ball Speed across the Times among Groups 155

4.12 The Mean Scores Changes of RPE across the Times among Groups 160

4.13 The Mean Scores Changes of Motivation across the Times among Groups 165

LIST OF APPENDICES

Appendix		Page
A	Systematic Review of Effects of Mental Fatigue on Racket Sports	203
B	Systematic Review of Effects of Music on Counteract Mental Fatigue	206
C	Stroop Task	210
D	Visual Analogue Scale for Mental Fatigue	213
E	Emotion Report Forms	215
F	Items of the Attentional Control Scale	217
G	Global-Local Processing Task	219
H	Twenty Statements Test (B. L. Fredrickson & C. Branigan, 2005)	223
I	Borg RPE Scale	225
J	Visual Analogue Scale for Motivation	227
K	Revised Competitive State Anxiety–2 (CSAI-2R)	229
L	Brief Self-Control Scale	231
M	Instruments of Measuring Table Tennis Ball Speed and Accuracy	233
N	RPE Permission	234
O	Ethics Committee Permission	236
P	Validity of the Intervention	237
Q	Validity of the Measurement	238
R	Homogeneity Test of Variances at Baseline Test	239

LIST OF ABBREVIATIONS

MF	Mental Fatigue
FMG	Fatigue Music Group
FNMG	Fatigue No Music Group
FCMG	Fatigue Control Music Group
FCNMG	Fatigue Control No Music Group
VAS-mf	Visual Analogue Scale for mental fatigue
VAS-Mo	Visual Analogue Scale for Motivation
ACS	Attention Control Scale
BSCS	Brief Self Control Scale
CSAI-2	Competitive State Anxiety Inventory-2
ICC	Intraclass Correlation Coefficient
GEE	Generalised Estimation Equations

CHAPTER 1

INTRODUCTION

1.1 Background

Table tennis is well known as "Ping-Pong"; the charm of table tennis attracts people all around the world. There are over 220-member nation associations in the International Table Tennis Federation (ITTF), and more than 300 million people worldwide regularly play table tennis, making it one of the most popular sports in the world (Weikert et al., 2014). People who play table tennis range from 8 to 80 years old; it is named the "lifetime" sport (McAfee, 2009). The benefits for children playing table tennis could be it's the best sport for the development of eye-hand coordination, and this is significant for further physical development. The table tennis competitions varied from local to Olympic games (McAfee, 2009).

The role of table tennis in China extends far beyond the boundaries of the sport itself; when Beijing hosted the 2008 Summer Olympic Games, it was not only a showcase of China's organisational capabilities but also a testament to the country's longstanding pursuit of Olympic glory (Chen et al., 2015; Lee & Tan, 2011). This aspiration has deeply influenced the development of competitive sports in China, with table tennis, often referred to as China's national sport, receiving the utmost attention (Chen et al., 2015; Zhang, 2018). Table tennis has been a critical element in China's strategy to achieve international recognition and status. The significance of table tennis in China transcends mere athletic achievement. Between 1988 and 2012, Chinese table tennis players amassed an impressive total of 47 Olympic medals; this success has cemented table tennis as a symbol of national pride and a powerful tool in elevating China’s global standing (Chen et al., 2015).

The concept of “ping-pong diplomacy” in the early 1970s epitomised this notion, as it played a crucial role in improving China’s international relations (Chen et al., 2015; Hong & Sun, 2000). The phrase “a small ball turning the big ball” describes how table tennis facilitated China’s re-entry into global diplomatic arenas, including its membership in the United Nations and its return to the International Olympic Committee (IOC) (Chen et al., 2015). The continued dominance of Chinese players in table tennis has occasionally sparked concerns about a “Chinese monopoly” (Chen et al., 2015). These concerns led the ITTF to implement various changes to the sports’ equipment standards, rules, and competition format to level the playing field and reduce China’s dominance in international competition, even though Chinese table tennis players Fan Zhendong, Wang Chuqin and Ma Long are ranked in the world’s Top three by ITTF. These excellent players have performed in international competitions and contributed to China’s dominance in table tennis worldwide (Chen et al., 2015).

China’s table tennis history has seen moments of vulnerability despite its dominance. The departure of elite players resulted in the men’s team winning only silver medals in 1991 and 1993, two consecutive world table tennis championships (Chen et al., 2015). Additionally, at the 1988 Seoul Olympic games, the first time table tennis was featured as an Olympic sport, Chinese players did not secure any top three positions in the men’s single category (Chen et al., 2015). Even in the 2020 Tokyo Olympics, Chinese mixed doubles Xu Xin & Liu Shiwen showed a loss to Japanese players Jun

Mizutani & Mima Ito (International Table Tennis Federation), leading to Chinese players facing fierce threats to hold first place worldwide. These setbacks affected the Chinese glory of competition and weakened the strategic use of sports to enhance international status as China's "ping-pong diplomacy".

Table tennis is not only with rich historical and cultural roots but also a high demanding activity that requires rapid decision-making, precise motor control, and sustained attention during fast-paced rallies. In high-level table tennis, players are frequently required to engage in sustained rallies, make quick decisions under pressure, and continuously adapt their strategies to counter diverse opponent tactics. These game-play situations impose significant cognitive loads, which can lead to mental fatigue. On the other hand, Table tennis is a fast-paced and highly strategic sport where stroke performance plays a crucial role in determining the outcomes of matches (Zhang et al., 2023). Executing precise and powerful strokes under varying competitive pressures is essential for success at all levels of play (Raab et al., 2005). Meanwhile, ball speed and accuracy are the two relevant technical parameters to describe stroke performance in table tennis (Girard & Millet, 2009; Mansec et al., 2016). High ball speeds can overwhelm opponents, reducing their reaction time and increasing the likelihood of forced errors (Rodrigues et al., 2002). Meanwhile, accuracy ensures that strokes are well-placed, targeting opponents' weak sports and maximising the strategic impact of each shot (Mansec et al., 2016). However, recent investigations reported that table tennis stroke performance is impaired by mental fatigue (Mansec et al., 2018).

1.1.1 Psychobiological State of Mental Fatigue and Sports Performance

Successful performance in table tennis may not solely depend on proficient movement control (Wong et al., 2020) but also involve cognitive control (Huang et al., 2024). The prolonged duration of cognitive control tasks could lead to a psychobiological state of mental fatigue (Filipas et al., 2024). Mental fatigue is a psychobiological state induced by prolonged cognitive tasks and accompanied by subjective feelings of "tiredness and lack of energy" (Boksem & Tops, 2008). Mental fatigue detrimentally affects cognitive and physical performance in daily life. It impacts productivity (O'Neill et al., 2013) and potentially elevates the risk of traffic accidents (Borghini et al., 2012), leading to significant adverse effects on human well-being (Guglielmi et al., 2012). Even during the COVID-19 pandemic, mental fatigue impaired the lockdown individuals' psychological symptoms (Torrente et al., 2022).

In recent years, investigations on mental fatigue have converted into sports domains. Marcora et al. (2019) reported that mental fatigue increased subjective fatigue, and people under mental fatigue conditions increased perceived exertion and decreased motivation. People with mental fatigue manifested increased reaction time and elevated reaction accuracy in cognitive performance (Migliaccio et al., 2022). The performance decrement was impaired by mental fatigue, not only in cognitive performance, but the physical performance was also impaired by mental fatigue. Marcora et al. found that individuals experienced time-to-exhaustion cycling with 80% of the peak power output decreased by 15% in time to exhaustion due to mental fatigue (Marcora et al., 2009). Pageaux et al. and Macmahon et al. instructed participants to conduct self-paced running; participants increased by 5% in 5 km and 2% in 3 km under mental fatigue conditions (MacMahon et al., 2014; Pageaux et al., 2014).

Furthermore, Mangin et al. found participants produced a target value of 20% MCV until exhaustion, and the time to exhaustion was 13% shorter in mental fatigue conditions (Mangin et al., 2021).

Although physical performance provides the foundation for sports outcomes, skill performance provides the directed effects that determine sports performance (Iso-Ahola, 2024). Mental fatigue impaired skill performance in soccer, basketball, table tennis, tennis and padel (Ding et al., 2024; Sun et al., 2021a). Smith et al. examined the mental fatigue of 12 moderately trained soccer players; the penalty time, passing, shot speed and accuracy were impaired by mental fatigue (Smith et al., 2016). Filipas et al. (2021) reported basketball free-throw performance was impaired by mental fatigue. Mansec et al. found that mental fatigue led to table tennis players' decreased speed by 2.2%, decreased accuracy by 6.7%, and increased faults by 5.4% in stroke performance (Mansec et al., 2018). The stroke performance was also observed in tennis and padel accuracy; Filipas et al. found tennis serve accuracy from the deuce side was impaired by mental fatigue (Filipas et al., 2024). Díaz-García et al. found that mental fatigue impaired padel stroke performance on drive, volley, bandeja, and drive attack (Díaz-García et al., 2024). These studies examined the effects of mental fatigue on cognitive, physical, and skill performance in sports. However, the underlying mechanism of the performance reduction impaired by mental fatigue still needs to be explored.

Beyond affecting physical performance, mental fatigue influences several psychobiological and cognitive dimensions that are critical during competitive play. Mental fatigue may alter emotional responses by increasing negative emotions and diminishing positive emotions, thereby affecting a player's confidence and resilience. Attention-related processes are also compromised. Mental fatigue narrows the scope of attention and reduces the ability to shift focus among multiple stimuli, such as the ball, the opponent's movement, and one's own positioning. This impairment in attention focusing and shifting can limit the thought-action repertoire, which in turn heightens the Rating of Perceived Exertion (RPE) and undermines motivation during play. Boksem and Tops (2008) have argued that mental fatigue restricts cognitive control, leading to a reduction in the executive functions that govern these processes. Additionally, theoretical perspectives presented by Hockey et al. (2013) suggest that a diminished capacity for cognitive control in fatigued individuals results in a cascade of effects on both performance and motivational states.

1.1.2 Music and Its' Benefits on Sports Performance

"Music is the sounds of human bodies and minds moving in creative, story-making ways" (Malloch & Trevarthen, 2018). Music is an intrinsic part of human culture and experience, deeply intertwined with the fabric of everyday life. Throughout history, music has been resented in every known human society, playing a crucial role in rituals, celebrations, communication, and personal expression (Miell et al., 2005; Turino, 2008). Almost every significant event cannot leave the music. For example, every time the Olympic Games have a theme song, it is well-known the theme song "You and Me" in China Olympic Games 2008 music aimed to emphasise unity, friendship, and the shared experience of the global community coming together for the Olympic Games widely spread all around the world (Kim & Kim, 2016), and "This Time for Africa" as the official song of the 2010 FIFA world cup held in South Africa became immensely popular worldwide and is often associate with globe sporting events due to its energetic and unifying theme (Hammond, 2012). No wonder, as the philosopher Nietzsche. Said, “Without music, life would be a mistake” (Krallmann, 2016). Not only the ceremonies of the significant events, but the music had already deeply immersed into people’s daily lives; it’s expected to find music in the coffee café and passengers listening to music with their earphones on the train - active people jogging with the energetic music (Sakata et al., 2006). Modern society has applied music as a specific therapy to assist in curing Alzheimer’s disease (Leggieri et al., 2019), assist patients with Dementia (Vink et al., 2003), and help patients with Parkinson’s disease (Pereira et al., 2019). Music was also applied to reduce pain and anxiety during labour (Santiváñez-Acosta et al., 2020).

Music is not only related to human life but also benefits human bodies. Some psychologists suggest music can significantly benefit both cognition and emotion. Juslin and Västfjäll demonstrate that music could evoke a wide range of emotional responses, from joy an excitement to sadness and nostalgia (Juslin, 2016; Juslin et al., 2008; Juslin & Västfjäll, 2008). These emotional experiences are facilitated by music’s ability to engage the brain’s reward system, release neurotransmitters like dopamine, and modulate the emotional state (Ferreri et al., 2019; Menon & Levitin, 2005). Consequently, music is often used therapeutically to manage stress, anxiety, and depression, showcasing its profound influence on mental fatigue (Kemper & Danhauer, 2005; Labbé et al., 2007; Moradipanah et al., 2009). Neurologists suggest music engages multiple brain areas, illustrating its complex and integrative nature. Studies utilising neuroimaging techniques have shown that listening to and performing music activates regions involved in auditory processing, motor control, and emotion regulation (Altenmüller et al., 2006; Moore, 2013). This extensive neural involvement indicated that music processing is a multifaceted activity encompassing sensory, cognitive, and emotional domains.

Moreover, music is also profound in the context of sports. Studies investigating music on sports performance could be retrieved in 1911; Ayres found the speed was increased by 8.5% faster in six-day cycling when listening to a military band (Ayres, 1911; Karageorghis, 2020). The impact of music on sports domains is varied in terms of psychological, psychobiological, physical, and skill performance (Akhshabi & Rahimi, 2021). Psychological benefits include enhanced affective response and flow and reduced anxiety (Davis & Thaut, 1989; Guyon et al., 2022; Moral-Bofill et al., 2022), and psychophysical benefits on the reduced rating of perceived exertion (Potteiger et al., 2000). Physiological benefits include improved physiological efficiency and strength, speed, and endurance performance. For example, the benefits of music improved endurance performance. Chtourous et al. (2012) found that male sprinters listening to music during warm-up increased the anaerobic performance of relative peak power and relative mean power. As for the psychophysical benefits, some studies applied the "dissociation effects" of music; Arazi et al. found that trained men listening to music during warm-up significantly decreased the perceived exertion (Arazi et al., 2015). As the effects proposed as "ergogenic effects", listening to music improved performance in strenuous motor tasks such as treadmill walking and 400 m treadmill running (Karageorghis et al., 2009; Simpson & Karageorghis, 2006).

Meanwhile, music influences affective and emotional responses. The brain stem reflex refers to the process by which the fundamental acoustic properties of music stimulate responses by signalling a potentially important or urgent event (Juslin & Västfjäll, 2008). For example, fast, loud music automatically simulates the listener by activating the central nervous system (Juslin & Västfjäll, 2008; Robinson, 1995). This stimulation results in elevated heart rate, blood pressure, body temperature, skin conductance, and muscle tension (Itao et al., 2018). Soft, slow music has the converse effect and thus decreases sympathetic arousal; such relaxing music often mimics the soothing sounds found in nature (Menen, 2004; O'Driscoll, 2019).

Besides "ergogenic effects" to improve performance and "dissociation effects", music also benefits recovery. However, applied music as a recovery strategy remained scarce; Jing and Xudong (2008) reported that 15-minute music effectively reduced heart rates, urinary protein, and perceived exertion after cycle ergometer until fatigue. Eliakim et al. found music during nonstructured recovery from intense exercise leads to increased activity, faster lactate clearance and decreased perceived exertion (Eliakim et al., 2012). Jones et al. (2017) reported music applied during the recovery period engenders a more pleasant experience during high-intensity interval training. Jia et al. (2016) suggested listening to music attenuated decreased parasympathetic nervous system activity after exercise. The efficacy of music induces a range of physiological changes involving respiration, heart rate, skin conductance, motor patterns, neuroendocrine response, and immunological function (Hodges, 2009). Although music benefits and promotes recovery from exercise, the studies investigating music for recovery still require further research to enhance the understanding of its application in sports recovery.

1.2 Problem Statement

Although the outstanding achievement of "Chinese monopoly" is representative of the status of Chinese table tennis as the "national sport", the means of table tennis for China is far beyond the sports competition. For a long time, "ping-pong diplomacy" has influenced the significance of Chinese people (Griffin, 2014). However, in recent years, in international competitions, Chinese table tennis consecutively lost the gold medal, seriously impacting the faith of the Chinese people. This hindered the government applied table tennis as diplomacy and affected the influence of Chinese status in the world.

As one of the fastest sports in the world (Toriola et al., 2004), 226 countries have associations with the ITTF (International Table Tennis Federation), and 350 million people watched the Tokyo Olympics Game. As the competitors of Chinese table tennis, Japanese players stood in the spotlight for the gold medal when Chinese mixed doubles Xu Xin & Liu Shiwen lost to Japanese players Jun Mizutani & Mima Ito (International Table Tennis Federation). This situation broke the myths of the "Chinese monopoly" and impacted the enthusiasm of Chinese table tennis fans. Concerning performance and determination, components are various body competencies, such as psychological factors, psychobiological states, technical tactical, and physical skills contributing to players' successful performance (Faber, 2016). Among these significant factors, stroke performance is an essential technical skill determining whether a player wins or loses in a match (Belli et al., 2019). Stroke performance in table tennis, usually measured by ball speed and accuracy, is vital for achieving match success (Belli et al., 2019). The faster the ball speed stroke by the player, the less reaction time remains for the opponent (Wong et al., 2020), and the ball's placement avoids the opponent's preferred strokes (Malagoli Lanzoni et al., 2014). Exploiting the opponent's weakness may induce favourable conditions for winning the match. However, ball speed and accuracy are impaired by mental fatigue (Mansec et al., 2018).

Mental fatigue-affected sports performance is complicated and multifaceted; understanding the mechanism of mental fatigue and sports performance decrement might provide a deeper insight into this domain. As the prominent theory of the psychobiological model of endurance performance proposed by Marcoro et al. (2009) suggested, the physiological explanation offers a deeper understanding of mental fatigue and sports performance. The mental fatigue activated the anterior cingulate cortex (ACC), which led to an elevated transmission of adenosine, corresponding to a decreased transmission of dopamine; the elevation of adenosine transmission increased the higher perceived exertion and the decreased dopamine led to reduced motivation (Marcora et al., 2009; Martin et al., 2018). These two physiological factors mediated the mental fatigue and the subsequent performance. The table tennis stroke performance decrement induced by mental fatigue might lead to players losing the match. Therefore, finding a practical and feasible strategy to counteract mental fatigue and performance decrement is significant.

Several strategies were investigated to counteract mental fatigue, including physiological, psychological, and behavioural (Proost et al., 2022). For example, psychological strategy, mindfulness, and systematic breathing with/without mental imagery were investigated (Loch et al., 2020; Proost et al., 2022). However, no significant positive or unclear effects were observed in counteract effectiveness. Some studies suggest that offering rewards as an extra incentive to increase motivation could attenuate mental fatigue (Brown & Bray, 2017). However, extrinsic rewards might undermine intrinsic motivation (Wiersma, 1992). Physiological strategies: caffeine, carbohydrates, mouth rinse, and smell odour were investigated, and behavioural strategies like aerobic exercise, mild-stream bathing, mechanical massage, nap, and physical activity were analysed to counteract mental fatigue (Mitsuo Hayashi et al., 2004; Lim et al., 2018; Oberste et al., 2021; Proost et al., 2022; Rokushima3ADG & Watanabe, 2010). However, due to the field setting and match context, it is not feasible for a player with mental fatigue to get a mechanical massage or take mild-stream bathing immediately. On the other hand, physiological strategy, for example, long-term caffeine supplements, might cause potential health risks (Nawrot et al., 2003). Hence, finding a practical and feasible strategy is significant.

Interestingly, listening to music could stimulate dopamine, transmitting benefits to individuals' positive emotions (Ferreri et al., 2019), and the psychophysiological "Dissociation effects" of listening to music could lead to distraction from the perceived exertion (Jones et al., 2014). As adenosine and dopamine are two significant neurotransmitters affected by mental fatigue (Marcora et al., 2009; Martin et al., 2018) , music positively affects these two critical pathways. Hence, a study suggested listening to music might be a promising and friendly strategy to counteract mental fatigue (Proost et al., 2022). Studies reported music was influential in mental fatigue-induced decrement of cognitive performance; for example, Guo et al. investigated relaxing music to counteract mental fatigue and reported university students in the relaxing music group perceived less mental fatigue feeling and cognitive performance was less affected by mental fatigue compared to the control group (Guo et al., 2015).

Behaviour performance, for example, Jacquet et al. reported that mentally fatigued adults who applied a personal preference music for recovery perceived less mental fatigue and performed motor control better in the arm-pointing task than the control group (Jacquet et al., 2021).

Chen et al. studied classical music to counteract mental fatigue and reported music conditions. Individuals decreased tiredness, increased vigilance, and concentration in subjective feelings, decreased reaction time, and increased incorrect answers in calculation performance (Chen et al., 2008). Even the secondary computerised music in the binaural beats effectively counteracts mental fatigue (Axelsen et al., 2020). As suggested by these studies, music is proposed as an effective strategy for counteracting mental fatigue with less mental fatigue and counteracting cognitive and behavioural performance decrement. However, no study reported music on counteracting mental fatigue-induced table tennis performance decrement.

Unsurprisingly, previous research on mental fatigue in the sports domain mainly focused on elite athletes (Mansec et al., 2018), representing the country's highest level of sports performance. However, limited studies investigated the effects of mental fatigue on performance among university players. University players are significant to examine as the reserved power to support international competition (Cooper, 2021). On the other hand, university players face training and study-related pressure due to mental fatigue. Thus, investigating mental fatigue on stroke performance among university table tennis players is significant.

Meanwhile, as table tennis stroke performance was impaired in elite table tennis players (Mansec et al., 2018), examining the practical and feasible strategy to counteract mental fatigue and mental fatigue-induced performance decrement among table tennis players remained unexplored. Therefore, this study aims to examine the effects of mental fatigue on the stroke performance of university table tennis players and music recovery by counteracting mental fatigue-induced performance decrement among university table tennis players. The examination of this study's aims could bring significance to sports science. Firstly, it could be a better understanding of mental fatigue in table tennis stroke performance and a better understanding of music as mental fatigue counteracts strategy in a sports context. Secondly, coaches and university table tennis players in sports contexts could realise the effects of mental fatigue on their stroke performance to avoid mental fatigue as much as they can, and when mental fatigue occurs, consider this strategy for recovery by counteracting mental fatigue-induced performance decrements. Furthermore, it could be attributed to Chinese table tennis holding the dominant place in international competitions, and the government applied table tennis as "ping-pong diplomacy" to increase its global status.

1.3 Objective of the Study

1.3.1 General Objectives

The general objective of this study is to examine the effects of mental fatigue and music recovery on stroke performance and psychological factors among university table tennis players.

1.3.2 Specific Objectives

Based on the general objectives of this thesis, the specific objectives are as follows:

1. To examine the effects of mental fatigue and music recovery on subjective feelings of mental fatigue among university table tennis players.
2. To examine the effects of mental fatigue and music recovery on positive and negative emotions among university table tennis players.
3. To examine the effects of mental fatigue and music recovery on attention control among university table tennis players.
4. To examine the effects of mental fatigue and music recovery on the scope of attention among university table tennis players.
5. To examine the effects of mental fatigue and music recovery on thought-action repertoire among university table tennis players
6. To evaluate the effects of mental fatigue and music recovery on stroke accuracy in terms of accuracy numbers, fault numbers and total score among university table tennis players.
7. To evaluate the effects of mental fatigue and music recovery on ball speed among university table tennis players.

1.4 Hypothesis

1.4.1 General Hypothesis

There is no significant difference in the effect of mental fatigue and music recovery on stroke performance and psychological factors among university table tennis players.

1.4.2 Specific Hypothesis

i. The Null Hypothesis for the First Objective

H01: There are no significant differences between the baseline test and post-test 1 on the value of subjective mental fatigue feeling in the mental fatigue music group (FMG) and mental fatigue no music group (FNMG) compared to the mental fatigue control music group (FCMG) and mental fatigue control no music group (FCNMG).

H02: There are no significant differences between post-test 1 and post-test 2 on the value of subjective mental fatigue feeling in FMG and FCMG compared to the FNMG and FCNMG.

ii. The Null Hypothesis for the Second Objective

H03: There are no significant differences between the baseline test and post-test 1 on the score of positive emotion in the FMG and FNMG compared to the FCMG and FCNMG.

H04: There are no significant differences between the baseline test and post-test 1 on the score of negative emotion in FMG and FNMG compared to the FCMG and FCNMG.

H05: There are no significant differences between post-test 1 and post-test 2 scores on the score of positive emotion in FMG and FCMG compared to the FNMG and FCNMG.

H06: There are no significant differences between post-test 1 and post-test 2 on the score of negative emotion in FMG and FCMG compared to the FNMG and FCNMG.

iii. The Null Hypothesis for the Third Objective

H07: There are no significant differences between the baseline test and post-test 1 on the score of attention focusing in FMG and FNMG compared to the FCMG and FCNMG.

H08: There are no significant differences between the baseline test and post-test 1 on the score of attention shifting in FMG and FNMG compared to the FCMG and FCNMG.

H09: There are no significant differences between post-test 1 and post-test 2 on the value score of attention focusing in FMG and FCMG compared to the FNMG and FCNMG.

H10: There are no significant differences between post-test 1 and post-test 2 on the value score of attention shifting in FMG and FCMG compared to the FNMG and FCNMG.

iv. The Null Hypothesis for the Fourth Objective

H11: There are no significant differences between the baseline and post-test 1 on the scope of attention in FMG and FNMG compared to the FCMG and FCNMG.

H12: There are no significant differences between post-test 1 and post-test 2 on the scope of attention in FMG and FCMG compared to the FNMG and FCNMG.

v. The Null Hypothesis for the Fifth Objective

H13: There are no significant differences between the baseline test and post-test 1 on the thought-action repertoire in FMG and FNMG compared to the FCMG and no FCNMG.

H14: There are no significant differences between post-test 1 and post-test 2 on the thought-action repertoire in FMG and FCMG compared to the FNMG and FCNMG.

vi. The Null Hypothesis for the Sixth Objective

H15: There are no significant differences between the baseline test and post-test 1 on the stroke accuracy numbers in FMG and FNMG compared to the FCMG and FCNMG.

H16: There are no significant differences between post-test 1 and post-test 2 on the stroke accuracy numbers in FMG and FCMG compared to the FNMG and FCNMG.

H17: There are no significant differences between the baseline and post-test 1 on the fault numbers in FMG and FNMG compared to the FCMG and FCNMG.

H18: There are no significant differences between post-test 1 and post-test 2 on the fault numbers in FMG and FCMG compared to the FNMG and FCNMG.

H19: There are no significant differences between the baseline test and post-test 1 on the stroke total score in FMG and FNMG compared to the FCMG and FCNMG.

H20: There are no significant differences between post-test 1 and post-test 2 on the stroke total score in FMG and FCMG compared to the FNMG and FCNMG.

vii. The Null Hypothesis for the Seventh Objective

H23: There are no significant differences between the baseline test and post-test 1 on the ball speed in FMG and FNMG compared to the FCMG and FCNMG.

H24: There are no significant differences between post-test 1 and post-test 2 on the ball speed in FMG and FCMG compared to the FNMG and FCNMG.

1.5 Significance of the Study

1.5.1 Theoretical Significance

The psychobiological model of endurance performance indicates that the psychobiological factors of perceived exertion and motivation mediated mental fatigue and performance (S. M. Marcora et al., 2009; Martin et al., 2018). This is reasonable for explaining the endurance performance; however, describing the skill performance decrement seems insufficient, as the higher perceived exertion is not the determining factor for the skill performance. Recently, Sun et al. suggested that attention is a significant factor to incorporate into the psychobiological model of endurance performance (Sun, Soh, et al., 2022a). Since mental fatigue activates the anterior cingulate cortex (ACC) and increases adenosine concentration, there is a corresponding decrease in dopamine (Sun, Soh, et al., 2022b). Moreover, ACC plays a crucial role in executive functions, especially attention control.

Furthermore, music's "dissociation effects" contributed to decreased perceived exertion and regulated the attention from perceived exertion to music (Jones et al., 2014). Meanwhile, listening to music could increase dopamine transmission, which was reduced by mental fatigue (Ferreri et al., 2019). Therefore, the adverse effects of mental fatigue on the performance might be attenuated by music. This study examined this mental fatigue in attention control and music recovery by counteracting the attention control performance decrements. The findings may reveal that attention is another psychological factor affected by mental fatigue on skill performance and confirm Sun et al. proposed that attention plays a crucial role in incorporating the psychobiological model of endurance performance.

The Broaden Theory is another theory that was applied in this study. This theory indicated that music-induced positive emotion benefits to regulate attention, and the scope of attention was broadened by positive emotion after listening to music (Fredrickson, 2004). Although the induced emotion response strategies are varied, for example, watching videos, watching some pictures, and listening to audio stimulation (Chen et al., 2021; B. L. Fredrickson & C. Branigan, 2005). However, music was reported as an effective strategy to induce positive emotion (Kim et al., 2010).

Although music has been widely applied in the "ergogenic effect" in sports performance (Karageorghis et al., 2013), music-induced positive emotion with Broaden's Theory has not been tested in sports. Thus, this theory might be proposed as a framework for counteracting mental fatigue in future studies of sports contexts.

1.5.2 Practical Significance

This study's practical contribution is to table tennis players and coaches. It provides empirical evidence for them to understand the impact of mental fatigue on table tennis stroke performance and psychological factors. By this study, coaches and table tennis players might avoid intense cognitive tasks that could induce mental fatigue before fierce competition. Furthermore, when mental fatigue occurs, this study also provides music as an effective strategy to counteract mental fatigue-induced performance decrement.

Another significance of this study is that it fills a practical gap in sports psychology, specifically the effects of mental fatigue on cognitive and stroke performance among university table tennis players. A previous study reported mental fatigue affected stroke performance among elite table tennis players (Mansec et al., 2018), and mental fatigue affected psychomotor performance (Habay et al., 2021). However, the mental fatigue on cognitive performance, emotional state, and stroke performance among university table tennis players remained unexplored. Meanwhile, the music recovery by counteracting the psychological factors and stroke performance among mentally fatigued table tennis players remained untested.

Therefore, this study contributed significantly to the knowledge and literature on mental fatigue in sports performance. By counteracting the performance decrement, music recovery might benefit coaches and table tennis players by helping them perform better in fierce competition.

1.6 Delimitation of Study

1.6.1 Population Delimitation

The study recruited university table tennis players with limited experience so that the results may differ from those of elite athletes. However, university table tennis players are reserved for elite athletes, and there are many international table tennis competitions for university students, such as the World University Games, World University Table Tennis Championships, and Asia-Pacific University Table Tennis Championships. On the other hand, university students are bound by mental fatigue because they face stress from training, competition, and studying. Furthermore, previous studies focused on elite table tennis athletes, and the mental fatigue counteract strategy for university table tennis players still needs to be discovered. To fill this gap, university table tennis players were recruited into this study.

1.6.2 Measurement Delimitation

The stroke performance of university table tennis players was measured by the return of the ball sent by the robot. Although in the field context of fierce competition, the ball's return may be consecutive and diverse, to minimise the confounding variable affecting the result, the ball sent by the robot was the same speed, frequency, and position of the balls for all the university table tennis players. Hence, these consistent parameters of the ball sent by the robot provided higher reliability in return for the ball of the stroke performance and were applied in this study.

Additionally, mental fatigue level was measured by subjective evaluation. Mental fatigue could be measured by subjective cognitive performance and physiological markers. However, these different measures can be presented in a variety of ways. Meanwhile, subjective measurement is a reliable indicator widely implemented in many studies to measure mental fatigue (Smith et al., 2019). Furthermore, this measurement is implemented for its minimum time requirements and straightforward interpretation. Hence, the subjective evaluation of mental fatigue was applied in this study.

1.6.3 Intervention Delimitation

The mental fatigue inducement of this study was applied to the Stroop task. However, the Psychomotor Vigilance Task, AX-Continuous Test and Stroop task are the cognitive tasks that most induce mental fatigue. These three mental fatigue inducements were not found to be the difference in cognitive performance and physiological (electroencephalogram and heart rate variability) markers. However, based on the systematic review of the effect of mental fatigue on racket sports performance (refer to Appendix A), five of six included studies investigated mental fatigue on the performance of racket sports applied the Stroop Task. Hence, the Stroop task was used as the intervention to induce mental fatigue for this study.

On the other hand, listening to music was examined as an intervention for recovering mentally fatigued university table tennis players. There are several strategies for recovering from mental fatigue, for example, taking a steam bath, smelling the odour, massaging, intake of creatine, caffeine, mindfulness, and nature exposure (Hayashi et al., 2004; Lim et al., 2018; Oberste et al., 2021; Proost et al., 2022; Rokushima & Watanabe, 2010). However, these strategies are limited to context, health risk potential, and experience. Compared to these strategies, music is a portable and friendly strategy to implement in the context of competition. Therefore, music was applied as the intervention for recovering the mental fatigue of university table tennis players in this study.

1.7 Limitations of Study

Limitations in any study concern potential weaknesses that are usually out of the researcher's control and are closely associated with the chosen research design, statistical model constraints, funding constraints, or other factors (Theofanidis & Fountouki, 2018). Although this study had carefully considered details in its design and execution, as with all studies, it is still imperative to highlight potential limitations.

1.7.1 Limitation of the First Intervention

Firstly, by concentrating exclusively on mental fatigue, this study enables a focused examination of its specific effects on table tennis stroke performance and psychological factors. In real-game situations, players often experience both mental and physiological fatigue. However, the scope of this research is confined to mental fatigue, deliberately excluding the combined effects of both fatigue types. This deliberate focus allows for a more precise analysis of mental fatigue's impact without the confounding influence of physiological fatigue. Future studies could benefit from exploring both mental and physiological fatigue to provide a more comprehensive understanding of their interactive effects on athletic performance.

Secondly, this study's mental fatigue inducement was conducted using the Stroop Task in a laboratory context. Although players will not experience the Stroop task in the field context, some studies suggest that smartphone use, long travel journeys to the competition, and consecutive competitions on the same day will cause the players to experience mental fatigue (Díaz-García et al., 2021; Fortes et al., 2021). Overall, there are three reasons to apply the Stroop Task to induce mental fatigue in table tennis players.

1) Based on the systematic review (see Appendix A, the effect of mental fatigue on racket sports performance), this review shows that the Stroop Task is the most widely used and reliable method of inducing mental fatigue for racket sports players.

2) Stroop Task involves sustained attention and inhibition, two critical factors for inducing mental fatigue. Sustained attention and inhibition are similar to table tennis players during fierce competition. Table tennis players should exert frequent inhibition to suppress external stimuli, for example, blocking the audience's cheers to focus on the current competition (You et al., 2018). Furthermore, table tennis players should focus on the ball's trajectory and response to win the points (Sun et al., 2021). This sustained attention process and inhibition are pretty similar to the actual scenario; thus, the Stroop Task was applied as the mental fatigue induced for this study.

3) Some studies suggested that mental fatigue should be experimentally induced (Ding et al., 2024; Santos et al., 2019). To investigate the effect of mental fatigue on subsequent performance, control confounding variables are significant in creating the cause-and-effect relationship between intervention and outcome. Hence, to examine the impact of mental fatigue on performance, the Stroop Task is recruited as the mental fatigue inducement

in this study.

1.7.2 Limitation of the Second Intervention

Moreover, there is a limitation regarding the intervention in music selection. The music genres are diverse, and individuals have different appetites for music genres. Selecting the appropriate music stimulus as the intervention for recovering mentally fatigued table tennis players. Three significant factors need to be considered in the determination. 1) the researcher gives the music as the specific stimulus or should be selected by the participants, 2) based on the Broaden Theory, the minimal duration for inducing positive emotion, 3) the appropriate volume for both stimuli effects and no health risk for recovering the mentally fatigued table tennis players. The music determination was presented in Chapter 3.5, the development of the intervention. Finally, the music of "Dreaming" by Ryuichi Sakamoto was determined to be the music recovery for mentally fatigued table tennis players in this study.

1) To examine the effects of the music intervention on the recovery of mental fatigue in university table tennis players and minimise the confounding variable affecting the results, "Dreaming" was determined by the researcher as the music intervention for all the players in the music intervention groups, for the consistent music intervention could minimal the music gene differences as the confounding variable to affect the recovery results. However, this music may not be optimal for the appetites of all table tennis players. However, a previous study suggests this music was ranked in the top 5 music list for inducing positive emotion. Meanwhile, the researcher surveyed these top 5 ranking music lists for inducing positive emotion, with over 100 university students' responses, "Dreaming" was the highest score for inducing positive emotion. Details are presented in Chapter 3, section 3.5, on the development of the intervention. Hence, the music "Dreaming" was selected as the recovery strategy for this study's mentally fatigued university

table tennis players.

2) The duration of music intervention, although the longer time, might affect recovery. However, a previous study reported that 3 minutes of music had already induced positive emotion and successfully induced a “broad effect” (Putkinen et al., 2017). The music “Dreaming” is 4.24 minutes, more than 3 minutes. Moreover, to ensure the intervention’s effects, the “Dreaming“ music intervention was played on a loop twice for 8.48 minutes. Hence, the 8.48 minutes of “Dreaming” was determined as the recovery strategy for this study’s mentally fatigued university table tennis players.

3) Although the volume is diverse, the lower volume might not affect the players because the players might not hear the music, and the higher volume might cause a hearing impairment risk. Studies reported that exposure to high-volume music has cumulative effects on hearing impairment and thus increases the risk of hearing loss (Zhao et al., 2010). At sound levels equivalent to 90 dB, a weighting filter (dBA) or above, the average permanent hearing after 10 years of exposure may reach values that produce a level of hearing loss (20 dB) that is noticeable to individual people themselves, with sound levels equivalent to 100 dBA or above, may cause a permanent hearing losing of ~40 to 45 dB after 10 years exposure (Daniell et al., 2002; Vogel et al., 2012). Hence, the volume of music for recovery was restricted to below 90 dBA to avoid the health risk potential. Meanwhile, previously investigated music in the sports performance volume was set to 80 dBA as loud and 70 dBA as quiet (Karageorghis et al., 2018). Considering individual hearing ability diversity, the suggested volume was set between 70 dBA and 80 dBA based on the most comfortable of the players and the personal hearing ability of this study.

1.8 Definition of Terms

The research variables of this study are defined into conceptual and operational aspects. The term and their definition are listed below:

1.8.1 Mental Fatigue

Conceptual Definition: mental fatigue is a psychobiological state characterised by a decline in cognitive and physical performance with subjective feelings of tiredness, often resulting from prolonged periods of demanding cognitive activity. It involves physiological and psychological components, affecting attention, decision-making, and overall mental function (Boksem & Tops, 2008).

Operational Definition: An acute psychobiological state in subjective evaluation with a 100 mm visual analogy scale induced by a 45-minute computerised Stroop Task. The Stroop task requires participants to engage in sustained attention and inhibition control, which are cognitive processes in table tennis competitions (Zhu et al., 2022). Prolonged cognitive activity could exhaust these processes. This acute exhausted psychobiological state is mental fatigue, impairing subsequent table tennis stroke performance (Mansec et al., 2018).

1.8.2 Music

Conceptual Definition: Music is an organised form of sound created using rhythm, significant melody, harmony, and dynamics to express ideas, emotions, and cultural values. It serves various purposes, including artistic expression, communication, entertainment, and therapy. In a broader sense, music is perceived as a universal language that can influence mood, cognitive functions, and physical performance (Thaut, 2013).

Operational Definition: In this study, music intervention was participants listening to “Dreaming” by Ryuichi Sakamoto played on a loop twice for 8.48 minutes at a self-determined suitable volume between 70 dBA to 80 dBA played by earphones. Music genre, duration and volume may affect individual cognitive performance and emotional state. The music determination was based on the definition of music and the objective of this study. Details are presented in Chapter 3, section 3.5, on the development of the intervention.

1.8.3 Stroke Performance

Conceptual Definition: Stroke performance refers to the effectiveness and efficiency with which a player executes strokes, such as forehand drives, backhand drives, topspins, and chops. It encompasses technical skill, precision, speed, power, and the ability to place the ball in challenging positions for the opponent consistently. Stroke performance is critical to a player's overall success and is influenced by biomechanics, timing, strategy, and mental function (Iino & Kojima, 2016; Zhang, 2017).

Operational Definition: In this study, stroke performance refers to table tennis players applying forehand stroke 45 times in each test session, measured by ball speed and stroke accuracy. Table tennis alternatively strokes three target positions with the parameters of two rectangular targets (80 cm length, 20 cm width) located 20cm from the tables' edges (both left and right sides). One semicircle 25 cm in diameter was located at the edge (Mansec et al., 2016; Mansec et al., 2018). Scoring with 2 points when the ball reached the target position, 1 point with a stroke of the ball on the table but did not reach the target position, and 0 points as the ball missed or out of the table. An average speed of 45 times strokes measured ball speed (Mansec et al., 2016; Mansec et al., 2018). Details have been presented in Appendix M.

1.8.4 Table Tennis Players

Conceptual Definition: Table tennis players refer to the person who plays table tennis, especially as a profession. Table tennis, also commonly known as ping pong, is a fast-paced indoor sport played on a table divided by a net, usually played by two or four players. Table tennis players use small paddles to hit a lightweight ball back and forth across the table, aiming to score points by making the ball bounce on the opponent's side in a way that prevents them from returning it.

Operational Definition: Table tennis players with more than two years of training experience in the university and aged 18 to 24 years old. They are also students taking standard courses at the university in Huaian City, Jiangsu Province, China.

CHAPTER 2

LITERATURE REVIEW

This chapter discussed three sections of this study. The first section addressed the core variable, which is mental fatigue, including 2.1 Terminology of mental fatigue; 2.2 The effect of mental fatigue as well as a systematic review to discuss the effect of mental fatigue on the performance of racket sports; 2.3 The inducement of mental fatigue; and 2.4 The manifestation of mental fatigue. The second section discussed recovery strategies, including 2.5 Strategies to counteract mental fatigue and a systematic review of music to counteract mental fatigue. The final section presented a 2.6 Theoretical framework, which included three prominent theories employed in the present study. The final section of this study's conceptual framework in 2.7 is shown.

2.1 Terminology of Mental Fatigue

Fatigue refers to "extreme tiredness resulting from mental or physical exertion or illness" and/or "a reduction in the efficiency of a muscle or organ after prolonged activity" (Pageaux & Lepers, 2018). Prolonged engagement in physical exertion is neuromuscular or muscle fatigue (Boyas & Guével, 2011; Gandevia, 2001). Meanwhile, prolonged engagement in mental exertion is defined as cognitive or mental fatigue (Boksem et al., 2006). Studies suggest cognitive fatigue is commonly viewed as a psychobiological state that occurs following an extended period of self-regulation activity, which leads to decrement in the performance of reasoned cognitive processing tasks over some time (Holtzer et al., 2010; McMorris et al., 2018). Mental fatigue is a psychobiological state induced by a prolonged period of demanding cognitive activity with a subjective feeling of tiredness and lack of energy (Boksem et al., 2006). “Mental fatigue” and “cognitive fatigue” refer to the psychobiological state induced by prolonged mental exertion. In the sports context, the term “mental fatigue” is widely applied to investigate its’ impacts on sports performance context (Boksem et al., 2006; Fortes et al.; Kosack et al., 2020; Sun et al., 2021). Although the terms “cognition fatigue” and “mental fatigue” were interchangeable, this study will consistently use the term “mental fatigue” because this study followed the theory of the psychobiological model of endurance performance to investigate not only the cognition process but also included the motivation, perception, as well as interactive relationship between these components.

2.2 The Effects of Mental Fatigue

The mental fatigue literature investigating the effect of mental fatigue is comprehensive. Generally, these effects are comprised of physical performance and cognitive performance. These two aspects are discussed, specifically as follows: 2.2.1 Effects of mental fatigue on physical performance, 2.2.2 Effects of mental fatigue on cognitive performance, and 2.2.3 Effects of mental fatigue on the performance of racket sports based on a systematic review.

2.2.1 Effects of Mental Fatigue on Physical Performance

The effects of mental fatigue on physical performance are historical and date from the late 19^{th} and 20^{th} centuries. In 1891, Angelo Mosso, a physiologist, found poor muscle endurance performance after several hours of lectures and verbal examinations among his fellow professors (Kunrath et al., 2020). Pioneer of Angelo Mosso’s work provided early evidence suggesting mental fatigue impairs physical performance. Over one century later, Marcora et al. (2009) examined the effects of mental fatigue on cardiorespiratory and musculoenergetic mechanisms; they found physical factors of heart rate and blood lactate, psychological aspects of success motivation and intrinsic motivation were not affected by mental fatigue. This study suggested that the perceived exertion significantly mediates mental fatigue and performance (Marcora et al., 2009). This theory contributed to the mental fatigue literature and provided the foundation mechanism explanation for the following studies to investigate the effect of mental fatigue on physical performance.

The effects of mental fatigue on physical performance were comprehensively synthesised into a systematic review by Van Cutsem et al. (2017). Their study categorised physical performance into whole-body endurance, muscle endurance, maximal strength, power, and anaerobic work (Van Cutsem et al., 2017). They also reported that mental fatigue affected whole-body endurance. Marcora et al. (2009) reported participants under mental fatigue conditions decreased a mean of 15% in time to exhaustion and exerted 80% of peak power output. Consistent findings were reported by Pageaux et al. (2014), and MacMahon et al. (2014), who found mentally fatigued participants increased by 5% and 2% in self-paced 5-km and 3-km running protocols. The endurance performance decrement affected by mental fatigue was reported in whole-body endurance domains and muscle endurance aspects. Pageaux et al. (2013) reported participants under mental fatigue conditions shortened 13% of their time to exhaustion on the maximal voluntary contraction. Inconsistent with endurance performance impairment by mental fatigue, maximal strength, power, and anaerobic work were reported as not impaired by mental fatigue. Martin et al. (2015) reported no condition or time effect on peak torque, mean torque, time to half peak torque, time to peak torque, and peak torque slope of maximal anaerobic exercise performance by mental fatigue. Duncan et al. (2015) and Martin et al. (2015) found there is no effect of mean cycling power during four consecutive 30-s Wingate anaerobic tests and no impact of countermovement jump height, mean power, peak force, concentric peak velocity, and eccentric displace of participants under mental fatigue condition.

To summarise, mental fatigue impairs physical performance and endurance performance. However, mental fatigue did not affect maximal strength, power, and anaerobic work (Van Cutsem et al., 2017). These empirical studies suggested that mental fatigue impaired endurance performance, consistent with Marcoro et al.'s (2009) proposed psychobiological model of endurance performance with higher perceived exertion as the factor affecting the performance. Menahile and Van Cutsem (2017) indicated that future studies should use appropriate paradigms to induce mental fatigue and explore the role of cognitive components on physical performance.

2.2.2 Effects of Mental Fatigue on Cognitive Performance

The effects of mental fatigue on cognitive performance are also very historical, as the milestone study Bartlett (1943) examined the fatigue in highly skilled work and reported prolonged cognitive work leads to a decrease in cognitive performance, including slower reaction time, more errors, and easily distracted attention (Bartlett, 1943). These cognitive performance decrements attributed to mental fatigue activated the anterior cingulate cortex (ACC), elevating the adenosine transmission and decreasing the dopamine transmission (Ishii et al., 2014; Martin et al., 2018). Cognitive performance depends on cognitive control, encompassing "higher order" mental functions aligned with internal intentions (Hommel et al., 2002; Miller, 2000).

Cognitive control involves mechanisms implemented in a distributed brain network, interacting to monitor and evaluate behaviour (overseeing) and execute control adjustments (regulation) (Cohen et al., 2000; MacDonald et al., 2000; Milham et al., 2003). Consequently, impairment in cognitive control leads to a decrement in cognitive performance among mentally fatigued participants (Lorist et al., 2005).

As the key component of cognitive control, attention is impaired by mental fatigue. Boksem et al. (2005) investigated the effects of mental fatigue on attention; they found eight healthy participants experienced a visual attention task for consecutive 3 hours without rest, mentally fatigued participants performed a reduction in goal-directed attention (top-down) and into stimulus-driven fashion (bottom-up) attention. Faber et al. (2012) investigated the effects of mental fatigue on visual selective attention. Seventeen mentally fatigued participants performed a reduction in selective attention and insufficient ability to block irreverent information after continuous cognitive tasks. Notably, the cognitive performance of attention impairment was related to a decrease in dopamine transmission, which reduced top-down cognitive control ability (van Schouwenburg et al., 2010).

To summarise, cognitive performance is impaired by mental fatigue, particularly in attention. Although the attention process is complex, studies suggest that goal-driven (top-down) attention is more impaired, while stimulus-driven attention is less affected (Boksem et al., 2005). Mental fatigue-related impairment in the attention process increases errors and longer reaction time (Sun et al., 2022). Given the vital role of attention processing in sports, as the attention control ability was impaired by mental fatigue, a study suggested that attention might be another significant factor in mediating mental fatigue and performance (Sun et al., 2022).

2.2.3 Effects of Mental Fatigue on Performance of Racket Sports Based on a Systematic Review

Stroke performance is a significant component in sports, especially in racket sports (Lees, 2003; O'Donoghue et al., 2013). To elaborately understand the effects of mental fatigue on table tennis stroke performance. A systematic review was conducted by the researcher titled "Does mental fatigue affect the performance in racket sports? a systematic review". This systematic review was published in BMC Sports Science Medicine and Rehabilitation (Rank Q2) with DOI: https://doi.org/10.1186/s13102-024-00963-w.

A thorough search was conducted on 28 December 2023; four databases, including Web of Science, PubMed, Scopus, SPORTDiscus (via EBSCOhost) and the Psychology and Behaviour Sciences collection, were searched (*via* EBSCOhost). Four-hundred and thirty-three items of results were conducted screening, and the final six studies met the predeterminate inclusion criteria and were synthesised in the systematic review. The search strategy, screen process and results table are presented in Appendix A. Based on this systematic review, some gaps were identified, as explained below:

i. Theoretical Gap

The stroke performance of elite table tennis players was impaired by mental fatigue. As the prominent theory, Marcora et al. (2009) proposed the psychobiological model of endurance performance. The endurance performance decrement was attributed to mental fatigue activating the ACC of the brain. Elevating the adenosine leads to increased perceived exertion, corresponding to decreased dopamine transmission and decreased motivation (Marcora et al., 2009; Martin et al., 2018). However, the table tennis stroke performance is skill performance; this skill performance impaired by mental fatigue is insufficient to be explained by the higher perceived exertion. The mental fatigue impaired cognitive performance, especially in attention control. (See section 2.2.2 Effects of mental fatigue on cognitive performance). Hence, this skill performance impaired by mental fatigue might be attributed to the mental fatigue impaired cognitive control ability. Sun et al. (2022) improved the psychobiological model of endurance performance. They proposed that attention control, as the significant component in the cognitive control process was impaired by mental fatigue, might be another mediator of skill performance. Thus, the improved theory by Sun et al. (2022) might be more appropriate to explain the mental fatigue in table tennis stroke performance and the extent of diversity performance (e.g. technical, tactical, psychomotor performance) in sports.

ii. Intervention Gap

Based on the systematic review, elite table tennis players' stroke performance was impaired by mental fatigue (Mansec et al., 2018). However, no study investigated the recovery strategy for mentally fatigued table tennis players and counteract this stroke performance decrement. Hence, this study focused on the recovery strategy of music to counteract mental fatigue-induced table tennis stroke performance decrements.

iii. Population Gap

A study suggested that elite players' table tennis stroke performance was impaired (Mansec et al., 2018). However, no study examined the effects of mental fatigue on table tennis stroke performance among university table tennis players. University table tennis players not only face stressful training but also face stressful courses. This stressful situation results in their bond of mental fatigue. To investigate university table tennis players, which could contribute to Chinese table tennis as the "national sport" (Chen et al., 2015). Meanwhile, there are several international table tennis competitions specifically for university table tennis players; investigating university table tennis players and helping them to achieve optimal performance are significant to Chinese table tennis international status.

2.3 The Inducement of Mental Fatigue

Mental fatigue could be induced by several aspects of daily life, from real-world contexts to laboratory settings. Previous study suggested that long-term driving could lead to mental fatigue (Zhao et al., 2011), which could increase the risk of accidents. Social media exposure induces mental fatigue, decreasing volleyball players' performance (Fortes et al., 2022). Playing video games induces mental fatigue and impaired basketball free-throw performance (Alarcón et al., 2017). Although mental fatigue inducements are diverse, previous study suggested that mental fatigue should be examined in a laboratory to control confounding variables and investigate efficiency (Martin et al., 2016).

Based on previous studies, AX-variant Continuous Performance Task (AX-CPT) and Stroop task are the most often used for inducing mental fatigue (Smith et al., 2019).

In AX-CPT, which requires vigilance, working memory, and response inhibition, previous studies reported that participants conducted AX-CPT to induce mental fatigue successfully (Mansec et al., 2018; Smith et al., 2019). The Stroop Task requires participants to be able to respond with inhibition and to pay sustained attention to the cognitive task (MacLeod & MacDonald, 2000).

In the incongruent Stroop Task, coloured words (“red”, “blue”, “green”, and “yellow”) require responses from participants (Smith et al., 2019). Participants must respond to identify the colour while ignoring the word’s meaning and then press the button on the response box when the trial is presented (Smith et al., 2019). Each trail presented for 1000ms followed by a 1500ms blank screen; any incorrect or missed response(>1700ms) will be signalled by a beep sound from the computer speakers (Smith et al., 2019). Although these mental fatigue inducements vary, these cognitive task inducements require participants to exert sustained attention and inhibitory during the cognitive task, and the more inhibitory process involved, the more mental fatigue occurs (Smith et al., 2019).

To ensure participants experience mental fatigue, the type of cognitive task and the task duration must be specified. Based on the systematic review “Does mental fatigue affect the performance in racket sports? a systematic review” with DOI: https://doi.org/10.1186/s13102-024-00963-w conducted by researcher, the results were presented in Appendix A. The duration of mental fatigue varied from 90 minutes (Mansec et al., 2018) to 30 minutes (Díaz-García et al., 2023). Gantois et al. (2020) reported that 30-minute Stroop tasks successfully induced mental fatigue, while the 15-minute cognitive tasks had insufficient duration to generate the required mental fatigue. Therefore, the minimal duration of cognitive tasks involving sustained attention and inhibitory should be at least 30 minutes.

2.4 The Manifestations of Mental Fatigue

Mental fatigue is the psychobiological state that affects performance in sports. To examine its effects, it is crucial to quantify the level of this state. Previous studies investigating the effects of mentally fatigued participants were compared to the control group or baseline data to indicate participants under mental fatigue conditions (Díaz-García et al., 2023; Mansec et al., 2018). The manifestation of mental fatigue is multifaceted subjectively, behaviourally, and physiologically (Van cutsem et al., 2017). Subjectively, mental fatigue manifestation is increased tiredness and lack of energy (Boksem & Tops, 2008), decreased motivation and alertness decrement (Boksem et al., 2006; van der Linden et al., 2006). Behaviourally, both cognitive and physical performance decrements were reported. Cognitive performance declines include decreased reaction time and accuracy (Habay et al., 2021). Physical performance declines encompass reductions in physical and skill performance (Van cutsem et al., 2017). Physiologically, mental fatigue manifests in alterations in brain activity (Hopstaken et al., 2015).

Smith et al. (2019) conducted a study to evaluate the effects of three distinct cognitive tasks that induce mental fatigue on cognitive, subjective, and physiological indicators of mental fatigue. A total of 11 males and six females participated, completing 45-minute sessions of the Psychomotor Vigilance Task (PVT), AX-CPT, and Stroop Task or watching an emotionally neutral documentary, with each session separated by 48 hours. Subjective mental fatigue was assessed using the Brunel Mood Scale and visual analogue scales (VAS). Cognitive performance was evaluated through a 3-minute PVT, Stroop task performance, while physiological indicators of mental fatigue were assessed using electroencephalography (EEG) and heart rate variability (HRV). Following the mental fatigue inducement, participants reported increased subjective mental fatigue across the three cognitive tasks compared to the baseline test.

Their study also reported no significant changes in the control condition (Smith et al., 2019). Significant interactions were found between VAS scores and all three cognitive tasks, as well as between the PVT, Stroop Task, and BRUMS (Smith et al., 2019). However, no significant interactions were observed in the physiological indicators as measured by EEG. The study concluded that tasks requiring response inhibition tend to induce mental fatigue more effectively over a longer duration than a simple vigilance task (Smith et al., 2019). Additionally, the VAS appeared to be a more practical method for assessing mental fatigue among subjective evaluations, cognitive performance measures, and physiological markers. (Smith et al., 2019)

2.5 The Strategies to Counteract Mental Fatigue

Given the impact of mental fatigue on daily life and its associated performance decrements, it is imperative to investigate strategies to counteract it. Previous study has proposed methods for counteracting mental fatigue across physiological, psychological, and behavioural aspects (Proost et al., 2022).

2.5.1 Physiological Strategies Counteract Mental Fatigue

Physiological strategies for counteracting mental fatigue include orally and non-orally administered methods (Proost et al., 2022). Oral strategies encompass caffeine intake, carbohydrate mouth rinse, creatine, and chicken essence. As a neuroenhancer, caffeine is well-researched for its ability to counteract mental fatigue. Azevedo et al. (2016) reported that caffeine ingestion (5 mg/kg) increased endurance performance by 14% in mentally fatigued participants and enhanced mood states. Similarly, Franco-Alvarenga et al. (2019) found that caffeine ingestion during a 20-km cycling session led to a 3% increase in mean power and a 1.7% reduction in completion time. Carbohydrate mouth rinses during cognitive tasks have also been shown to be effective against mental fatigue. Bailey et al. (2021) demonstrated that mouth rinsing with carbohydrates successfully countered mental fatigue, as evidenced by improvements in subjective and neurophysiological markers. Consistent findings were reported by Brietzke et al. (2020), who noted there are positive effects of carbohydrate mouth rinses on maximal incremental test performance.

Besides caffeine and carbohydrate mouth rinses, creatine supplementation has been suggested to counteract mental fatigue. Van Cutsem et al. (2020) found that creatine supplementation improved physical (strength endurance) and prolonged cognitive task performance (Stroop accuracy) in 14 participants. However, no effects were observed on sports-psychomotor or cognitive (Flanker) performance. Similarly, Watanabe (2002) reported that creatine supplementation (8 g/day for five days) successfully combated mental fatigue and enhanced performance in simple mathematical calculations. Furthermore, chicken essence, rich in amino acids such as tyrosine (a dopamine precursor), has been suggested to counter mental fatigue. Nagai et al. (1996) and Yamano et al. (2013) reported that participants who consumed chicken essence for seven days in the morning experienced decreased feelings of fatigue and improved cognitive performance.

In addition to these oral supplements, non-oral strategies, such as smell-specific odours, have also been investigated to counter mental fatigue. Kato et al. (2012) found that participants who intermittently smelled odours such as citral, green, and menthol experienced improvements in cognitive-motor performance, counteracting mental fatigue effectively. Similarly, Saito et al. (2018) developed a honey-like floral odour, which enhanced participants' response rates, effectively counteracting mental fatigue. These physiological strategies have been reported to counteract mental fatigue effectively. Some studies also suggested psychological strategies to counteract mental fatigue.

2.5.2 Psychological Strategies Counteract Mental Fatigue

Psychological strategies for counteracting mental fatigue include mediating motivation, mindfulness, and systematic breathing with or without mental imagery. Monetary incentives have been investigated to enhance individuals' external motivation to combat mental fatigue. Hopstaken et al. (2016) found that increasing task rewards led participants to largely ignore irrelevant rewarding stimuli, resulting in improved task engagement and performance under mental fatigue conditions. Similarly, Herlambang et al. (2019) reported that after increasing the task reward, participants' irrelevant rewarding stimuli were largely ignored, and task engagement and performance were restored even in the highly fatigued condition. Brown and Bray (2017) observed that monetary incentives mitigated the adverse effects of high mental fatigue on physical endurance and altered central drive to motor units. Mindfulness has been proposed as another effective strategy to alleviate mental fatigue. Axelson et al. (2020) investigated the effects of mindfulness among novice and experienced practitioners, finding that cognitive task performance was less affected by mental fatigue compared to control conditions and novice practitioners.

Additionally, systematic breathing techniques, with or without mental imagery, have been explored as strategies to counteract mental fatigue. Loch et al. (2020) compared solely systematic breathing, systematic breathing combined with mental imagery, and control mental strategies following a 60-minute AX-CPT task designed to induce mental fatigue. However, they found no significant differences among these groups. In addition to psychological strategies, behavioural strategies for counteracting mental fatigue have also been extensively studied.

2.5.3 Behavioural Strategies Counteract Mental Fatigue

Behavioural strategies to counteract mental fatigue include physical sensation-based intervention (e.g., mild-stream bath, physical activity, and massage), visual intervention (e.g., exposure to pellet stove and nature exposure), auditory intervention (e.g., listening to music and binaural beats) and nap. For the physical sensation-based intervention of mild-stream bath, Mizuno et al. (2010) reported that after the mental fatigue task, participants in mild-stream bathing performed better on the cognitive task of reaction time than routine bathing for counteracting mental fatigue. For physical activity to counteract mental fatigue, Obserste et al. (2021) investigated how acute aerobic exercise effectively enhances recovery from mental fatigue on cognitive flexibility performance and subjective well-being. Moreover, massage intervention was examined to counteract mental fatigue. Lim et al. (2018) investigated mechanical massage, brain massage and a combination on the recovery of mental fatigue; they found massage promotes participants decreased subjective fatigue feeling, sustained attention, verbal short-term and memory and non-verbal long-term memory performance better than the control condition. They also reported combinate (mechanical and binaural massage) promotes recovery better than sole mechanical massage after mental fatigue.

An investigation of visual-based interventions to counteract mental fatigue is also examined. Tanaka et al. (2011) investigated exposure to a pellet stove for 30 minutes to recover from mental fatigue; exposure to the pellet stove condition performed fewer errors in cognitive tasks, subjective healing, more warmth, and sympathetic nerve activity parasympathetic nerve activity compared to the control condition. Nature exposure was suggested as the mental fatigue counteract strategy; Sun et al. (2022) investigated mentally fatigued university soccer players after 12.50 minutes of nature exposure significantly counteracts the decision-making performance decrement. Music was suggested as the mental fatigue counteractive strategy for the auditory intervention to counteract mental fatigue. Guo et al. (2015) investigated university students listening to folk music while conducting one-hour AX-CPT. University students were less mentally fatigued in subjective fatigue feeling, and reaction time was less affected by mental fatigue compared to no music group.

A consistent finding was reported by Jacquet et al. (2021), who investigated mental fatigue participants who listened to self-selected music to counteract mental fatigue; participants performed the arm-point tasks better after listening to music compared to the control condition. Besides the original music, music has also been secondary computerised to counteract mental fatigue. Axelsen et al. (2020) computerised music to binaural beats (beta range, 14 Hz). They found participants who listened to binaural beats were less affected by mind wandering by mental fatigue compared to the control group. Notably, these studies suggested listening to music counteracts mental fatigue effectively. Moreover, Proost et al. (2022) suggested that music might be a promising strategy for counteracting mental fatigue in diverse contexts.

Besides stimulating physical sensations, taking a nap to counteract mental fatigue has also been investigated. Hayashi et al. (2004) investigated ten university students with a mental fatigue condition and recovery strategies using 20 a short nap or rest. Participants under nap conditions on mental fatigue recovery and fatigue prevention better than those in a rest condition (Hayashi et al., 2004). Similarly, a 25-minute power nap was investigated by Loch et al. (2020). However, it is inconsistent with Hayashi et al. (2004). Loch et al. (2020) reported no significant difference in the power nap group compared to other groups. These inconsistent results could not draw a reliable conclusion on the effectiveness of naps in counteracting mental fatigue and require further studies to examine.

2.5.4 Music Counteracts Mental Fatigue Based on Systematic Review

Music effectively counteracts mental fatigue on cognitive and motor control performance (Guo et al., 2015; Jacquet et al., 2021). Furthermore, Proost et al. (2022) suggested music might be a promising strategy for counteracting mental fatigue in diverse contexts. To comprehensively synthesise the effects of music on counteracting mental fatigue, a systematic review titled “Does music counteract mental fatigue? A systematic review.” was conducted by the researchers. This systematic review is under the review of Plos One. A thorough search was conducted on 18 November 2023 in four databases, including PubMed, Web of Science, Scopus, SPORTDiscus (*via*

EBSCOhost) and Psychology and Behaviour Sciences collection (*via* EBSCOhost). A total of 736 articles were acquired in the initial search result; after careful screening, nine studies met the predeterminate inclusion and exclusion criteria and were synthesised into the systematic review. The search strategy, screen process and results table are presented in Appendix B. Based on the systematic review, some gaps were identified and explained below:

i. Theoretical Gap

The prominent theory of the psychobiological model of endurance performance explains that sports performance affected by mental fatigue activates the ACC, elevating the adenosine with higher perceived exertion and corresponding to a decrease in dopamine transmission with decreased motivation (Marcora et al., 2009; Martin et al., 2018). In other words, mediated perceived exertion and motivation would mediate the performance decrement affected by mental fatigue (Sun et al., 2022). However, in cognitive performance and skill performance, these two mediators could not be enough to explain the performance cognitive performance decrement and skill performance decrement. Since the attention control process overlaps with mental fatigue, as Sun et al. (2022) suggested, attention control might be another significant factor that mediates mental fatigue and skill performance. Thus, the improved psychobiological model of endurance performance by Sun et al. might be more appropriate in this study, and this theory might be extended to cognitive and skill performance (Sun et al., 2022).

Meanwhile, as the prominent "Broaden Theory" by Fredrickson (2004) proposed, positive emotion could mediate attention control to broaden the scope of attention, as music is bound with emotional responses. Listening to positive emotional music induces positive emotions, which mediates attention control ability and subsequently affects the performance. Meanwhile, listening to music stimulates dopamine transmission (Ferreri et al., 2019), while mental fatigue activates the ACC, decreasing dopamine transmission. Thus, the "broaden theory" might merge into the existing theory to examine the music recovery to counteract mental fatigue.

ii. Outcome Gap

Based on the systematic review, studies have examined the effects of music on counteracting mental fatigue in cognitive and motor control performance. Skill performance requires coordinating cognitive processing, motor control, and physical capabilities to achieve optimal outcomes. Since mental fatigue has been shown to impact skill performance (Sun et al., 2021). Yet, there is a lack of research examining the effects of music on mental fatigue and skill performance decrements in a sports context. Investigating the effects of music on counteracting mental fatigue and the stroke performance decrement among table tennis players would provide valuable insights for coaches and athletes aiming to enhance performance in competition.

iii. Population Gap

Studies have suggested that music could counteract mental fatigue-induced cognitive performance decrements among university students and healthy adults (Guo et al., 2015; Jacquet et al., 2021). However, no study has examined music as a recovery strategy to counteract mental fatigue and stroke performance decrements among university table tennis players. The status of table tennis as the "*National sport*" in China (Chen et al., 2015), investigating the effects of music recovery on counteracting mental fatigue and stroke performance decrements among university table tennis players could contribute to maintaining China's dominant international status in sports competitions.

2.6 Theoretical Framework

This study is guided by the three prominent theories of the Strength Model of Self-Regulation (Baumeister & Vohs, 2018), the Improved Psychobiological Model of Endurance Performance (Marcora et al., 2009; Sun et al., 2022), and the Broaden-and-Build Theory (Fredrickson, 2004). This section introduces these three theories and establishes the theoretical framework of this study.

2.6.1 The Introduction of Three Theories

i. The First Theory-The Strength Model of Self-Regulation

Self-regulation refers to the process of an individual, based on standards, altering his/her thoughts, emotions, impulses, performance, behaviours, and responses intentionally (Baumeister & Vohs, 2016). Standards refer to something that should or should not be, including goals, norms, values, morals, laws, and expectations, as well as the comparison between oneself in the present moment and past or oneself with others (Baumeister & Vohs, 2016). The strength of self-regulation, referred to as willpower, is a critical component in regulating behaviour, enabling individuals to tempt and adhere to long-term goals. This theory consisted of two gist: ***global*** and ***finite***, and one moderator: ***trait self-control*** (Baumeister & Vohs, 2016; Sun et al., 2022).

Finite: The process of self-regulation depends on limited resources; Baumeister & Vohs (2016) metaphor these limited resources as energy. The state of diminished self-regulation resources is referred to as Ego depletion (Baumeister & Vohs, 2016). Ego depletion impacts several aspects of individuals, including an increase in impulsive and disinhibited behaviours (Vohs & Faber, 2007). A previous study suggested that compared to nondepleted people, depleted people are willing to spend more money for the same good (Vohs & Faber, 2007). Alcohol problem people drink more alcohol when their limited resources are depleted (Muraven et al., 2002). Ego depletion has also been examined in the context of sports performance. Previous studies report long-term goals (Baumeister & Steinhilber, 1984; Iso-Ahola, 2013; Wilson et al., 2013). Depleted athletes performed fewer push-ups and sit-ups compared to nondepleted athletes (Dorris et al., 2012). After the self-control task, participants presented lower mean power output in a 10-km cycling time trail than nondepleted participants (Englert & Wolff, 2015). Also, isometric handgrip performance decreases after depleting the finite self-control resource (Bray et al., 2012). This suggested exerting a self-regulation process depleted the internal resource, and as this resource is finite and depleted, it leads to subsequent performance decrement.

Global: Exerting self-regulation processes deplete finite resources, and these resources share the same "resource pool", even in different tasks and functions (Baumeister & Vohs, 2016). Previous study reported that it evoked participants' emotional responses, and subsequent physical stamina performance decreased (Muraven et al., 1998). Participants exert self-control overeating; individuals forced themselves to eat radishes compared to tempting chocolates, and subsequent tasks (i.e. Unsolvable puzzles) quit faster than no exert self-control condition (Baumeister et al., 1998). Thus, this suggests that the decrement in performance presented by the resource is global, even in unrelated tasks (Baumeister & Vohs, 2016).

Trait Self-Control: The American Psychological Association defines “trait” as an enduring personality characteristic that describes or determines an individual’s behaviour across various situations. The stable differences among individuals in self-control ability are called trait self-control (TSC); Schmeichel & Zell (2007) explained that individuals better at overriding dominant response tendencies have differences in self-control ability associated with several desirable outcomes (Schmeichel & Zell, 2007). Traditionally, high trait self-control is described as a keen ability to resist temptation; Ent et al. (2015) argued high trait self-control is linked to avoiding rather than merely resisting temptation. Previous study reported that people with high self-control are better able to control their thoughts, regulate their emotions, and inhibit their impulses than people with low self-control (Bratslavsky et al., 1998). Higher self-control is the response to greater well-being, better grades of academic performance, and better interpersonal relations (Tangney et al., 2004).

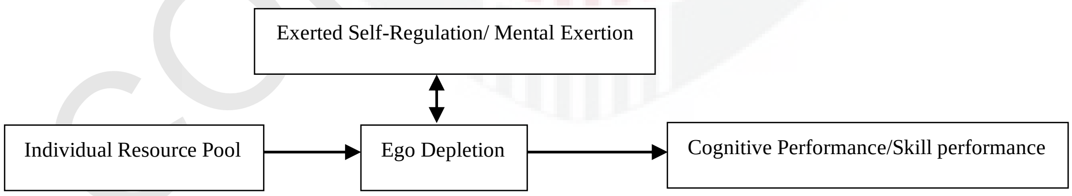


Figure 2.1 : The Strength Model of Self-Regulation
[Source: Baumeister et al. (1994)]

ii. The Second Theory-Psychobiological Model of Endurance Performance

To investigate the effects of mental fatigue on sports performance, Marcora et al. (2009) examined all the physiological and psychological markers and proposed the

Psychological Model of Endurance Performance based on Motivational Intensity Theory (Wright, 2008). In Marcora et al. (2009) study, they recruited 16 participants who cycled to exhaustion at 80% peak power after a mental fatigue-inducing cognitive task; the time to exhaustion of participants in the mental fatigue condition was significantly shorter than the control condition. Furthermore, this study also found that the decrement in performance was not attributed to cardiorespiratory and musculoenergetic factors but was mediated by higher perceived exertion, corresponding to lower motivation.

Mental fatigue-inducing tasks activate the ACC in the brain (Martin et al., 2018), providing the physiological explanation of mental fatigue-impaired subsequent physical tasks from a neurobiological rationale aspect (Marcora et al., 2009; Martin et al., 2018), and the effects of ACC on effort-based decision-making lead to decreased endurance performance (Sgherza et al., 2002). For a better understanding of the physiological mechanism of mental fatigue on performance, Martin et al. (2018) reported mental fatigue impaired performance from a physiological standpoint. They noted that cognitively demanding tasks increase the activation of ACC and lead to brain metabolic activity increment, including increased adenosine release, and this increased adenosine transmitting accompanied by higher perceived effort. Meanwhile, the increased adenosine transmission interacted with the dopamine transmission, leading to decreased motivation.

Notably, the Psychobiological Model of Endurance Performance theory explains the mechanism of mental fatigue that affects endurance performance. However, previous study also reported that skill performance, such as basketball free throw (Filipas et al., 2021), table tennis stroke performance (Mansec et al., 2018), and soccer decision-making performance (Sun et al., 2022), is also affected by mental fatigue. This skill performance decrement by mental fatigue may not be enough to be explained by the Psychobiological Model of Endurance Performance. Perceived exertion and motivation are not the determinants that affect skill performance decrement, as mental fatigue and cognitive control overlap in ACC. Hence, this skill performance decrement may be attributed to attention control deficiency affected by mental fatigue. As a result, Sun et al. (2022) improved the Psychobiological Model of Endurance Performance by adding attention as the third psychobiological factor to the Psychobiological Model of Exercise Performance. This extension might contribute to the mental fatigue literature and the extent of the endurance performance to diversity performance (e.g. technical, tactical, and psychomotor) in sports.

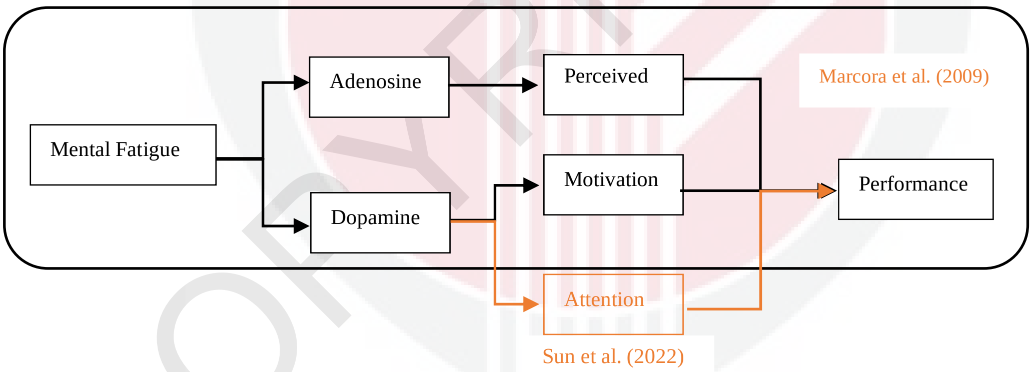


Figure 2.2 : Psychobiological Model of Endurance Performance
[Source: Marcora et al. (2009) and improved by Sun et al. (2022)]

iii. The Third Theory-The Broaden-and-Build Theory

The broaden-and-build theory emphasises the adaptive value of positive emotions, suggesting positive emotions contribute to momentary well-being and have lasting benefits by shaping an individual's perception, thoughts and actions to foster growth and resilience (Fredrickson, 2004). Specifically, positive emotions, such as joy, gratitude, or amusement, are theorised to broaden the individuals' attention (Fredrickson, 2004). When experiencing positive emotion, the attentional scope expands, allowing individuals to perceive a wide range of stimuli and possibilities in the environment; this broadening effect contrasts with the narrowed focus often associated with negative emotions, like fear or anxiety (Fredrickson, 2004). Positive emotion mediates the cognitive control ability by activating dopamine transmission, broadening the scope of attention focusing.

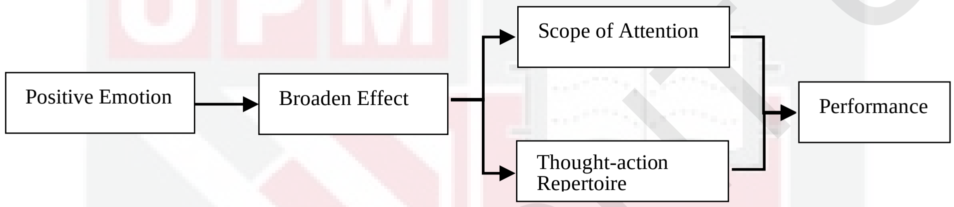


Figure 2.3 : The Broaden Effect of Broaden-and-Build Theory
[Source: Barbara Fredrickson (1998)]

2.6.2 Framework Establishment

The established theoretical framework of this study is shown in Figure 2.4; this framework merged the three distinct theories to illustrate how mental fatigue affects table tennis stroke performance and how music stimulates positive emotion to recover the mental fatigue-induced performance decrement. The orange part is the main contribution of the improved Psychobiological Model of Endurance performance.

The Strength Model of Self-Regulation explains the individual performance decrement due to prior mental exertion, as the individual-exerted self-regulation process depletes the *resource*. The two gist of this resource are *finite* and *global*, which means prior mental exertion led to subsequent performance decrement even in the different tasks (detailed in 2.6.2 section). To exert self-regulation, a depleted resource state is ego-depletion, and sustained ego-depletion leads to a psychobiological state of mental fatigue.

The Broaden Effect of Broaden-and-Build theory illustrates that emotion mediates the cognitive process; specifically, individual experience of positive emotion mediates the scope of attention and thought-action repertoire (Fredrickson & Christine Branigan, 2005). Listening to music induces positive emotion stimuli, increased dopamine transmission, and mental fatigue leads to a decrease in dopamine transmission; this overlapping may indicate mental fatigue-induced performance decrement could be counteracted by listening to music-induced positive emotion.

The Psychobiological Model of Endurance Performance indicates mental fatigue impaired endurance performance decrement mediated by the higher perceived exertion corresponding to decreased motivation rather than cardiorespiratory and musculoenergetic mechanisms. However, the skill performance decrement induced by mental fatigue is not enough explained by higher perceived exertion and motivation. Since mental fatigue activates the ACC, it leads to subsequent performance decrement. ACC is crucial for the cognitive control process, including conflict monitoring, error detection, emotion regulation, decision-making, and attention allocation. According to the improved Psychobiological Model of Endurance performance by Sun et al. (2022), the skill performance decrement by mental fatigue may be mediated by reduced attention control ability.

Although the complication of the brain and the behaviour, the Strength Model of Self-Regulation indicated that prior mental exertion led to the subsequent performance decrement. Improved Psychobiological Model of Endurance Performance illustrates that the mental fatigue activated by the ACC led to increased adenosine transmission with elevated perceived exertion, corresponding to a decrement in dopamine transmission with decreased motivation and attention control. The positive effect of Broaden-and-Build theory explains that listening to music induces positive emotional stimulus; the dopamine transmits, mediates the attention control process, and may be the recovery strategy for counteracting mental fatigue and performance decrement.

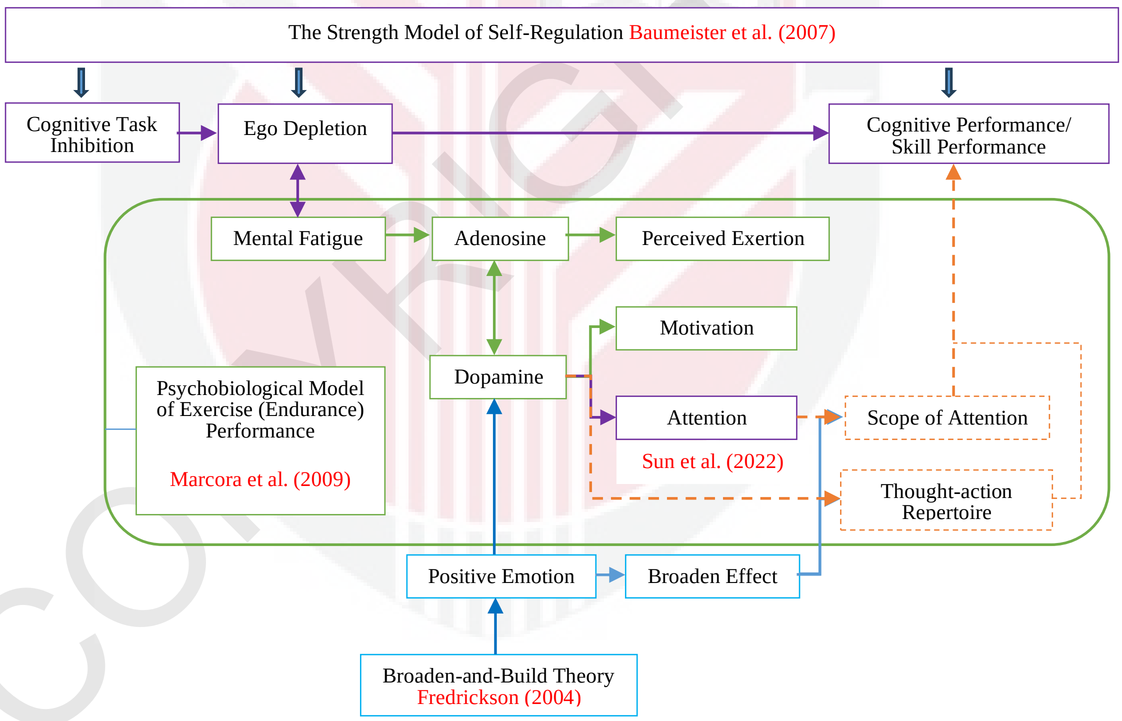


Figure 2.4 : Theoretical Framework of This Study

2.7 Conceptual Framework

The conceptual framework below details the concepts of this study. This study examines the effect of mental fatigue on table tennis stroke performance among university table tennis players. Previous studies suggested that prolonged sustained cognitive tasks led the players to a mental fatigue condition (Mansec et al., 2018; Sun et al., 2022). Therefore, this study examines the effect of mental fatigue on stroke performance among university table tennis players.

On the other hand, listening to music stimulates the emotional response. As the Broaden-and-Build theory suggested, positive emotion mediated the cognitive control process, broadening the scope of attention and thought-action repertoire. Meanwhile, listening to music induced a positive emotional response stimulus for dopamine transmission (Ferreri et al., 2019), as dopamine transmission decreased under mental fatigue conditions (Martin et al., 2018). However, a previous study suggested that music induces positive emotional stimuli and increases dopamine transmission (Ferreri et al., 2019). Thus, this study investigates listening to music to promote recovery of table tennis stork performance decrement caused by mental fatigue.

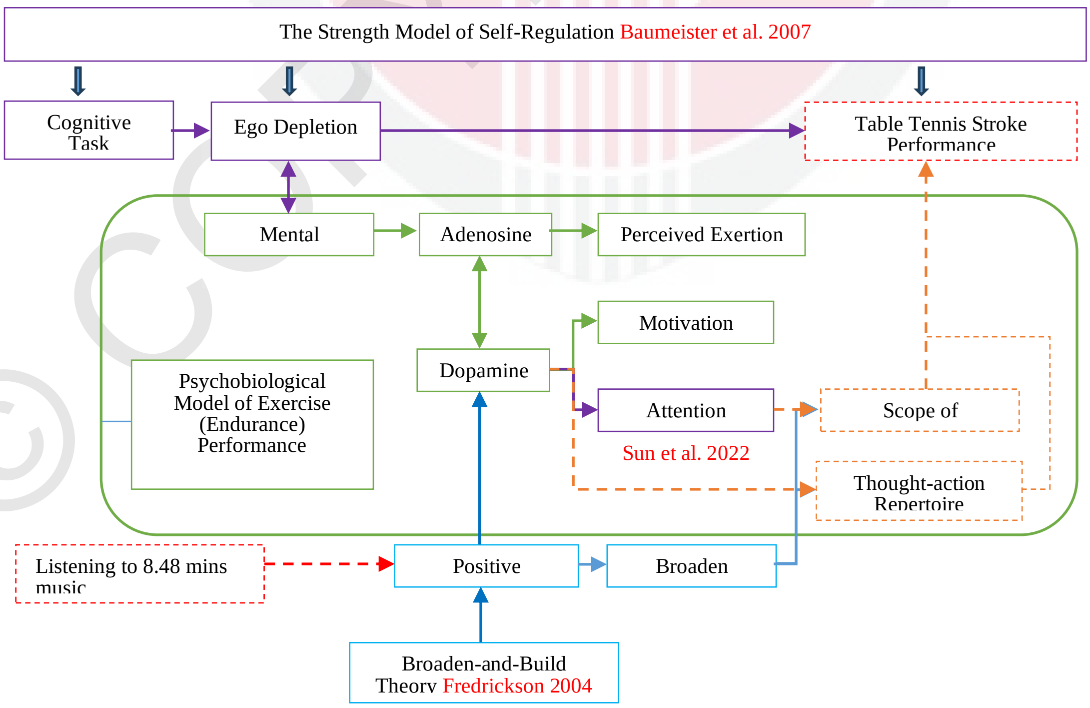


Figure 2.5 : The Conceptual Framework of This Study

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter discussed the research methodology of this study, specifically including (1) study design, (2) subjects, (3) research instruments, (4) developed the interventions, (5) control of the covariant, (6) validation for the protocol, (7) pilot study, (8) data collection procedure, and (9) statistical analyses.

3.2 Study Design

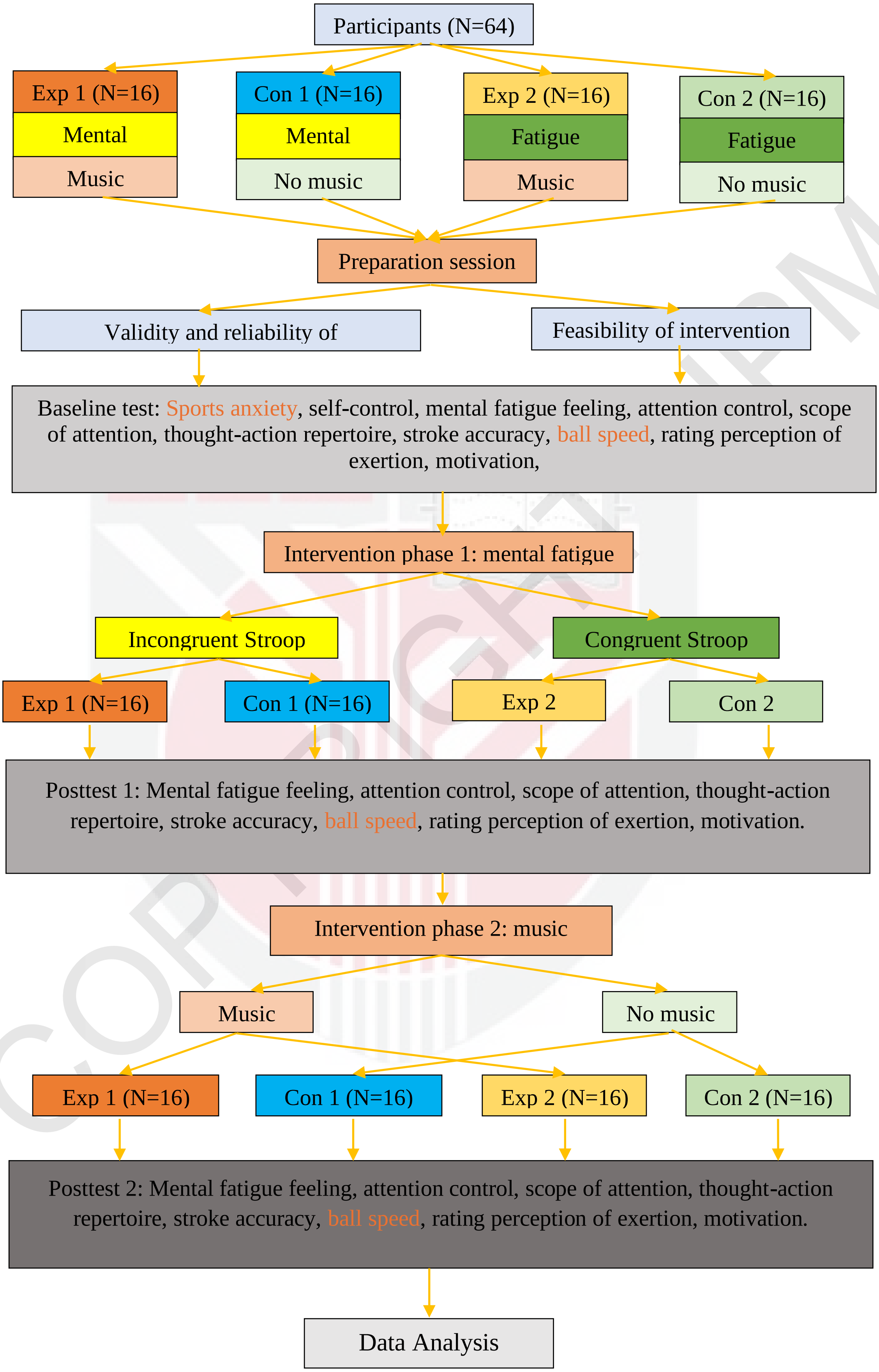
To examine the effects of mental fatigue and music recovery on table tennis stroke performance and psychological factors among university table tennis players. This study was an experimental, pre-test and post-test design study, consisting of cluster randomised controlled trials with four arms. The advantage of RCTs is the straightforward investigation of cause-effect relationships with minimal bias and confounding factors. Meanwhile, RCTs are considered the golden standard for evaluating efficacy in clinical studies and conservative evidence-based medical treatment (Spieth et al., 2016). In this study, mental fatigue inducement and music recovery were the interventions. University table tennis players' mental fatigue feeling, stroke performance and related factors were the dependent variables. Table tennis players in four universities were randomly assigned into four groups. Dependent variables of mental fatigue feeling, stroke performance of stroke accuracy and ball speed, and psychological factors of positive and negative emotion, attention control, scope of attention, thought-action repertoire, perception of exertion and motivation were measured at baseline test, post-test 1 after mental fatigue inducement, and post-test 2 after music recovery. The details are in Figure 3.1 study flow chart.

3.3 Subjects

This section discusses the population and sampling, sample size, inclusion criteria and exclusion criteria, and details are shown in the following sections.

3.3.1 Population and Sampling

The current study was conducted in Huaian City, Jiangsu province of China. Since this study focused on the university table tennis players and the study was designed as cRCT, students from four distinct universities (Huaiyin Institution of Technology, Nanjing Forest University, Jiangsu Food and Parametrical Science College and Jiangsu Electronic Information College) were recruited for this study. The final participants of each cluster were randomly (online randomisation program: *https://www.random.org*) assigned into fatigue music group (FMG), fatigue no music group (FNMG), fatigue control music group (FCMG) and fatigue control no music group (FCNMG)


Participants (N=64)
Exp 1 (N=16)
Mental
Music
Con 1 (N=16)
Mental
No music
Exp 2 (N=16)
Fatigue
Music
Con 2 (N=16)
Fatigue
No music
Preparation session
Validity and reliability of
Feasibility of intervention
Baseline test: Sports anxiety, self-control, mental fatigue feeling, attention control, scope of attention, thought-action repertoire, stroke accuracy, ball speed, rating perception of exertion, motivation,
Intervention phase 1: mental fatigue
Incongruent Stroop
Congruent Stroop
Exp 1 (N=16)
Con 1 (N=16)
Exp 2
Con 2
Posttest 1: Mental fatigue feeling, attention control, scope of attention, thought-action repertoire, stroke accuracy, ball speed, rating perception of exertion, motivation.
Intervention phase 2: music
Music
No music
Exp 1 (N=16)
Con 1 (N=16)
Exp 2 (N=16)
Con 2 (N=16)
Posttest 2: Mental fatigue feeling, attention control, scope of attention, thought-action repertoire, stroke accuracy, ball speed, rating perception of exertion, motivation.
Data Analysis

3.3.2 Sample Size

In experimental study, sample size determination is crucial to establishing a cause-effect relationship and examining the effects between independent and dependent variables. A sample size that is too small will fail to find significance, while a sample size that is too large could waste time and money (Kim & Seo, 2013). Hence, the determination of the appropriate sample size is significant.

Sample size determination could apply the power calculation method, and the effect size, alpha level, power, and effect size interacted. In other words, among these four factors, the acquired three factors could calculate the factor left. Under sample size calculation, effect size, power, and alpha level should be determined (Peterson & Foley, 2021).

i. Sample Size Calculation Based on Effect Size

Effect size represents the magnitude of a change in an outcome, the strength of a relationship, or differences (Peterson & Foley, 2021). The effect size determination of the current study was based on previous studies. The first objective of the current study is to examine mental fatigue's effect on stroke performance among university table tennis players. Thus, the minimal effect size of studies investigating mental fatigue on table tennis stroke performance should be selected. Meanwhile, another objective of this study is to examine the effects of music on the recovery of table tennis stroke performance among mentally fatigued university table tennis players. Hence, the previous studies investigating music intervention on mental fatigue recovery should be selected; detailed information is shown in Table 3.1.

Table 3.1 : Effect Size Calculation for the Variables of This Study

Research objectives	Variables	Extracted data	Effect size f	Reference
Effects of mental fatigue on stroke performance	Mental fatigue	**Pre:14.7 ± 11.6 Post: 55.9 ± 24.5**	0.970	Mansec et al. (2017)
	Attention control	$\eta^2 = 0.309$	0.669	Boksem et al. (2005)
	Perception of exertion	Cohen's $d_z = 0.542$	0.271	Mansec et al. (2017)
	ball speed	Cohen's $d_z = 0.669$	0.335	Mansec et al. (2017)
	Stroke accuracy	Cohen's $d_z = 0.553$	0.277	Mansec et al. (2017)
Effects of music on the recovery of mental fatigue	Pleasant	Cohen's dz = 2.600	1.300	Jacquet et al., 2021
	Mental fatigue	Cohen's dz = 1.134	0.567	Jacquet et al., 2021
	Cognitive/behavioral performance	$\eta^2 = 0.24$	0.563	Guo et al., 2015

The minimal effect size among all variables, including studies examining mental fatigue's effect on table tennis stroke performance and music's recovery on mental fatigue, is 0.271. Then, 0.271 is determined as the effect size of this study to calculate the sample size. Power represents the probability of rejecting the null hypothesis when it is false (Peterson & Foley, 2021). Based on previous studies, this study established a power of 0.80 (Cohen, 2013).

The alpha level refers to whether a study's outcome is statistically significant and indicates the probability of making a type I error, insinuating there is a statistical difference or relationship when there is not. Based on the previous study's suggestion, this study's alpha level was set at 0.05 (Cohen, 2013).

As a result, inputted effect size = 0.271 into G*power 3.1 software with α = 0.05; power (1-β) = 0.8, F-test, ANOVA Repeated measures, within-between interaction was established. As a result, the total sample size was 44, with 83.05% actual statistical power. Detailed in Figure 3.2.

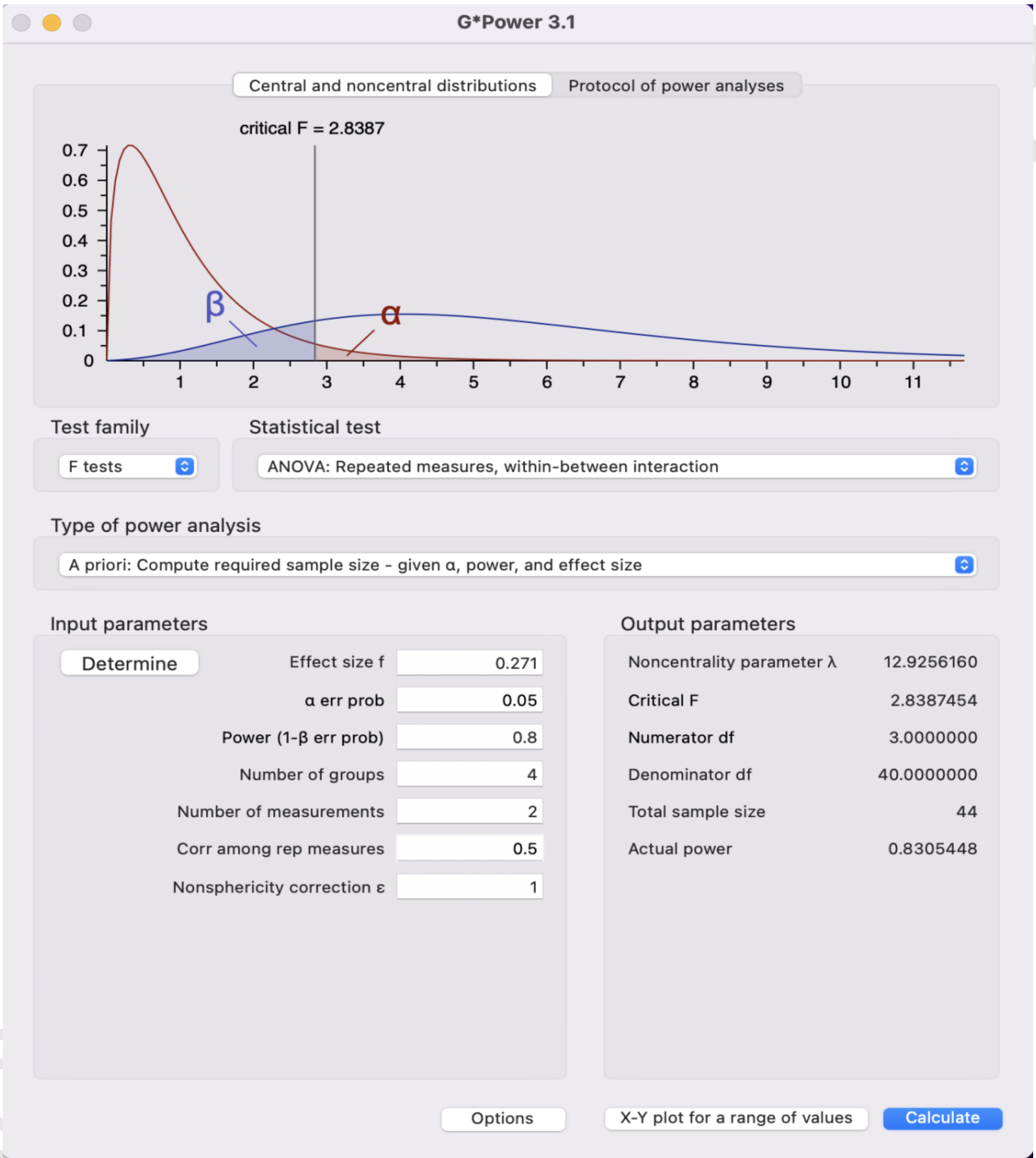


Figure 3.1 : Sample Size Calculation Based on the Repeated Measure within-between Interaction

ii. Sample Size Calculation Based on the Study Design

Considering the current study designed as a cluster-randomised controlled trial, the primary implication of adopting a cRCT is the outcomes of individuals within the same cluster tend to be correlated (Campbell et al., 2005). The statistical measure of the degree of correlation is known as the intra-cluster correlation coefficient (ICC). ICC is defined as the proportion of variation in the outcome that the variation between clusters can explain (Campbell et al., 2005). Hence, reliable estimates of the likely size of ICCs are essential for robust sample size calculation (Campbell et al., 2005). Studies suggested that human research's ICC values should range between 0.01 to 0.02 (Murray & Short, 1995; Murray & Short, 1997). Based on the previous studies, the ICC of this study was set at ICC = 0.01.

The sample size was calculated based on the following equation:

Equation 1:

$$\mathbf{DE = 1+\rho(M-1)}$$

Equation 2:

$$\mathbf{ESS = DE*mk}$$

Where M = number of participants in a cluster, DE = design effect, ESS = effective sample size, k = number of clusters, ρ = intra cluster correlation coefficient (ICC), mk = total number of participants in a cluster study. Therefore, in the present study, the total sample size was:

$$\mathbf{ESS = [1+0.01*(11-1)]*11*4=48.4}$$

iii. Sample Size Calculation Based on the Drop-Out and Rules of the Thumb

The sample size calculation results of the current study is 48.4; for 10% drop-out consideration, the final sample size should be at least 53.78. Since the study was designed as four groups of the current study, there were 14 participants per group, and 56 participants should be enrolled on the current study. However, according to the rule of thumb, previous studies suggest that the minimum sample size of cause-comparative or experimental studies should be 15 per group (RVSPK et al., 2020; Van Belle, 2011). Hence, the final sample size was determined to increase to 16 participants, with eight males and eight females per group, a total of 64 participants enrolled in the current study.

3.3.3 Inclusion and Exclusion Criteria

To fulfil the aims of this study, the effects of mental fatigue on table tennis stroke performance and the effects of music on recovery of stroke performance among mentally fatigued university table tennis players, as well as both inclusion and exclusion criteria for participants, were set. Participant eligibility was assessed using a self-report form administered during the initial screening phase. This form ensured that all participants met the predefined inclusion and exclusion criteria before proceeding to the experimental stage. Detailed information was as follows:

i. Healthy both physically and psychologically

ii. Registered as regular university students in both males and females.

iii. At least two years of table tennis experience

iv. No sleeping difficulties

The exclusion criteria for potential participants should be as follows:

i. Participants with a history of psychological disorders

ii. Participants involved in any other experiment.

iii. Participants who do not enjoy music.

iv. Participants who are colour blind.

The participants included were healthy physically and psychologically. Participants with diseases were not included in the current study. Meanwhile, participants with self-reported sleeping difficulties were excluded from the current study since the sleeping condition affected the outcome (Filipas et al., 2021).

Participants were excluded for the history of psychological disorders to avoid the unforeseen risk of results (Riskind & Alloy, 2006). Meanwhile, participants were involved in any other experiment that could carry crossover effects on the result. Considering that the music was conducted to induce positive emotion, the positive emotion would not be induced successfully if the participant did not enjoy the music (Ballmann, 2021). However, some university students may not be able to enjoy the music, so the exclusion is still set to ensure that participants listening to music-induced positive emotions are successful. At last, the Stroop task involved identifying the colour process; any colour-blind participants were excluded.

3.4 Research Instruments

The dependent variables of this study were measured three times: 1) a baseline test for measuring all the variables at baseline time, 2) post-test 1 measuring all dependent variables to examine the effects of mental fatigue on each dependent variable. And 3) post-test 2 measuring all dependent variables to examine the effects of music on recovery of dependent variables among mentally fatigued university table tennis players. The measurement details and permission for use are in Appendix (A-K). Table 3.2 provides the summary of instruments measuring dependent variables.

Table 3.2 : Summary of Research Instrument

Variable		Instrument	Inventor / Citation	Scale
Dependent variables	Mental fatigue (inducement)	Stroop task	Jensen & Rohwer (1966)	N/A
	Mental fatigue (measurement)	VAS-MF	Hayes (1921)	100 mm
	Positive/ Negative emotion	Emotion report form	Ekman et al. (1980)	9-point Likert scale
	Attention control	ACS	Yang & He (2019)	4-point Likert scale
	Scope of attention	Globe-local processing task	Kimchi & Palmer (1982)	8 points scoring
	Thought-action repertoire	Twenty statement tests	Kuhn & McPartland (2017)	20 items scoring
	Accuracy	Stroke performance test	Mansec et al. (2016)	3 points scoring
	Speed	Stroke performance test	Jiménez-Olmedo et al. (2021)	Video analysis Kinovea software
Secondary variable	Motivation	VAS-Mo	Hayes (1921)	100 mm
	RPE	Borg RPE	Borg (1998)	15 levels
Control variables	Self-control	BSCS	Tan & Guo (2008)	5-point Likert scale
	Sports anxiety	CSAI-2R	Zhu (1994)	4-point Likert scale

Note. N/A: Not applicable, RPE: Rating perception of exertion, VAS-MF: Visual analogy scale for mental fatigue, VAS-Mo: Visual analogy scale for motivation, ACS: Attention control scale, BSCS: Brief self-control scale, CSAI-2R: competitive state anxiety inventory-2, N/A: not applicable

3.4.1 Measurement of Dependent Variables

This study protocol consisted of two-phased interventions. The first phase of intervention is to examine the effect of mental fatigue on university table tennis players' stroke performance and psychological factors. The invention's second phase is to evaluate music's effects on the recovery of mentally fatigued university table tennis players' stroke performance and psychological factors. The dependent variables of the current study consisted of three aspects:

i. The dependent variable of subjective evaluation: 1) Mental fatigue feeling.

ii. Dependent variables of psychological factors: 2) Positive and negative emotion; 3) Attention control; 4) Scope of attention; 5) Thought-action repertoire. 6) Rate perception of exertion; 7) Motivation

iii. Dependent variables of stroke performance 8) Stroke accuracy; 9) ball speed.

1) The Instrument for Measuring Mental Fatigue Feeling

Mental fatigue feeling was evaluated by VAS-Mf (Visual Analogue Scale); participants were instructed to move a single vertical line to evaluate "mental fatigue level". VAS is a 100-mm horizontal line with two anchors, which "0" presents "none at all", and "100" represents the "maximal" fatigue. Studies reported VAS is a valid and easily interpreted measurement for evaluating mental fatigue (Smith et al., 2019). Detailed information has been presented in Appendix D.

2) The Instrument for Measuring Positive and Negative Emotional State

Previous studies suggested listening to music could stimulate the emotional response (Fredrickson & Branigan, 2005). The positive and negative emotional state of this study was evaluated by Emotion Report Forms (Fredrickson & Branigan, 2005). The

Emotional Reported Forms consisted of nine emotions: amusement, anger, anxiety, contentment, disgust, fear, happiness, sadness, and serenity, with 9-point Likert scales (0 = not at all; 8 = a great deal). Participants were instructed to rank the most significant amount of feeling before and right after interventions. A detailed form is presented in Appendix E.

3) The Instrument for Measuring Attention Control

The attention control of this study was measured by the attention control scale (ACS) (Derryberry & Tucker, 1994; Yang & He, 2019)); ACS is a 4-point Likert self-reported questionnaire with 20 items, scoring range (1 = almost never to 4 = always). The ACS consisted of 2 subscales: attention focusing and attention shifting. Participants were instructed to respond to questions based on their current situation. Detailed information is presented in Appendix F.

4) The Instrument for Measuring the Scope of Attention

A Global-local visual processing task measured the scope of attention (Kimchi & Palmer, 1982). The global-local visual processing task consists of 16 items. A stimulus triad consists of a standard figure at the top of the page and two comparison figures at the left and right below the page. Participants were instructed to circle *a* or *b* to respond to the comparison figure similar to the standard figure at their first and most impression (Fredrickson & Branigan, 2005). The judgments could be based on either the global configuration aspect or the local elements (Fredrickson & Branigan, 2005). As shown in Figure 3-3 below, if participants choose comparison a (e.g., triangle made up of triangular elements), it is more similar to the standard figure, meaning participants' choices were based on global configuration. If participants choose comparison *b* (e.g., square made up of squares), which is more similar to the standard figure, their choice was based on the local detail elements. Each global response was marked as one score, otherwise marked as 0. The higher score represented a global bias linked to a broadened scope of attention; otherwise, low scores reflect a local bias related to a narrowed scope of attention.

This study assessed the scope of attention using an 8-item global-local visual processing task since global-local triads with standard figures comprised of few local elements (e.g., 3-4) produced the most variance in responding associated with emotion state (Fredrickson & Branigan, 2005). Detailed information is presented in Appendix G.

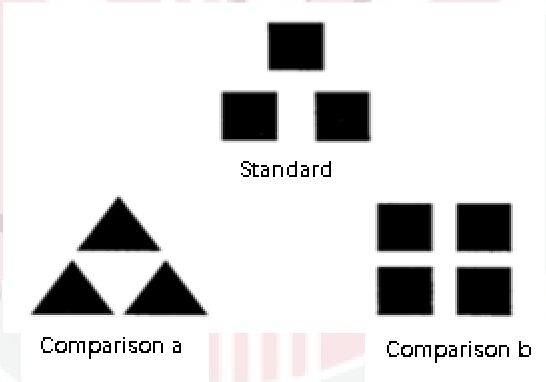


Figure 3.2 : Example Item of Global-Local Visual Processing Task
[Source: kimchi& Palmer, (1982)]

5) The Instrument for Measuring Thought-Action Repertoire

The breadth of the thought-action repertoire was measured by a modified, open-ended Twenty Statements Test (TST) (Fredrickson & Branigan, 2005). Participants were instructed to complete 20 blank lines with: “I would like to _______.” The total number of participant responses was counted, and the score was 0 to 20. Higher scores indicate that participants present a greater range of thought-action responses (Fredrickson & Branigan, 2005). Detailed information is presented in Appendix H.

6) The Instrument for Measuring the Perception of Exertion

Borg RPE measured the perception of exertion (Williams, 2017). The Borg RPE was reported as easily applied in an actual exercise context without adjusting for each exercise. The Borg RPE is a scale (6 = "no exertion at all" and 20 = "maximal exertion"). Participants were instructed to respond to "How hard you are working on the task based on your overall exertion, including physical and mental exertion at the current moment". Detailed information is presented in Appendix I.

7) The Instrument for Measuring the Motivation

The Visual Analogue Scale -Motivation (VAS - Mo) measured motivation toward an upcoming task (Stubbs et al., 2000). Participants were instructed to move a single vertical line to evaluate "motivation toward the subsequent task." VAS is a 100-mm horizontal line with two anchors, where "0" represents "none at all" and "100" means the "maximal" motivation. Studies have reported that VAS–Mo is a valid tool for evaluating motivation for an upcoming task (Sun et al., 2022). Detailed information is presented in Appendix J.

8) The Instrument for Measuring Stroke Accuracy

The table tennis stroke performance test measured stroke accuracy, which scored the total points of the ball location stroked by university table tennis players (Mansec et al., 2016). The parameters of the three accuracy locations are two rectangular targets (80 cm length, 20 cm width) located at 20cm from the tables' edges (both left and right sides). One semicircle 25 cm in diameter was located at the edge's centre (Mansec et al., 2016). The score ranged from 2 points, 1 point and 0 points, and the criteria are as follows: 2 points were granted when the ball reached the target place, 1 point was granted when the ball reached the table but did not touch the target, 0 points was marked when the ball does not reach the table (Mansec et al., 2016). Detailed information is presented in Appendix M.

9) The Instrument for Measuring Ball Speed

Ball speed was measured by video analysis software (Kinovea version 0.9.1), and the high-speed camera was set at 1.0 m away in line with the net from the table's edge. The video recording parameter was set to 1080 progressive scanning, with 240 frames per second. A previous study reported that Kinovea was considered a trustworthy instrument for measuring velocity-based training (Jiménez-Olmedo et al., 2021). The players' mean speed of the ball hit was calculated by averaging the 45 times ball speed values (Mansec et al., 2016). Detailed information is presented in Appendix M.

3.4.2 Measurement of Control Variables

Based on previous studies, sports anxiety could be a factor affecting sports performance (Kleine, 1990; Woodman & Hardy, 2003). Hence, the control variable of sports anxiety was measured to minimise the confounding effects. Furthermore, based on the gist of the theory of the strength model of self-regulation, the trait of self-control might be different among different individuals (Baumeister et al., 2016). Hence, the control variable of self-control was measured to minimise the confounding effects.

1) The Instrument for Measuring Sports Anxiety

Sports anxiety was measured by Revised Competitive State Anxiety–2 (CSAI-2R) (Cox et al., 2003; Zhu, 1994). CSAI-2R is a psychometric tool comprising three distinct subscales: somatic anxiety, cognitive anxiety, and self-confidence anxiety. The somatic anxiety scale comprised seven items. The Cognitive anxiety scale consisted of five items and five items in the self-confidence anxiety subscale. Each item is rated on a 4-point Likert-type scale, while one represents not at all and four represents very much (Cox et al., 2003). Participants were instructed to indicate how they felt the moment before the competition and games (Cox et al., 2003; Zhu, 1994). Detailed information is presented in Appendix K.

2) The Instrument for Measuring Self-Control

Self-control was measured by the Brief Self-control Scale (BSCS). Self-control refers to deliberately modifying or suppressing inter reactions while effectively interrupting undesirable behavioural inclinations and exercising restraint by abstaining from their enactment (Baumeister & Heatherton, 1996). Self-control could be measured by a Self-control scale (SCS) with 36 items. The benefit of BSCS is the reduction of participant burden (Morean et al., 2014). The BSCS is the short-form version measuring Self-control with 13 items. The 13 items of the BSCS consisted of a 5-point rating scale anchored by 1 *(not at all like me)* and 5*(very much like me)*. Participants were instructed to indicate how much each statement was based on their right-moment state (Morean et al., 2014; Tangney et al., 2004). Detailed information is presented in Appendix L.

3.5 Developed the Intervention

This section introduced the interventions and comparisons conducted in four different groups. Regarding this study's study aims, the four groups' interventions were in two phases. The intervention for the first phase was based on the first study's aim: to examine the effects of mental fatigue on table tennis stroke performance and psychological factors among university players. The inducement of mental fatigue was based on previous studies that applied the Stroop task for inducing mental fatigue. Specifical information is detailed in 3.5.1, inducing mental fatigue. The second intervention phase was based on the second study's aims: to examine the effects of listening to music recovery on stroke performance and psychological factors among mentally fatigued university table tennis players. The interventions for different groups are presented in Table 3.3.

The determination of music selection is based on two-phased determination procedures (I, based on the previous literature, reported that the top five inducing positive emotion music lists were selected as the potential music intervention. II, field investigation of Chinese university students based on the top 5 music list to determine the top music inducing the most positive emotion) for developing as the music recovery from mental fatigue. The determination process was detailed in 3.5.2, listening to music recovery for recovery from mental fatigue.

Table 3.3 : Interventions among Four Groups in the Two Phased

Groups	Phase 1	Phase 2
FMG	Incongruent Stroop Task	Music intervention
FNMG	Incongruent Stroop Task	No music
FCMG	Congruent Stroop Task	Music intervention
FCNMG	Congruent Stroop Task	No music

Note: FMG: fatigue music group, FNMG: fatigue no music group, FCMG: fatigue control music group, FCNMG: fatigue control no music group

3.5.1 First Intervention for Inducing Mental Fatigue

Stroop task Instrument for inducing mental fatigue was the Stroop task created by E-Prime software. Several studies reported that the Stroop task could induce mental fatigue successfully (Smith et al., 2019; Sun et al., 2022). The Stroop task requires sustained attention and response inhibition involvement in cognitive processes (MacLeod & MacDonald, 2000). In the Stroop task, coloured words (“red”, “yellow”, “blue”, “green”) were presented one at a time on the computer screen. Participants were instructed to identify the colour of the word while ignoring the meaning of the word itself (e.g., in the word “yellow” with the colour “red”, the correct response should be “red”; any other response was assumed to be a wrong response) (Smith et al., 2019). The trails of the Stroop task for FMG and FNMG were arranged in 100% incongruent (i.e., the word “red” with the colour “blue”), as previous studies have suggested that cognitive tasks involving sustained attention and inhibition induce mental fatigue, with greater involvement of inhibition leading to more pronounced mental fatigue (Smith et al., 2019).

The trials of the Stroop task for the FCMG and FCNMG groups were arranged with 100% congruent stimuli (i.e., the word 'red' displayed in red) for comparison. Participants were instructed to respond to each trial as fast and correctly as possible by pressing the keyboard displayed on the screen. The parameters of the computer version Stroop task were set as "100-point font for 1000ms, followed by feedback "response time" and "correct rate" for 1500ms before the next word displayed." Therefore, 1080 stimuli were used for 45 minutes of the Stroop task with each word 2500ms (Smith et al., 2019). The computer version of the Stroop task was created by the software "E-Prime" (Sun et al., 2022). Detailed information is presented in Appendix C.

3.5.2 Second Intervention: Listening to Music Recovery from Mental Fatigue

The second phase of the intervention is to examine the effects of listening to music on the recovery of mental fatigue. A previous study reported music effectively countering mental fatigue in cognitive performance (Guo et al., 2015). Meanwhile, listening to music stimuli was an effective intervention to induce the change of emotion (Suda et al., 2008). However, the emotional change induced by listening to music depends on the genre of music. Hence, the appropriate music selection was significant in determining positive emotion inducement. Based on the study of Zhou. (2022), which proposed a list of music-inducing emotional responses (Zhou, 2022). The top five music inducing positive emotion were selected; these top five music are shown in Table 3.4.

Table 3.4 : Top 5 Music Lists

Rank	Name of the songs	Inventor
1st	Dreaming	Ryuichi Sakamoto
2nd	Rushin	Ryuichi Sakamoto
3rd	Das Lied von der Erde	Gustav Mahler
4th	The Sea (I. From Dawn to Noon on the Sea)	Claude Debussy
5th	The Galloping Horses	Traditional Chinese Folk Song

Music lists induce emotion response from Zhou. 2022.

To minimise the confounding variables of the music genre that affect the outcome, the top 5 music-induced positive emotions were selected as the potential intervention of this study. Considering the participants were university students, a survey of emotion inducement by music was conducted among university students. A total of 108 responses from university students were received. Details are presented in Tables 3.5 and Figure 3.4.

Table 3.5 : Scoring of Emotion Induced by Music

Emotions	Dreaming	Rushin	Das Lied von der Erde	The Sea	The Galloping Horses
Amusement	5.1	4.43	4.67	3.38	3.81
Anger	1.19	1.45	1.24	1.52	1.43
Anxiety	1.46	1.71	1.34	1.96	1.68
Contentment	4.17	3.61	4.06	3.22	3.4
Disgust	1.23	1.58	1.42	1.66	1.45
Fear	1.06	1.17	1.16	1.69	1.33
Happiness	4.21	3.58	4.08	2.92	3.51

As a result, Ryuichi Sakamoto's song "Dreaming" was reported as the most influential song for evoking positive emotions. Hence, it was determined as the music intervention of the current study.

Considering the duration of music intervention for inducing positive emotion, the previous study reported that 3 minutes of music had already been successful in inducing positive emotion (Putkinen et al., 2017). The duration of the music piece “Dreaming” is 4.24 minutes. However， the “Dreaming” music intervention was played on a loop twice, for 8.48 minutes, to ensure the intervention’s effects. Participants in FMG and FCMG experienced 8.48 minutes of “Dreaming” music with a black screen. Meanwhile, participants in FNMG and FCNMG spent 8.48 minutes on a black screen without music.

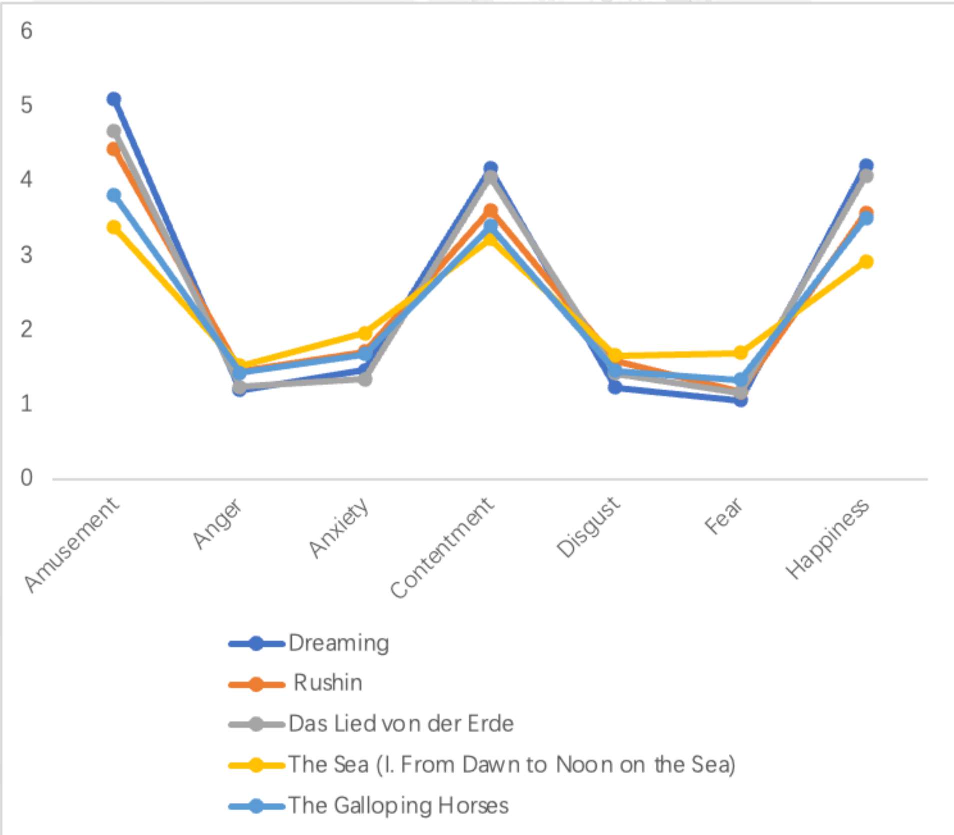


Figure 3.3 : Scoring of Emotion Induced by Music

3.6 Control the Covariant

Mental fatigue intervention covariant control process. Participants in four groups experienced 1080 stimuli for 45 minutes with the same parameters to control covariant factors that affected the outcomes. The differences in Stroop task for inducing mental fatigue between FCMG, FCNMG and FMG, FNMG was the FMG and FNMG experienced 100% incongruent Stroop task stimulus (world-colour 100% unmatched trials). The FCMG and FCNMG experienced the 100% congruent Stroop Task (world-colour 100% matched trials). Participants in the incongruent Stroop task involved both sustained attention and inhibition cognitive processes. In contrast, participants in the congruent Stroop only involved more straightforward sustained attention without the inhibition process; other parameters (i.e., font size, stimuli duration, feedback, and blank screen duration) are the same in the Stroop task.

Music intervention for the mental fatigue recovery covariant control process, to minimise the confounding variables that affected the dependent variables, was inputted to the "Jianyin" video processing software to generate the black screening with and without music. As a result, 8.48 minutes of music "Dreaming" was treated in FMG and FCMG. Meanwhile, the exact duration of 8.48 minutes of black screening without music was treated in FNMG and FCNMG. To minimise confounding factors, music stimulus was broadcasted by headphones (Beats studio) (Axelsen et al., 2020). Also, the participants in no music groups were instructed to wear the headphones without music intervention but only face the black screening in front of the computer to recover.

3.7 Validation for the Protocol

"Content validity" refers to determining the extent to which the dimensions and aspects of a concept can be defined correctly (Sireci, 1998). The intervention was validated by six experts, including one who specialised in cognitive psychology, one expert who specialised in sports psychology, one who specialised in music psychology, one expert who specialised in sports performance, one expert who specialised in sports performance, one expert specialised in positive psychology, and one table tennis coach. The protocol was validated through intervention and measurement. Detailed information was presented in Table 3.6, a list of panels of experts.

Table 3.6 : List of Panels of Experts

No.	Designation	Specialisation	Institution
1	Professor	Cognitive Psychology	SEU
2	Professor	Sports Psychology	SEU
3	Lecturer	Music Psychology	UPM
4	Professor	Sports performance	JSETC
5	Association Professor	Positive Psychology	UPM
6	Coach	Table tennis	JSFPC

SEU： Southeast university, UPM: Universiti Putra Malaysia, JSETC: Jiangsu Electronic Information Technology College, JSFPC: Jiangsu Food and Pharmaceutical Science College

3.7.1 Validity of the Intervention

The content validity of the intervention was analysed by the content validity index (CVI), and each item was ranked on a four-point scale (1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 = highly relevant). The CVI was determined for each item by dividing the number of the experts who ranked 3 or 4 by the total number of experts (Fernández-Domínguez et al., 2016). Scale developers often apply a criterion of 0.83 as CVI's lower acceptability limit (Desai & Patel, 2021).

The Kappa coefficient statistical measure assesses the level of agreement between ratters while accounting for the possibility of agreement occurring by chance. The lowest Kappa value is 0.40, which is an adequate agreement (Viera & Garrett, 2005). The formula is shown as the following:

$$k = \frac{P_o - P_C}{1 - P_C}$$

$$p_c = [N!/A!(N-A)!]^{*}0.5^{N}$$

Po = Observed Agreement, Pc = Expected Agreement, N = Number of experts, A = numbers of agree the item is relevant or clarity

Based on the results of the training program validation. The CVI results suggested that all items achieve an acceptable range with relevance (CVI = 0.833-1.000 and Kappa = 0.816-1.000). Meanwhile, all the items reached acceptable levels for clarity (CVI = 0.833 - 1.000 and Kappa = 0.833 - 1.000). Overall, the intervention of content validity has acceptable content validity. The details are shown in Appendix P.

3.7.2 Validity of the Measurements

The validity of the measurement of this study consisted of field-testing tools and questionnaires.

i. Validity of the Field-Test Tools

The validity of the measurement of the dependent variables, including mental fatigue, was assessed by the Visual Analog Scale (VAS-Mf), the global-local visual processing task measured the scope of attention, thought-action repertoire assessed by the twenty-statement task, stroke accuracy evaluated through stroke performance tests, and ball speed analysed via video analysis using Kinovea software, was established based on a field-tested tool. Additionally, secondary outcomes were evaluated, such as the perception of exertion measured by the Borg RPE scale and motivation assessed by the VAS-Mo. The content validity was determined through an evaluation by six experts. The results indicated an acceptable relevance range (CVI = 0.833–1.000, Kappa = 0.816–1.000) and clarity (CVI = 0.833–1.000, Kappa = 0.816–1.000) for all items. Details are presented in Appendix Q.

ii. Validity of the Questionnaires

The validity of the variables was assessed using questionnaires. The emotion report form measured the dependent variable of emotional state, the attention control scale measured the dependent variable of attention control, the brief self-control scale measured the control variable of self-control, and sports anxiety was measured by the competitive state anxiety inventory - 2. All questionnaires were administered in their Chinese versions, as validated by previous studies (Tan & Guo, 2008; Yang & He, 2019; Zhu, 1994). The results of the Content Validity Index (CVI) indicated an acceptable relevance range for the questionnaires (CVI = 0.833–1.000, Kappa = 0.816–1.000). Similarly, the clarity of all questionnaires was also within the acceptable range (CVI = 0.833–1.000, Kappa = 0.816–1.000). Details are presented in Appendix Q.

3.8 Pilot Study

The pilot study aimed to measure the reliability of all the measurements and examine the feasibility of the interventions.

3.8.1 Testing the Reliability of the Instruments

The instruments of this study consisted of two types of measurement: field-tested tools and questionnaire measurements. There are two distinct methods to test the reliability of the instruments. For the measurements of field-test tools, the reliability was determined by the intra-correlation coefficient (ICC) for test-retest (Weir, 2005). For the questionnaires, Cronbach's alpha was used to test the internal consistency of the questionnaire (Tavakol & Dennick, 2011), and both ICC and Crobach's alpha for reliability were examined since both field-test tool and questionnaire measurement were applied in this study. The details of the results are shown in Table 3.7.

3.8.2 Testing the Feasibility of Experimental

This section examines whether the intervention was appropriate for further experimentation. The study suggested that the pilot study should have 10 - 40 participants and be at least 10% of the sample project. Therefore, the pilot study of this study was determined to have a 24-sample size (six per group). Meanwhile, the same inclusion and exclusion criteria as the main experimental were determined by participant selection.

According to the pilot experiment, the overall feasibility is high. There were no barriers to the intervention process or misunderstanding of the measurement procedure. However, two details were improved. Firstly, the participants were university players; they had heavily major courses to study on the workdays, and they were concerned that heavy course study might cause mental fatigue and affect the result of the experiment. Hence, the main experiments were scheduled on weekends because they had no course. Secondly, the participants in the control group, when they sat and relaxed in front of the computer, were quickly attracted by the environment's noise. The unforeseen environmental stimulation distracted participants; this might be the confounding variable affecting the result. Therefore, participants in the control group were also instructed to wear earphones when they sat and relaxed during the main experiment.

Table 3.7 : Results of Reliability

Measurements	Component	Cronbach's alpha	ICC
VAS-MF	-	-	0.816
VAS-MO	-	-	0.831
RPE	-	-	0.826
Scope of Attention	-	-	0.852
Thought-action repertoire	-	-	0.870
BSCS	-	-	0.851
CSAI-2	Cognitive anxiety	0.792	-
	Somatic anxiety	0.773	-
	Self-confidence	0.794	-
Emotion report form	Positive	0.848	-
	Negative	0.785	-
ACS	Attention focusing	0.786	-
	Attention shifting	0.771	-
Stroke performance	Accuracy: Accuracy	-	0.797
	Accuracy: Fault	-	0.787
	Speed	-	0.766

3.9 Data Collection Procedures

3.9.1 Data Collection Permission by the Ethics Committee

Before the data collection, the protocol and all related documents were sent to the Yancheng NO.1 People's Hospital ethics committee. The ethics committee proposed no objections to ethical issues regarding the current study. The committee issued the approval letter with reference no: 2023-K-168, attached in Appendix O.

3.9.2 Data Collection Permission by Participants

Additionally, a written consent form was provided for participants to sign, indicating their willingness to participate in the study. The consent form ensured that players received sufficiently detailed information about the study, enabling them to make an informed, voluntary, and rational decision regarding their participation.

3.9.3 Data Collection Procedure in Real Experimental

The data collection procedure in real experimental consisted of three sessions: 1) a prepared session, 2) a familiarisation session, and 3) a testing session. Detailed information is presented in Table 3.8 data collection procedures.

Table 3.8 : Data Collection Procedures

Session	Period	Contents
1	Preparation	Instructed the assistants guarantee the result accuracy
2	Familiarization	Familiar with the instruments
3	Testing	Baseline test Mental fatigue intervention Post-test 1 dependent variables Music recovery intervention Post-test 2 dependent variables

i. Prepared Session

One day before the familiarisation, the assistants were given specific instructions. The assistants (1 professor and eight lectures) with sports backgrounds in Jiangsu Food and Pharmacal Science College helped the participants. Each lecture helped two participants; if the lecture addressed a problem that could not be solved, the professor helped them.

Specifically, the contents provided to the participants by the lectures:

1) 3-minute calm-down instruction to the participants.

2) Preparation of the questionnaire and scale to the participants

3) Instructed participants to open the E-prime software to conduct the Stroop task.

4) Recording the participants' stroke performance

5) The researcher instructed the participants to open the music software and wear the headphones for recovery.

6) The researcher collected the results of the test together for further data analysis.

7) Other necessary help if the participants met.

ii. Familiarisation

The familiarisation consisted of two domains: 1) instructed the participants on the experiment's instruments, and each was elaborately described to the participants. 2) instructed participants to get enough sleep (7-9 hours), avoid strenuous exercise, have no alcohol or caffeine intake, and not spend too much time on smartphone use 24 hours before the experiment.

3.9.4 Measurement Procedures

i. Demographic Information Collection

Demographic information, including age, height, weight, and table tennis experience, was collected before the experiment began.

ii. Baseline Test

At the baseline test, participants were instructed to complete the questionnaires and scales based on the most conformance with the current situation: Visual Analogy Scale for Mental Fatigue (VAS-Mf), Motivation to upcoming task (VAS-Mo), Attention control scale (ACS), Emotion state reported form (ESF), Self-control Scale (SCS), Scope of attention task (SOA), Thought-action repertoire (TAR), Perception of exertion (RPE), Competitive State Anxiety Inventory (CSAI-2) and table tennis performance of stroke accuracy and speed were measured at baseline session.

iii. The First Intervention of Mental Fatigue Intervention

In FMG and FNMG, the incongruent Stroop task with the unmatched mean-colour words with a 100-point front was presented on the screen. Participants were instructed to respond to each trial as fast and correctly as possible by pressing the response button they could. Each trail was presented as 1000ms, followed by feedback "response time" and "correct rate" and the blank screen for 1500ms before the next word was displayed." Therefore, 1080 stimuli were used for 45-minute Stroop tasks (Smith et al., 2019). In FCMG and FCNMG, participants experienced the congruent Stroop task, in which the meaning and colour matched the responding task; the participant experienced a congruent Stroop task with no inhibition and reacted with a simple reaction task. Other parameters of the Stroop task were set in the same way as FMG and FNMG.

iv. Post-Test 1

After mental fatigue inducement, participants were instructed to complete the VAS-MF, ESF, ACS, SOA, TAR, RPE, and VAS-MO, and table tennis performance of stroke accuracy and speed was measured immediately after the mental fatigue-inducing task.

v. The Second Intervention of Listening to Music

After post-test 1, participants were instructed to wear the headphones and open the music software. Participants in FMG and FCMG were asked to listen to the 8.48 minutes of "Dreaming" with a black screen and instruction with "no need to try to identify the music but relax as much as possible". Participants in FNMG and FCNMG were instructed to relax for the same duration in front of the black screen and "try to relax yourself as much as possible".

vi. Post-Test 2

After the intervention, participants were instructed to complete the VAS-MF, ESF, ACS, SOA, TAR, RPE, VAS-MO, and table tennis performance of stroke accuracy and speed again immediately after music recovery.

3.10 Statistical Analyses

All statistical analyses of the current study were conducted by SPSS software (Version 26.0, SPSS Inc., Chicago, IL); the significance level of the current study was $p < 0.05$. The statistical analyses were conducted on four domains: (I) the demographic information of participants, (II) the test of assumptions of normality and homogeneity of variances, (III) descriptive statistics analyses of equality of groups at baseline test, (IV) inferential statistics for each of the hypotheses.

Since this study was designed as cRCT, descriptive statistics were conducted for participants' demographic information; Mean and standard deviation were reported. Generalised estimation equations (GEE) were conducted for inferential statistics. GEE was the most frequently utilised in cluster RCTs to determine the intervention's effect on each hypothesis's outcomes (Hardin & Hilbe, 2002). Four tables with one figure were conducted to explain the results of each hypothesis: (I) descriptive statistics Mean, standard errors of variables across the time for groups, (II) interaction effect (group*time) were conducted for analyses, (III) pairwise comparison of each variable within-group, (IV) pairwise comparison of each variable between groups, figures for each variable across the time for all groups was presented for showing the results clearly. The post hoc test was conducted to evaluate the variation in dependent variables. Detailed results were presented in Chapter 4, and each hypothesis and statistical analysis were shown in Table 3.9 the statistical analysis for each hypothesis.

Table 3.9 : The Statistical Analysis for Each Hypothesis

	Hypotheses	Statistical Analysis
H01	There are no significant differences of MF intervention and music recovery on MF feeling among four groups across the time.	Generalized Estimating Equations (GEE)
H02	There are no significant difference of MF and music on positive and negative emotion among four groups across the time.	
H03	There are no significant difference of MF and music on attention control among four groups across the time.	
H04	There are no significant difference of MF and music on scope of attention among four groups across the time.	
H05	There are no significant difference of MF and music Though-action repertoire among four groups across the time.	
H06	There are no significant difference of MF and music on stroke accuracy among four groups across the time.	
H07	There are no significant difference of MF and music on ball speed among four groups across the time.	

CHAPTER 4

RESULTS

4.1 Introduction

This chapter presents the result of mental fatigue on university table tennis players' stroke performance and psychological factors. Meanwhile, the results of music intervention on the recovery of table tennis stroke performance and psychological factors were reported. Firstly, descriptive statistics analysis was used to compare subjects' demographic information, including age, height, weight, and training experience among four groups. Secondly, the assumption of testing the normality, homogeneity, and equality of groups at baseline test were examined. Followed by inferential statistics were used to address the hypotheses of this study. The analyses were based on the hypothesis according to the seven research objectives.

4.2 Test of Assumptions

Before data analysis, the normality and homogeneity of participants' demographic characteristics and confounding variables at the baseline test are tested. Meanwhile, the normality and homogeneity of all continuous dependent variables at baseline test, post-test 1 and post-test 2 were required to be examined to determine the following data analysis.

4.2.1 Normality Test

i. The Normality of Participants' Demographic Characteristics

The Shapiro-Wilk test examined the normality of subjects' demographic characteristics (age, height, weight, and training experience). Based on the results of the Shapiro-Wilk test (Table 4-1), the P-values among the four groups were above 0.05 in age, height, weight, and training experience. Therefore, the demographic characteristics of participants in the four groups were normally distributed. The normality of demographic characteristics is detailed in Table 4.1.

ii. The Normality of Confounding Variables

Before analysing the data, confounding variables were also analysed at baseline to determine the subsequent statistics analyses. The normality of all confounding variables at the baseline test was examined using the Shapiro-Wilk test and based on the results of the normality test (Table 4.1), cognitive anxiety score, self-confidence anxiety, total anxiety score, and self-control met the normal distribution ($P > 0.05$). In contrast, the somatic anxiety score did not meet the normal distribution ($P \leq 0.05$). The normality of confounding variables is detailed in Table 4.1.

iii. The Normality of Dependent Variables

The Shapiro-Wilk test examined the normality of all continuous dependent variables at all three test time points (baseline test, post-test 1, and post-test 2) (Table 4.1). The result presented that the variable of mental fatigue, accuracy numbers, and motivation met the normal distribution ($P > 0.05$). Meanwhile, the other variables of positive emotion, negative emotion, attention focusing, attention shifting, scope of attention, thought-action repertoire, faults numbers, total score, ball speed, and RPE did not meet the normal distribution ($P \leq 0.05$). The normality of dependent variables is detailed in Table 4-1.

4.2.2 Homogeneity Test of Variances

The homogeneity of variance is an assumption of group comparison that tests whether groups meet the equality of variances. The homogeneity for all variables, including demographic characteristics, confounding variables, and the dependent variables at baseline, was conducted using Levene's test.

i. Homogeneity Test of the Participant's Demographic Characteristics

Since all variables regarding the demographic characteristics of participants were normally distributed, Levene's Test evaluated the homogeneity of the groups' demographic characteristics. Based on Levene's test variables of participants in age, height, weight, and experience, the p-values were above 0.05 (Appendix R), indicating the table tennis players' demographic characteristics met the assumption of homogeneity of variances among groups. The homogeneity test of the participant's demographic characteristics is detailed in Appendix R.

Table 4.1 : Normality Test of the Demographic Characteristics, Confounding Variables and Dependent Variables

	Variables	Groups	Baseline test		Post-test 1		Post-test 2	
			Statistic	P value	Statistic	p value	Statistic	p value
Normality of demographic characteristics	Age	FMG	0.921	0.175	/	/	/	/
		FNMG	0.888	0.051	/	/	/	/
		FCMG	0.910	0.114	/	/	/	/
		FCNMG	0.922	0.184	/	/	/	/
	Height	FMG	0.954	0.552	/	/	/	/
		FNMG	0.914	0.133	/	/	/	/
		FCMG	0.902	0.086	/	/	/	/
		FCNMG	0.955	0.566	/	/	/	/
	Weight	FMG	0.960	0.669	/	/	/	/
		FNMG	0.967	0.788	/	/	/	/
		FCMG	0.958	0.632	/	/	/	/
		FCNMG	0.956	0.591	/	/	/	/
	Training experience	FMG	0.935	0.294	/	/	/	/
		FNMG	0.954	0.552	/	/	/	/
		FCMG	0.917	0.148	/	/	/	/
		FCNMG	0.951	0.503	/	/	/	/
	Somatic anxiety	FMG	0.812	0.004	/	/	/	/
		FNMG	0.916	0.145	/	/	/	/
		FCMG	0.803	0.003	/	/	/	/

Table 4.1 : Continued

Normality of confounding variables		FCNMG	0.953	0.539	/	/	/	/
	Cognitive anxiety	FMG	0.938	0.328	/	/	/	/
		FNMG	0.979	0.953	/	/	/	/
		FCMG	0.907	0.104	/	/	/	/
		FCNMG	0.908	0.108	/	/	/	/
	Self-confidence anxiety	FMG	0.95	0.493	/	/	/	/
		FNMG	0.918	0.154	/	/	/	/
		FCMG	0.986	0.995	/	/	/	/
		FCNMG	0.930	0.243	/	/	/	/
	Total anxiety score	FMG	0.952	0.530	/	/	/	/
		FNMG	0.947	0.437	/	/	/	/
		FCMG	0.920	0.169	/	/	/	/
		FCNMG	0.936	0.304	/	/	/	/
	Self-control	FMG	0.958	0.634	/	/	/	/
		FNMG	0.973	0.880	/	/	/	/
		FCMG	0.953	0.546	/	/	/	/
		FCNMG	0.91	0.135	/	/	/	/
	Mental fatigue feeling	FMG	0.934	0.279	0.943	0.381	0.922	0.180
		FNMG	0.921	0.174	0.918	0.156	0.909	0.112
		FCMG	0.956	0.591	0.974	0.894	0.938	0.32
		FCNMG	0.966	0.763	0.925	0.206	0.939	0.336

Table 4.1 : Continued

Normaliy test of dependent variables	Positive emotion	FMG	0.905	0.095	0.942	0.371	0.952	0.515
		FNMG	0.921	0.174	0.907	0.104	0.895	0.067
		FCMG	0.969	0.816	0.918	0.158	0.942	0.378
		FCNMG	0.887	0.049	0.931	0.257	0.933	0.274
	Negative emotion	FMG	0.890	0.055	0.786	0.002	0.648	< 0.001
		FNMG	0.874	0.031	0.780	0.001	0.809	0.004
		FCMG	0.818	0.005	0.787	0.002	0.644	< 0.001
		FCNMG	0.825	0.006	0.878	0.037	0.851	0.014
	Attention focusing	FMG	0.925	0.206	0.918	0.155	0.944	0.405
		FNMG	0.876	0.033	0.961	0.689	0.903	0.090
		FCMG	0.962	0.700	0.944	0.394	0.958	0.625
		FCNMG	0.930	0.248	0.93	0.239	0.928	0.230
	Attention shifting	FMG	0.944	0.405	0.809	0.004	0.961	0.688
		FNMG	0.903	0.0900	0.970	0.841	0.953	0.531
		FCMG	0.958	0.625	0.932	0.263	0.904	0.092
		FCNMG	0.928	0.230	0.949	0.469	0.935	0.297
	Scope of attention	FMG	0.928	0.226	0.829	0.007	0.926	0.209
		FNMG	0.909	0.112	0.945	0.417	0.855	0.016
		FCMG	0.927	0.222	0.748	0.001	0.814	0.004
		FCNMG	0.866	0.024	0.961	0.671	0.874	0.032

Table 4.1 : Continued

Normaliy test of dependent variables	Thought-action Repertoire	FMG	0.932	0.266	0.920	0.170	0.937	0.315
		FNMG	0.880	0.039	0.880	0.039	0.851	0.014
		FCMG	0.914	0.136	0.899	0.077	0.959	0.645
		FCNMG	0.933	0.269	0.962	0.705	0.932	0.261
	Accuracy numbers	FMG	0.962	0.701	0.919	0.164	0.947	0.437
		FNMG	0.896	0.068	0.964	0.728	0.958	0.619
		FCMG	0.970	0.838	0.954	0.556	0.955	0.567
		FCNMG	0.948	0.458	0.981	0.974	0.965	0.748
	Fault numbers	FMG	0.945	0.414	0.924	0.194	0.966	0.763
		FNMG	0.897	0.071	0.952	0.522	0.909	0.112
		FCMG	0.899	0.077	0.928	0.227	0.859	0.019
		FCNMG	0.974	0.892	0.946	0.422	0.975	0.909
	Total Scores	FMG	0.929	0.239	0.920	0.166	0.972	0.870
		FNMG	0.871	0.028	0.983	0.985	0.934	0.280
		FCMG	0.953	0.534	0.964	0.73	0.946	0.431
		FCNMG	0.963	0.715	0.975	0.907	0.930	0.241
	Speed	FMG	0.980	0.963	0.865	0.023	0.951	0.505
		FNMG	0.916	0.144	0.881	0.040	0.967	0.789
		FCMG	0.951	0.498	0.962	0.693	0.936	0.301
		FCNMG	0.916	0.145	0.993	1.000	0.921	0.176

Table 4.1 : Continued

Normaility test of secondary dependent variables	RPE	FMG	0.853	0.015	0.878	0.036	0.921	0.173
		FNMG	0.933	0.269	0.834	0.008	0.886	0.048
		FCMG	0.925	0.205	0.927	0.218	0.884	0.044
		FCNMG	0.814	0.004	0.869	0.026	0.888	0.051
	Motivation	FMG	0.955	0.570	0.937	0.309	0.974	0.902
		FNMG	0.930	0.240	0.954	0.547	0.929	0.235
		FCMG	0.960	0.655	0.954	0.559	0.979	0.953
		FCNMG	0.969	0.820	0.940	0.351	0.916	0.143

ii. Homogeneity Test of the Confounding Variables

Based on the results of Levene's test (Appendix R), confounding variables of cognitive anxiety, self-confidence anxiety, and total anxiety score met the homogeneity of the variance ($P > 0.05$). In contrast, the self-control score did not meet the homogeneity of the variance ($P \leq 0.05$). The homogeneity of confounding variables is detailed in Appendix R.

iii. Homogeneity Test of the Dependent Variables

Based on the result of Levene's test (Appendix R), the variables of mental fatigue feeling, accuracy numbers and motivation met the assumption of homogeneity of variance ($P > 0.05$). The homogeneity of the dependent variables is detailed in Appendix R.

4.2.3 Equality of Groups at Baseline

Checking the equality of groups at the baseline test determined the selection of the following appropriate statistical analyses. The demographic characteristics of participants, confounding variables, and dependent variables met both normal distribution and homogeneity of variance, which was tested by one-way ANOVA.

i. Homogeneous of Participants' Demographic Characteristics

Since the normality and homogeneity test results of participants' demographic characteristics were insignificant ($p > 0.05$), one-way ANOVA was carried out to assess the differences among groups. According to the results of one-way ANOVA (Table 4.2), there were no significant differences among the four groups regarding age ($F = 0.791$, $P = 0.503$), height ($F = 0.156$, $P = 0.926$), weight ($F = 2.042$, $P = 0.118$)

and training experience (F = 0.539, P = 0.658). Therefore, participants in four groups were homogeneous in terms of demographic characteristics.

ii. Equality of Confounding Variables at Baseline Test

Based on the results of the normality test (Table 4.1) and homogeneity of variances test (Appendix R), the confounding variable of cognitive anxiety, self-confidence anxiety and total anxiety score met both normal distribution and homogeneity of variance at the baseline test. Hence, one-way ANOVA was applied to evaluate the differences among groups. Based on the result (Table 4-2), the confounding variable of cognitive anxiety (F = 0.862, P = 0.466); self-confidence anxiety (F = 0.761, P = 0.521) and total anxiety score (F = 0.472, P = 0.703) were met the equality among the four groups at baseline test. The analysis indicating participants' cognitive anxiety, self-confidence anxiety, and total anxiety were homogeneous among groups.

On the other hand, the Kruskal-Wallis H test examined the confounding variables of somatic anxiety and self-control that did not meet normality and homogeneity of variance. The result revealed no significant difference in the variables of somatic anxiety (W = 5.741, P = 0.259) and self-control (W = 0.259, P = 0.967) among four groups (Table 4-2). The analysis indicated that participants' somatic anxiety and self-control were homogeneous among groups.

iii. Equality of Dependent Variables among Groups at Baseline Test

Based on the result of the normality test (Table 4-1) and homogeneity of variance test (Appendix R). The variables of mental fatigue feelings and accuracy numbers met normal distribution and homogeneity of variance at baseline test, based on the result of one-way ANOVA, the variables of mental fatigue feeling ($F = 0.069$, $P = 0.976$), accuracy numbers ($F = 0.301$, $P = 0.825$) and motivation ($F = 0.674$, $P = 0.571$) met the equality of groups at baseline test (Table 4.2). The analysis reveals that dependent variables of mental fatigue feeling and accuracy numbers among groups were equal in the baseline test.

On the other hand, the dependent variables of positive emotion, negative emotion, attention focusing, attention shifting, scope of attention, thought-action repertoire, faults numbers, total score, speed, and RPE did not meet normal distribution. The dependent variable of motivation did not meet the homogeneity of variance and was analysed by the Kruskal-Wallis H test. Based on the results of the Kruskal-Wallis H test (Table 4.2), dependent variables of positive emotion ($W = 0.251$, $P = 0.969$), negative emotion ($W = 0.143$, $P = 0.986$), attention focusing ($W = 3.288$, $P = 0.349$), attention shifting ($W = 2.132$, $P = 0.546$), the scope of attention ($W = 0.237$, $P = 0.971$), thought-action repertoire ($W = 0.770$, $P = 0.857$), faults numbers ($W = 2.537$, $P = 0.469$), the total score ($W = 0.161$, $P = 0.762$), ball speed ($W = 2.338$, $P = 0.505$), and RPE ($W = 1.153$, $P = 0.764$) met the equality among groups at the baseline test ($p > 0.05$). The analysis reveals that the dependent variables among groups were equality in the baseline test.

Table 4.2 : Mean Comparison among Groups for the Demographic Information, Confounding and Dependent Variables at Baseline Test

	Variable	Mean (SD) / Median (IQR)				F/W	P
		FMG	FNMG	FCMG	FCNMG		
Demographic information	Age (year) *a*	20.25 (1.23)	20.56 (0.89)	20.00 (1.09)	20.13 (1.08)	0.791	0.503
	Height (cm) *a*	174.19 (5.86)	174.69 (7.54)	173.44 (5.46)	173.56 (4.19)	0.156	0.926
	Weight (kg) *a*	68.13 (14.01)	74.63 (13.75)	63.19 (13.77)	69.31 (10.75)	2.042	0.118
	Experience (year) *a*	4.06 (1.91)	4.25 (1.44)	4.63 (1.93)	4.75 (1.65)	0.539	0.658
Confounding variables	Cognitive anxiety *a*	18.63 (3.85)	21.13 (6.15)	21.13 (5.01)	20.88 (5.56)	0.869	0.462
	Self-confidence anxiety *a*	26.13 (6.63)	23.63 (4.69)	23.63 (5.28)	24.25 (4.67)	0.775	0.513
	Total anxiety *a*	60.11 (6.58)	62.70 (8.00)	62.79 (8.34)	63.43 (11.08)	0.460	0.711
	Somatic anxiety *b*	14.29 (3.92)	17.14 (5.71)	17.14 (3.93)	17.14 (8.21)	5.741	0.259
	Self-control *b*	39.00 (4.75)	39.00 (5.00)	39.00 (6.50)	39.50 (10.75)	0.259	0.967
Dependent variables	Mental fatigue feeling a	3.19 (1.42)	3.25 (1.61)	3.30 (1.54)	3.08 (1.36)	0.069	0.976
	Accuracy numbers a	18.00 (5.75)	17.75 (4.36)	19.00 (4.97)	17.25 (6.20)	0.301	0.825
	Motivation a	7.76 (1.07)	7.53 (1.78)	7.04 (1.59)	7.29 (1.49)	0.674	0.571
	Positive emotion *b*	4.50 (3.75)	4.50 (2.00)	5.00 (2.00)	5.00 (3.00)	0.251	0.969
	Negative emotion *b*	1.50 (3.50)	1.50 (1.75)	1.00 (3.50)	2.00 (1.00)	0.143	0.986
	Attention focusing *b*	26.00 (3.75)	25.00 (4.00)	26.00 (4.75)	24.00 (6.75)	3.288	0.349
	Attention shifting *b*	24.00 (5.25)	25.00 (2.00)	25.50 (4.75)	25.50 (4.00)	2.132	0.546

Table 4.2 : Continued

	Scope of attention *b*	5.50 (2.75)	5.50 (3.00)	5.00 (2.00)	5.50 (2.00)	0.237	0.971
	Thought-action repertoire *b*	5.50 (5.75)	5.50 (5.50)	5.00 (4.75)	7.00 (3.75)	0.77	0.857
	Faults *b*	7.00 (3.00)	5.50 (1.00)	7.00 (3.00)	6.50 (3.75)	2.537	0.469
	Total score *b*	55.50 (11.50)	57.00 (4.75)	57.00 (10.75)	54.50 (12.50)	1.161	0.762
	Speed *b*	47.45 (4.30)	47.20 (8.08)	46.35 (5.40)	47.65 (4.42)	2.338	0.505
	RPE *b*	8.00 (2.75)	8.00 (1.75)	8.00 (1.75)	8.00 (0.75)	1.153	0.764

a: based on the one way Anova, (Mean and SD), *b*: based on the Kruskal Wallis (Median and IQR),SD: Standard deviation, IQR: interquartile Range

4.3 Inferential Statistics

This section presents the results of inferential statistics to test all research hypotheses. First, the Generalised Estimating Equations (GEE) method was used to analyse this study's seven objectives and corresponding hypotheses. Second, the effect size of the interventions was determined.

4.3.1 First Objective of Mental Fatigue Feelings

The first objective of this study is to examine the effects of mental fatigue and music recovery on subjective feelings of mental fatigue among university table tennis players.

a) Null hypothesis 1: there were no significant differences in the Stroop task on the mental fatigue feeling of table tennis players.

b) Null hypothesis 2: there were no significant differences in music on the recovery of mental fatigue feeling of table tennis players.

The GEE was used to determine if there was a difference in feelings of mental fatigue across the time and groups. Table 4.3 presents the descriptive statistics of mental fatigue in three distinct time points and four groups.

Table 4.3 : Descriptive Statistics (Mean, SE) for MF Feelings

Variable	Time	FMG	FNMG	FCMG	FCNMG
MF feelings	Baseline	3.19 (0.344)	3.25 (0.388)	3.30 (0.372)	3.08 (0.329)
	Post-test 1	7.53 (0.395)	7.43 (0.499)	4.95 (0.350)	5.12 (0.356)
	Post-test 2	5.21 (0.543)	7.22 (0.407)	3.68 (0.424)	4.92 (0.458)

Concerning the impact of the Stroop task on MF feelings (Table 4.4), GEE analysis revealed significant main effects of group ($\chi^2 = 15.030$, $p < 0.05$) and time ($\chi^2 = 217.822$, $p < 0.001$) on MF feelings. The significant interaction effect between group and time ($\chi^2 = 36.919$, $p < 0.001$) suggests that the groups demonstrated varying patterns and changes in MF feelings over time. Similarly, for the effect of music on MF feelings, GEE analysis revealed significant main effects of group ($\chi^2 = 38.545$, $p < 0.001$) and time ($\chi^2 = 24.485$, $p < 0.001$). The significant interaction effect (group*time, $\chi^2 = 18.514$, $p < 0.001$) indicates that the groups exhibited distinct patterns and changes in MF feelings over time.

Table 4.4 : Results of GEE on MF Feeling

Variable	Intervention	Source	Wald Chi-Square	df	p value
MF feelings	Mental fatigue	Group	15.030*	3	< 0.05
		time	217.822*	1	< 0.001
		Group * time	36.919*	3	< 0.001
	Music recovery	Group	38.545*	3	< 0.001
		time	24.485*	1	< 0.001
		Group * time	18.514*	3	< 0.001

*: Significant difference at 0.05 level, df: degree of freedom.

The post hoc test Least Significant Difference (LSD) was utilised to evaluate the difference in MF feeling on the comparison within the group (baseline test vs post-test 1, post-test 1 vs post-test 2, baseline test vs post-test 2) and the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the result of the post hoc test (LSD) (Table 4-5) for within group comparison it was found that the differences in MF feeling between the baseline test and post-test 1 were statistically significant in FMG ($p < 0.01$), FNMG ($p < 0.01$), FCMG ($p < 0.01$), and FCNMG ($p < 0.01$). To explore the magnitude of the effect, Cohen's d effect size (small, $d = 0.2$, medium, $d = 0.5$, and large, $d = 0.8$) was calculated based on the mean and standard deviation. Results of the effect size indicated that after mental fatigue inducement, FMG ($d = 2.835$), FNMG ($d = 2.260$), FCMG ($d = 1.107$), and FCNMG ($d = 1.444$) had a large effect size compared to the baseline test. Meanwhile, the differences in MF feeling between post-test 1 and post-test 2 were statistically significant in FMG ($p < 0.001$) and FCMG ($p < 0.001$) but not statistically significant in FNMG ($p = 0.556$) and FCNMG ($p = 0.591$). Results of the effect size indicated that after the recovery period, FMG ($d = 1.180$) and FCMG ($d = 0.790$) had a large effect size compared to post-test 1.

On the other hand, the differences in MF feeling between the baseline test and post-test 2 were statistically significant in FMG ($p < 0.001$), FNMG ($p < 0.001$) and FCNMG ($p < 0.001$) but not statistically significant in FCMG ($p = 0.515$). Results of the effect size indicated a large effect size in FMG ($d = 1.079$), FCMG ($d = 2.416$), and FCNMG ($d = 1.120$) between post-test 2 and baseline test.

Regarding the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4.5), the differences of MF feeling between FMG and FNMG ($p = 0.904$), FMG and FCMG ($p = 0.824$), FMG and FCNMG ($p = 0.813$), FNMG and FCMG ($p = 0.926$), FNMG and FCNMG ($p = 0.731$), and FCMG and FCNMG ($p = 0.650$) were not statistically significant in the baseline test.

Table 4.5 : Pairwise Comparison of MF Feeling (within group)

Comparison			Group	MD	SE	P value	95% CI		Effect size (d)
							Lower	Upper	
Mental fatigue feeling	Baseline VS	Post-test 1	FMG	-4.338*	0.343	<0.001	-5.009	-3.666	2.835
			FNMG	-4.175*	0.468	<0.001	-5.092	-3.258	2.260
			FCMG	-1.650*	0.479	0.001	-2.589	-0.711	1.107
			FCNMG	-2.044*	0.344	<0.001	-2.718	-1.369	1.444
	Post-test 1 VS	Post-test 2	FMG	2.313*	0.437	<0.001	1.456	3.169	1.180
			FNMG	0.206	0.350	0.556	-0.480	0.893	0.110
			FCMG	1.269*	0.444	<0.001	0.399	2.139	0.790
			FCNMG	0.200	0.372	0.591	-0.530	0.930	0.118
	Baseline VS	Post-test 2	FMG	-2.025*	0.590	0.001	-3.182	-0.868	1.079
			FNMG	-3.969*	0.502	<0.001	-4.952	-2.985	2.416
			FCMG	-0.381	0.585	0.515	-1.528	0.766	0.231
			FCNMG	-1.844*	0.410	<0.001	-2.648	-1.040	1.120

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

According to these results it was found that, the differences in MF feeling between FMG and FCMG ($p < 0.01$), FMG and FCNMG ($p < 0.01$), FNMG and FCMG ($p < 0.01$), FNMG and FCNMG ($p < 0.01$) were statistically significant in the post-test 1, but not statistically significant between FMG and FNMG ($p = 0.875$), FCMG and FCNMG ($p = 0.735$) in the post-test 1. Results of the effect size indicated that large effect size on MF feeling between FMG and FCMG ($d = 1.671$), FMG and FCNMG ($d = 1.603$), FNMG and FCMG ($d = 1.390$), FNMG and FCNMG ($d = 1.288$). On the other hand, in post test 2, the differences in MF feeling between FMG and FNMG ($p < 0.01$), FMG and FCMG ($p < 0.05$), FNMG and FCMG ($p < 0.01$), FNMG and FCNMG ($p < 0.01$), and FCMG and FCNMG ($p < 0.05$) were statistically significant, but not statistically significant between FMG and FCNMG (p = 0.813). Results of the effect size indicated that large effect size on the MF feeling between FMG and FNMG (d = 1.013), FNMG and FCMG (d = 2.060), FNMG and FCNMG (d = 1.286), FMG and FCMG (d = 0.761), FCMG and FCNMG (d = 0.679) in the post-test 2.

Table 4.6 : Pairwise Comparison of MF Feeling (between groups)

	Comparison	MD	SE	P value	95% CI Lower	95% CI Upper	Effect size (d)
Baseline test	FMC VS FNMC	-0.063	0.519	0.904	-1.079	0.954	0.041
	FMC VS FCMG	-0.112	0.506	0.824	-1.105	0.880	0.076
	FMG VS FCNMG	0.112	0.476	0.813	-0.820	1.045	0.081
	FNMG VS FCMG	-0.050	0.538	0.926	-1.103	1.003	0.032
	FNMG VS FCNMG	0.175	0.509	0.731	-0.822	1.172	0.118
	FCMG VS FCNMG	0.225	0.496	0.650	-0.747	1.197	0.155
Post-test 1	FMG VS FNMG	0.100	0.637	0.875	-1.147	1.347	0.054
	FMG VS FCMG	2.575*	0.528	<0.001	1.541	3.609	1.671
	FMG VS FCNMG	2.406*	0.532	<0.001	1.364	3.448	1.603
	FNMG VS FCMG	2.475*	0.610	<0.001	1.280	3.670	1.390
	FNMG VS FCNMG	2.306*	0.613	<0.001	1.105	3.508	1.288
	FCMG VS FCNMG	-0.169	0.499	0.735	-1.147	0.809	0.116
Post-test 2	FMG VS FNMG	-2.006*	0.678	0.003	-3.335	-0.677	1.013
	FMG VS FCMG	1.531*	0.689	0.026	0.181	2.881	0.761
	FMG VS FCNMG	0.294	0.710	0.679	-1.098	1.685	0.142
	FNMG VS FCMG	3.538*	0.588	<0.001	2.386	4.689	2.060
	FNMG VS FCNMG	2.300*	0.612	<0.001	1.100	3.500	1.286
	FCMG VS FCNMG	-1.237*	0.624	0.047	-2.461	-0.014	0.679

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Figure 4.1 presents the mean MF feelings over time. There was an overall increase in MF feelings across all groups, but this effect was more pronounced among the FMG and FNMG groups. Notably, MF feelings remained stable for FNMG and FCNMG groups at post-test 2, while FMG and FCMG groups experienced a decline in MF feelings at post-test 2.

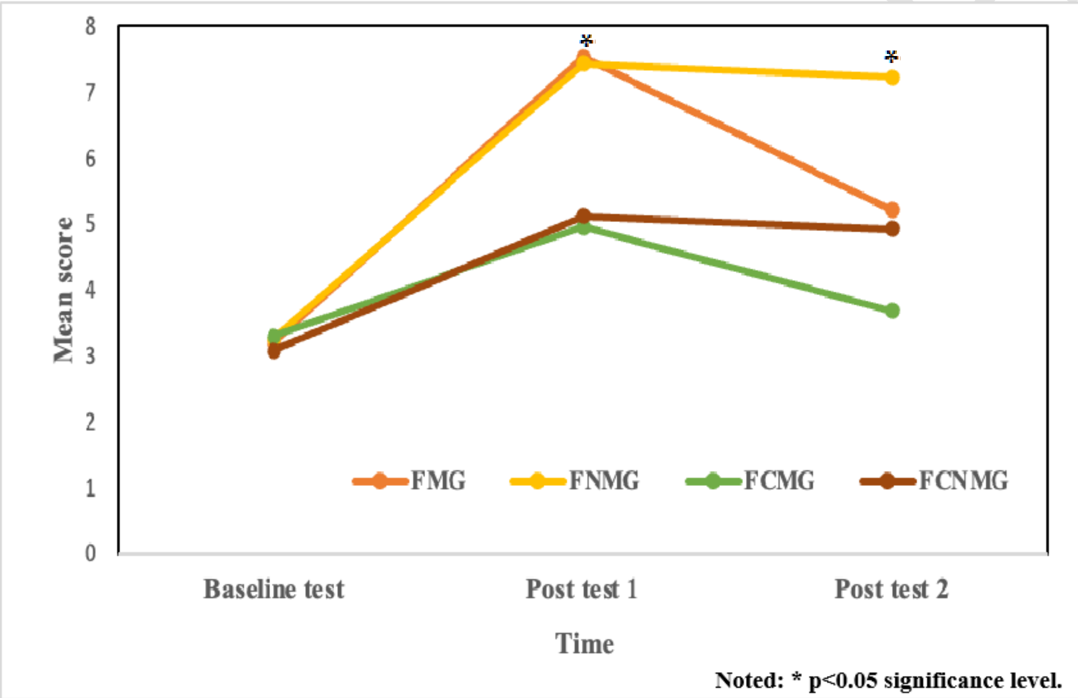


Figure 4.1 : The Mean Scores Changes of Mental Fatigue Feelings across the Times among Groups

4.3.2 Second Objective of Positive and Negative Emotion

The second objective of the current study is to examine the effects of mental fatigue and music recovery on positive and negative emotions among university table tennis players.

a) Null hypothesis 3: there were no significant differences in mental fatigue on the positive emotion scores of table tennis players.

b) Null hypothesis 4: there were no significant differences in music on the recovery of positive emotion scores of table tennis players.

c) Null hypothesis 5: there were no significant differences in mental fatigue on the negative emotion scores of table tennis players.

d) Null hypothesis 6: there were no significant differences in music on the recovery of negative emotion scores of table tennis players.

The GEE was utilised to determine whether positive and negative emotions differed across time and among the groups. Table 4-7 presents descriptive statistics of positive and negative emotions at baseline test, post-test 1, and post-test 2.

Table 4.7 : Descriptive Statistics (Mean, SE) for Positive and Negative Emotion Scores

Variable	Time	FMG	FNMG	FCMG	FCNMG
Positive emotion score	Baseline	4.81 (0.554)	4.69 (0.421)	4.88 (0.432)	4.63 (0.394)
	Post-test 1	4.19 (0.588)	4.50 (0.638)	4.50 (0.612)	4.25 (0.359)
	Post-test 2	6.94 (0.428)	4.00 (0.586)	6.63 (0.780)	4.19 (0.620)
Negative emotion score	Baseline	2.00 (0.415)	1.88 (0.394)	2.13 (0.558)	1.81 (0.283)
	Post-test 1	1.31 (0.315)	1.31 (0.382)	1.19 (0.202)	1.50 (0.234)
	Post-test 2	0.38 (0.150)	1.19 (0.333)	0.50 (0.125)	1.13 (0.263)

Concerning the impact of MF on positive emotions (Table 4.8), GEE analysis revealed no significant main effects of group ($\chi^2 = 0.243$, $p = 0.970$) or time ($\chi^2 = 2.586$, $p = 0.108$). The non-significant interaction effect between group and time ($\chi^2 = 0.548$, $p = 0.908$) suggests that the groups did not exhibit varying patterns or changes in positive emotions over time. In contrast, for the effect of music on positive emotions, GEE analysis revealed a significant main effect of time ($\chi^2 = 20.373$, $p < 0.001$), but no significant main effect of group ($\chi^2 = 6.850$, $p = 0.077$). The significant interaction effect ($\chi^2 = 39.457$, $p < 0.001$) indicates that the groups demonstrated distinct patterns and changes in positive emotions over time.

Regarding the impact of MF on negative emotions (Table 4.8), the GEE analysis revealed a significant change over time ($\chi^2 = 13.316$, $p < 0.001$), but no significant difference between the groups ($\chi^2 = 0.024$, $p = 0.999$) or interaction effect between group and time ($\chi^2 = 1.628$, $p = 0.653$). The results indicate that both the intervention and control groups experienced similar reductions in negative emotions over time, but the MF intervention group did not show a significantly greater reduction than the control group. In contrast, for the effect of music on negative emotions, there was a significant main effect of group ($\chi^2 = 19.307$, $p < 0.001$), but no significant change over time ($\chi^2 = 4.601$, $p = 0.203$) or interaction effect between group and time ($\chi^2 = 6.465$, $p = 0.091$). The results indicate that both the intervention and control groups experienced similar reductions in negative emotions over time, but the music intervention group did not show a significantly greater reduction than the control group.

Table 4.8 : Results of GEE on Positive and Negative Emotion Score

Variable	Intervention	Source	Wald Chi-Square	df	p value
Positive emotion	Mental fatigue	Group	0.243	3	0.970
		time	2.586	1	0.108
		Group * time	0.548	3	0.908
	Music recovery	Group	6.850	3	0.077
		time	20.373*	1	< 0.001
		Group * time	39.457*	3	< 0.001

Table 4.8 : Continued

Negative emotion	Mental fatigue	Group	0.024	3	0.999
		time	13.361*	1	< 0.001
		Group * time	1.628	3	0.653
	Music recovery	Group	4.601	3	0.203
		time	19.307*	1	< 0.001
		Group * time	6.465	3	0.091

*: Significant difference at 0.05 level, df: degree of freedom.

The post hoc test (LSD) was utilised to evaluate the differences in positive and negative emotion scores on the comparison within the group (baseline test vs post-test 1, post-test 1 vs post-test 2, baseline test vs post-test 2) and the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4-10), the differences in positive emotion level between the baseline test and post-test 1 were not statistically significant in FMG ($p = 0.104$); FNMG ($p = 0.690$); FCMG ($p = 0.563$) and FCNMG ($p = 0.341$). Meanwhile, the differences in positive emotion scores between post-test 1 and post-test 2 were not statistically significant in FNMG ($p = 0.238$) and FCNMG ($p = 0.916$) but statistically significant in FMG ($p < 0.01$) and FCMG ($p < 0.01$). The effect size results indicated a larger effect size in FMG ($d = 1.295$) and FCMG ($d = 0.734$) in post-test 2 compared to post-test 1. On the other hand, the differences in positive emotion scores between the baseline test and post-test 2 were not statistically significant in FNMG ($p = 0.147$) and FCNMG ($p = 0.512$) but statistically significant in FMG ($p < 0.01$) and FCMG ($p < 0.05$). Effect size results indicated the large effect size in FMG ($d = 1.039$) and FCMG ($d = 0.672$) at post-test 2 compared to the baseline test.

As for the negative emotion level (Table 4-10), the differences in negative emotion score between the baseline test and post-test 1 were not statistically significant in FCMG ($p = 0.063$) and FCNMG ($p = 0.231$) but statistically significant in FMG ($p < 0.05$) and FNMG ($p < 0.05$). The effect size results indicated a medium effect size in FMG ($d = 0.452$) and FNMG ($d = 0.351$) in post-test 1 compared to the baseline test. Meanwhile, the differences in negative emotion scores between post-test 1 and post-test 2 were not statistically significant in FNMG ($p = 0.590$) and FCNMG ($p = 0.154$) but statistically significant in FMG ($p < 0.01$) and FCMG ($p < 0.01$). Results of effect size showed a large effect size in FMG ($d = 0.919$) and FCMG ($d = 0.991$) in post-test 1 compared to post-test 2. On the other hand, the differences in negative emotion scores between the baseline test and post-test 2 were statistically significant in FMG ($p < 0.01$), FNMG ($p = 0.05$), FCMG ($p < 0.01$) and FCNMG ($p < 0.05$). Results of effect size indicated that the large effect size in FMG ($d = 1.262$) and FCMG ($d = 0.973$), with the medium effect size in FNMG ($d = 0.456$) and FCNMG ($d = 0.609$) in post-test 2 test compared to the baseline test.

Table 4.9 : Pairwise Comparison of Positive and Negative Emotion (within group)

Comparison			Group	MD	SE	P value	95% CI		Effect size (d)
							Lower	Upper	
Positive emotion score	Baseline VS	Post-test 1	FMG	0.625	0.384	0.104	-0.128	1.378	0.265
			FNMG	0.188	0.470	0.690	-0.733	1.108	0.084
			FCMG	0.375	0.649	0.563	-0.897	1.647	0.171
			FCNMG	0.375	0.394	0.341	-0.397	1.147	0.241
	Post-test 1 VS	Post-test 2	FMG	-2.750*	0.400	<0.001	-3.534	-1.966	1.295
			FNMG	0.500	0.424	0.238	-0.331	1.331	0.198
			FCMG	-2.125*	0.467	<0.001	-3.040	-1.210	0.734

Table 4.9 : Continued

		FCNMG	0.063	0.596	0.916	-1.106	1.231	0.030
	Baseline VS Post-test 2	FMG	-2.125*	0.384	<0.001	-2.878	-1.372	1.039
		FNMG	0.688	0.474	0.147	-0.241	1.616	0.326
		FCMG	-1.750*	0.721	0.015	-3.163	-0.337	0.672
		FCNMG	0.438	0.667	0.512	-0.870	1.745	0.204
Negative emotion score	Baseline VS Post-test 1	FMG	0.688*	0.303	0.023	0.095	1.281	0.452
		FNMG	0.563*	0.233	0.016	0.105	1.020	0.351
		FCMG	0.938	0.504	0.063	-0.050	1.925	0.541
		FCNMG	0.313	0.261	0.231	-0.199	0.824	0.292
	Post-test 1 VS Post-test 2	FMG	0.938*	0.257	<0.001	0.433	1.442	0.919
		FNMG	0.125	0.232	0.590	-0.329	0.579	0.084
		FCMG	0.688*	0.211	0.001	0.273	1.102	0.991
		FCNMG	0.375	0.263	0.154	-0.141	0.891	0.365
	Baseline VS Post-test 2	FMG	1.625*	0.352	<0.001	0.9348	2.3152	1.262
		FNMG	0.688	0.350	0.050	0.001	1.374	0.456
		FCMG	1.625*	0.558	0.004	0.531	2.719	0.973
		FCNMG	0.688*	0.276	0.013	0.147	1.228	0.609

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Regarding the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4-11). The differences in positive emotion score between FMG and FNMG (p = 0.857), FMG and FCMG (p = 0.929), FMG and FCNMG (p = 0.783), FNMG and FCMG (p = 0.756), FNMG and FCNMG (p = 0.914), FCMG and FCNMG (p = 0.669) in baseline test were not statistically significant. Meanwhile, the differences in positive emotion score between FMG and FNMG (p = 0.719), FMG and FCMG (p = 0.713), FMG and FCNMG (p = 0.928), FNMG and FCMG ($p = 1.000$), FNMG and FCNMG ($p = 0.733$), FCMG and FCNMG ($p = 0.725$) in pre- test were also not statistically significant. On the other hand, the differences in positive emotion score in post-test 2 between FMG and FCMG ($p = 0.725$); and FNMG and FCNMG ($p = 0.826$) were not statistically significant, but statistically significant between FMG and FNMG ($p < 0.01$), FMG and FCNMG ($p < 0.01$), FNMG and FCMG ($p < 0.01$), FCMG and FCNMG ($p < 0.05$). The results of effect size indicated the large effect size between FMG and FNMG ($d = 1.385$), FMG and FCNMG ($d = 1.249$), FNMG and FCMG ($d = 0.921$), FCMG and FCNMG ($d = 0.837$) in the post-test 2.

Regarding the negative emotion score, based on the post hoc test (LSD) results (Table 4-10). The differences in negative emotion score between FMG and FNMG ($p = 0.827$), FMG and FCMG ($p = 0.857$), FMG and FCNMG ($p = 0.709$), FNMG and FCMG ($p = 0.714$), FNMG and FCNMG ($p = 0.897$), FCMG and FCNMG ($p = 0.617$) in baseline test were not statistically significant. Meanwhile, the differences in negative emotion score between FMG and FNMG ($p = 1.000$), FMG and FCMG ($p = 0.738$), FMG and FCNMG ($p = 0.633$), FNMG and FCMG ($p = 0.773$), FNMG and FCNMG ($p = 0.676$), FCMG and FCNMG ($p = 0.312$) in pre- test were also statistically significant. On the other hand, the differences in negative emotion scores in post-test 2 between FMG and FCMG ($p = 0.522$), FNMG and FCMG ($p = 0.053$), FNMG and FCNMG ($p = 0.883$), but statistically significant between FMG and FNMG ($p < 0.05$), FMG and FCNMG ($p < 0.05$), FCMG and FCNMG ($p < 0.05$). The results of effect size indicated that there was a large effect size between FMG and FNMG ($d = 0.762$), FCMG and FCNMG ($d = 0.734$), and FMG and FCNMG ($d = 0.847$) in the post-test 2.

Table 4.10 : Pairwise Comparison of Positive and Negative Emotion (between groups)

		Comparison	MD	SE	P value	95% CI Lower	95% CI Upper	Effect size (d)
Positive emotion score	Baseline test	FMG VS FNMG	0.125	0.696	0.857	-1.238	1.488	0.062
		FMG VS FCMG	-0.063	0.702	0.929	-1.439	1.314	0.030
		FMG VS FCNMG	0.188	0.679	0.783	-1.144	1.519	0.094
		FNMG VS FCMG	-0.188	0.603	0.756	-1.370	0.995	0.106
		FNMG VS FCNMG	0.063	0.577	0.914	-1.068	1.193	0.037
		FCMG VS FCNMG	0.250	0.585	0.669	-0.896	1.396	0.146
	Post-test 1	FMG VS FNMG	-0.313	0.867	0.719	-2.012	1.387	0.123
		FMG VS FCMG	-0.313	0.849	0.713	-1.976	1.351	0.126
		FMG VS FCNMG	-0.063	0.689	0.928	-1.412	1.287	0.030
		FNMG VS FCMG	0.000	0.884	1.000	-1.732	1.732	0.000
		FNMG VS FCNMG	0.250	0.732	0.733	-1.184	1.684	0.117
		FCMG VS FCNMG	0.250	0.710	0.725	-1.141	1.641	0.121
	Post-test 2	FMG VS FNMG	2.938*	0.726	<0.001	1.515	4.361	1.385
		FMG VS FCMG	0.313	0.890	0.725	-1.432	2.057	0.120
		FMG VS FCNMG	2.750*	0.754	<0.001	1.273	4.227	1.249
		FNMG VS FCMG	-2.625*	0.976	0.007	-4.538	-0.713	0.921
		FNMG VS FCNMG	-0.188	0.853	0.826	-1.860	1.485	0.075
		FCMG VS FCNMG	2.438*	0.996	0.014	0.485	4.391	0.837
Negative emotion score	Baseline test	FMG VS FNMG	0.125	0.572	0.827	-0.996	1.246	0.075
		FMG VS FCMG	-0.125	0.695	0.857	-1.488	1.238	0.062
		FMG VS FCNMG	0.188	0.502	0.709	-0.796	1.171	0.128
		FNMG VS FCMG	-0.250	0.683	0.714	-1.589	1.089	0.125
		FNMG VS FCNMG	0.063	0.485	0.897	-0.888	1.013	0.044
		FCMG VS FCNMG	0.313	0.626	0.617	-0.914	1.539	0.171

Table 4.10 : Continued

Post-test 1	FMG VS FNMG	0.000	0.496	1.000	-0.971	0.971	<0.001
	FMG VS FCMG	0.125	0.374	0.738	-0.609	0.859	0.114
	FMG VS FCNMG	-0.188	0.393	0.633	-0.957	0.582	0.152
	FNMG VS FCMG	0.125	0.432	0.773	-0.723	0.973	0.099
	FNMG VS FCNMG	-0.188	0.448	0.676	-1.066	0.691	0.143
	FCMG VS FCNMG	-0.313	0.309	0.312	-0.918	0.293	0.346
Post-test 2	FMG VS FNMG	-0.813*	0.365	0.026	-1.529	-0.096	0.761
	FMG VS FCMG	-0.125	0.195	0.522	-0.508	0.258	0.219
	FMG VS FCNMG	-0.750*	0.303	0.013	-1.344	-0.156	0.847
	FNMG VS FCMG	0.688	0.356	0.053	-0.010	1.385	0.661
	FNMG VS FCNMG	0.063	0.425	0.883	-0.770	0.895	0.050
	FCMG VS FCNMG	-0.625*	0.291	0.032	-1.196	-0.054	0.734

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Figure 4.2 depicts the mean positive emotion scores over time. All groups exhibited stable positive emotion levels at post-test 1. However, FMG and FCMG groups experienced increased positive emotion scores, while FNMG and FCNMG groups maintained constant levels at post-test 2.

Figure 4.3 illustrates the mean negative emotion scores over time. All groups experienced a decline in negative emotions at both post-test 1 and post-test 2. However, FMG and FCMG groups exhibited a more significant decrease in negative emotions at post-test 2, while FNMG and FCNMG groups experienced a less pronounced decline.

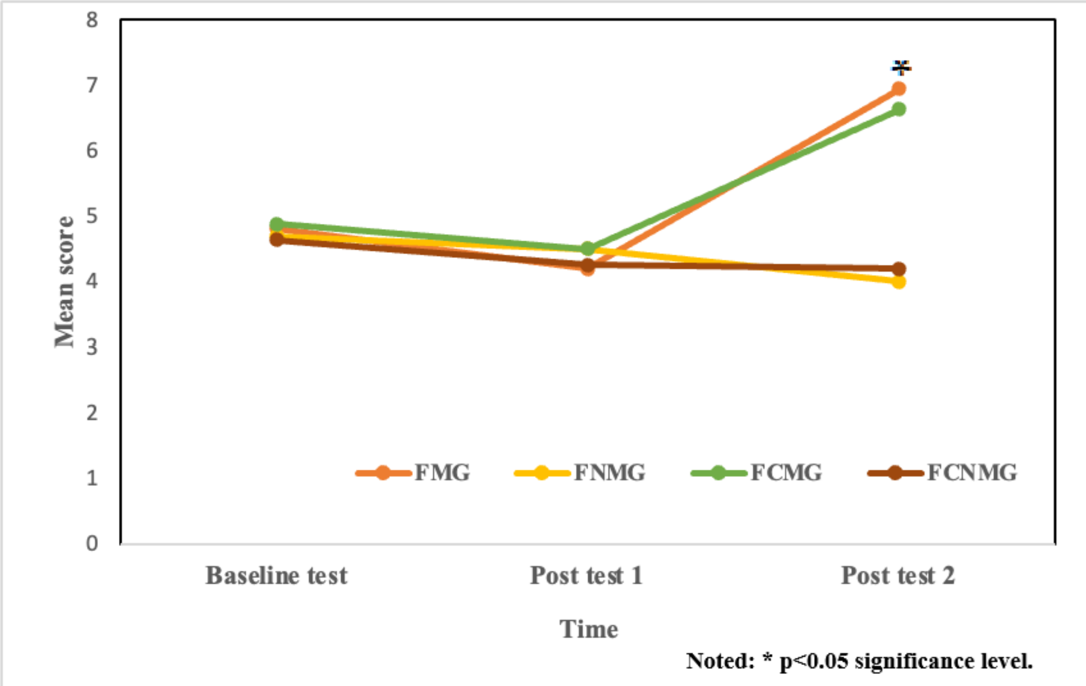


Figure 4.2 : The Mean Scores Changes of Positive Emotion across the Times among Groups

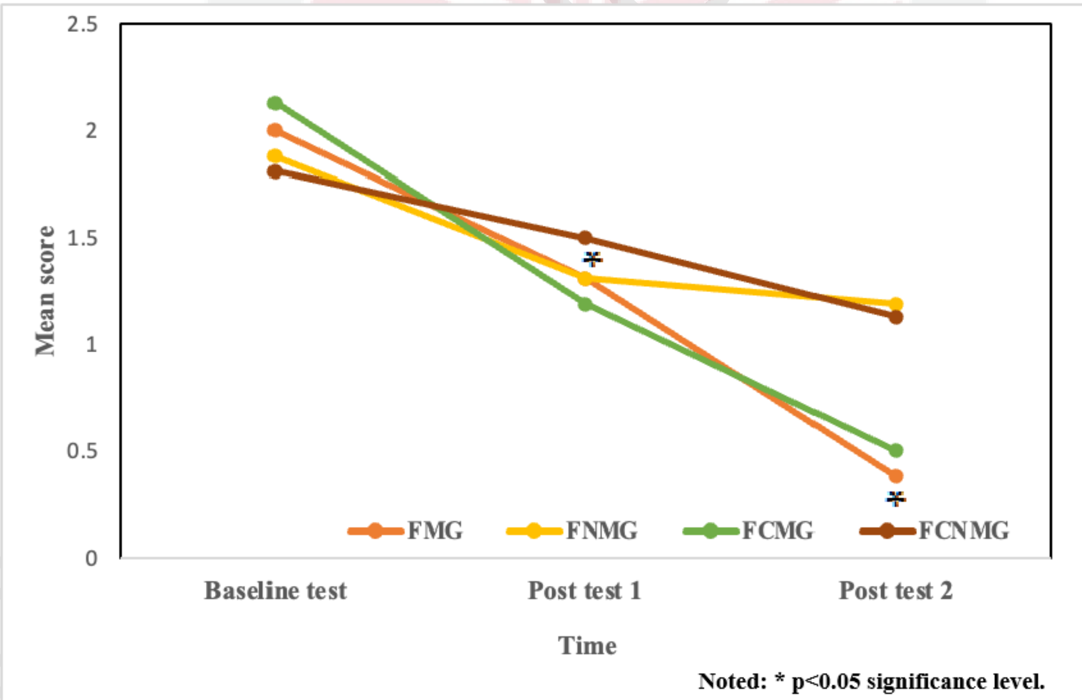


Figure 4.3 : The Mean Scores Changes of Negative Emotion across the Times among Groups

4.3.3 Third Objective of Attention Control

The third objective of the current study is to examine the effects of mental fatigue and music recovery on attention control among university table tennis players.

a) Null hypothesis 7: there were no significant differences in MF on table tennis players' attention focusing.

b) Null hypothesis 8: there were no significant differences in music on the recovery of table tennis players' attention focusing.

c) Null hypothesis 9: there were no significant differences in MF on the table tennis players' attention shifting.

d) Null hypothesis 10: there were no significant differences in music on the recovery of table tennis players' attention shifting.

The GEE was utilised to determine if there was a difference in attention focusing and attention shifting among the four groups. Table 4.11 presents the descriptive statistics of attention focusing and attention shifting for four groups in the baseline test, post-test 1, and post-test 2.

Table 4.11 : Descriptive Statistics (Mean, SE) for Attention Focusing and Attention Shifting

Variable	Time	FMG	FNMG	FCMG	FCNMG
Attention focusing	Baseline	25.56 (0.785)	24.06 (0.583)	25.69 (0.717)	25.13 (1.003)
	Post-test 1	23.06 (0.899)	22.19 (0.509)	23.50 (0.606)	24.50 (0.931)
	Post-test 2	24.44 (0.701)	22.63 (0.441)	24.63 (0.655)	24.06 (0.670)
Attention shifting	Baseline	24.44 (0.701)	24.63 (0.441)	25.63 (0.655)	25.06 (0.670)
	Post-test 1	22.19 (0.444)	21.94 (0.742)	22.88 (0.749)	23.00 (0.910)
	Post-test 2	24.13 (0.458)	22.56 (0.606)	24.94 (0.831)	22.75 (0.916)

Concerning the impact of MF on attention focusing (Table 4.12), GEE analysis revealed a significant change over time ($\chi^2 = 217.822$, $p < 0.001$), but no significant difference between the groups ($\chi^2 = 5.201$, $p = 0.158$). However, the significant interaction effect between group and time ($\chi^2 = 36.919$, $p < 0.05$) indicating that the MF groups had a differential effect on attention focusing compared to the control groups. In contrast, for the effect of music on attention focusing, GEE analysis revealed significant main effects of both time ($\chi^2 = 9.271$, $p < 0.05$) and group ($\chi^2 = 5.041$, $p < 0.05$). The interaction effect between group and time ($\chi^2 = 6.617$, $p = 0.085$). The results indicate that the music intervention and control groups experienced similar reductions in attention focusing over time. Still, the music intervention group did not show a significantly more significant reduction than the control group.

Regarding the impact of MF on attention shifting (Table 4.12), the GEE analysis revealed a significant change over time ($\chi^2 = 21.760$, $p < 0.001$), but no significant difference between the groups ($\chi^2 = 4.059$, $p = 0.255$), nor an interaction effect between group and time ($\chi^2 = 0.297$, $p = 0.961$). The results indicate that the intervention and control groups experienced similar attention-shifting reductions over time. Still, the MF intervention group did not show a significantly more significant reduction than the control group. In contrast, for the effect of music on attention shifting, the GEE analysis revealed a significant main effect of time ($\chi^2 = 19.244$, $p < 0.001$), but no significant main effect of group ($\chi^2 = 3.054$, $p = 0.383$). There was a significant interaction effect between group and time ($\chi^2 = 14.827$, $p < 0.05$), indicating that the music groups had a differential effect on attention shifting compared to the control groups.

Table 4.12 : Results of GEE on Attention Focusing, and Attention Shifting

Variable	Intervention	Source	Wald Chi-Square	df	p value
Attention focusing	Mental fatigue	Group	5.201	3	0.158
		time	217.822*	1	< 0.001
		Group * time	36.919*	3	< 0.05
	Music recovery	Group	9.271*	3	< 0.05
		time	5.041*	1	< 0.05
		Group * time	6.617	3	0.085
Attention shifting	Mental fatigue	Group	4.059	3	0.255
		time	21.760*	1	< 0.001
		Group * time	0.297	3	0.961
	Music recovery	Group	3.054	3	0.383
		time	19.244*	1	< 0.001
		Group * time	14.827*	3	< 0.05

*: Significant difference at 0.05 level, df: degree of freedom.

The post hoc test (LSD) was utilised to evaluate the differences in attention-focusing and attention-shifting scores on the comparison within the group (baseline test vs post-test 1, post-test 1 vs post-test 2, baseline test vs post-test 2) and the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4-14). The differences in attention-focusing scores between the baseline test and post-test 1 in FCNMG ($p = 0.139$) were not statistically significant. Still, there was a significant difference in FMG ($p < 0.01$), FNMG ($p < 0.01$) and FCMG ($p < 0.01$). The result of effect size indicated that there was a large effect size in FNMG ($d = 0.829$), FMG ($d = 0.717$) and FCMG ($d = 0.798$) in the baseline test compared to post-test 1. Meanwhile, the differences in attention focusing score between post-test 1 and post-test 2 in FNMG ($p = 0.460$) and FCNMG ($p = 0.416$)

were not statistically significant, but statistically significant in FMG ($p < 0.05$) and FCMG ($p < 0.05$). The effect size results indicated a medium effect size in FMG ($d = 0.413$) and FCMG ($d = 0.432$) in post-test 2 compared to post-test 1. On the other hand, the differences in attention-focusing scores between the baseline test and post-test 2 in FCMG ($p = 0.175$) and FCNMG ($p = 0.125$) were not statistically significant, but statistically significant in FMG ($p < 0.05$) and FNMG ($p < 0.05$). The effect size results indicated a medium effect size in FMG ($d = 0.366$) and a large effect size in FNMG ($d = 0.673$) in post-test 2 compared to the baseline test.

As for the attention shifting score, based on the results of the post hoc test (LSD) (Table 4.13), the differences of attention shifting score in the baseline test and post-test 1 in FCNMG ($p = 0.070$) were not statistically significant, but statistically significant in FMG ($p < 0.05$), FNMG ($p < 0.05$) and FCMG ($p < 0.01$). The results of the effect size indicated there was a large effect size in FMG ($d = 0.928$), FNMG ($d = 1.066$) and FCMG ($d = 0.946$) in the post-test 1 compared to the baseline test. Meanwhile, the differences in attention shifting score between post-test 1 and post-test 2 in FNMG ($p = 0.196$) and FCNMG ($p = 0.620$) were not statistically significant, but statistically significant in FMG ($p < 0.01$) and FCMG ($p < 0.01$). The effect size results indicated a large effect size in FMG ($d = 1.040$) and a medium effect size in FCMG ($d = 0.631$) in post-test 2 compared to post-test 1. On the other hand, the differences of attention shifting in baseline test and post-test 2 in FMG ($p = 0.726$), FCMG ($p = 0.472$), and FCNMG ($p = 0.052$) were not statistically significant, but statistically significant in FNMG ($p < 0.05$). The effect size results indicated a large effect size in FNMG ($d = 0.942$) in the post-test 2 compared to the baseline test.

Table 4.13 : Pairwise Comparison of Attention Focusing and Attention Shifting Score (within group)

Comparison		Group	MD	SE	P value	95% CI Lower	95% CI Upper	Effect size (d)
Attention focusing	Baseline VS Post-test 1	FMG	2.500*	0.702	<0.001	1.125	3.875	0.717
		FNMG	1.875*	0.551	0.001	0.795	2.955	0.829
		FCMG	2.188*	0.525	<0.001	1.159	3.216	0.798
		FCNMG	0.625	0.423	0.139	-0.204	1.454	0.156
	Post-test 1 VS Post-test 2	FMG	-1.375*	0.592	0.020	-2.536	-0.215	0.413
		FNMG	-0.438	0.593	0.460	-1.599	0.724	0.222
		FCMG	-1.125*	0.499	0.024	-2.103	-0.147	0.432
		FCNMG	0.438	0.537	0.416	-0.616	1.491	0.131
	Baseline VS Post-test 2	FMG	1.125*	0.491	0.022	0.1624	2.0876	0.366
		FNMG	1.438*	0.631	0.023	0.201	2.674	0.673
		FCMG	1.063	0.783	0.175	-0.472	2.597	0.375
		FCNMG	1.063	0.693	0.125	-0.296	2.421	0.000
Attention shifting	Baseline VS Post-test 1	FMG	2.250*	0.966	0.020	0.356	4.144	0.928
		FNMG	2.688*	1.056	0.011	0.618	4.757	1.066
		FCMG	2.750*	1.014	0.007	0.763	4.737	0.946
		FCNMG	2.063	1.137	0.070	-0.166	4.291	0.625
	Post-test 1 VS Post-test 2	FMG	-1.938*	0.428	<0.001	-2.777	-1.098	1.040
		FNMG	-0.625	0.483	0.196	-1.572	0.322	0.223
		FCMG	-2.063*	0.569	<0.001	-3.178	-0.947	0.631
		FCNMG	0.250	0.504	0.620	-0.738	1.238	0.066
	Baseline VS Post-test 2	FMG	0.313	0.891	0.726	-1.435	2.0597	0.128
		FNMG	2.063*	0.859	0.016	0.379	3.746	0.942
		FCMG	0.688	0.955	0.472	-1.184	2.559	0.222
		FCNMG	2.313	1.188	0.052	-0.016	4.641	0.697

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Regarding the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4.14), the differences of attention-focusing score between FMG and FNMG ($p = 0.125$), FMG and FCMG ($p = 0.906$), FMG and FCNMG ($p = 0.731$), FNMG and FCMG ($p = 0.079$); FNMG and FCNMG ($p = 0.360$), FCMG and FCNMG ($p = 0.648$) in baseline test was not statistically significant. Meanwhile, the differences in attention-focusing scores between FMG and FNMG ($p = 0.397$), FMG and FCMG ($p = 0.687$); FMG and FCNMG ($p = 0.267$); FNMG and FCMG ($p = 0.097$); FCMG and FCNMG ($p = 0.368$) in post-test 1 were not statistically significant, but statistically significant between FNMG and FCNMG ($p < 0.05$). Effect size results indicated a large effect between FNMG and FCNMG ($d = 0.746$) in post-test 1. On the other hand, the differences in attention-focusing scores between FMG and FCMG ($p = 0.845$); FMG and FCNMG ($p = 0.699$); FNMG and FCNMG ($p = 0.073$); FCMG and FCNMG ($p = 0.548$) in post-test 2 were not statistically significant, but statistically significant between FMG and FNMG ($p < 0.05$); FNMG and FCMG ($p < 0.05$). The effect size results indicated a large effect size between FMG and FNMG ($d = 0.749$) and FNMG and FCMG ($d = 0.867$) in post-test 2.

Regarding attention shifting score, based on the results of the post hoc test (LSD) (Table 4.14), the differences in attention shifting score between FMG and FNMG ($p = 0.821$), FMG and FCMG ($p = 0.216$), FMG and FCNMG ($p = 0.519$), FNMG and FCMG ($p = 0.205$); FNMG and FCNMG ($p = 0.585$), FCMG and FCNMG ($p = 0.548$) in baseline were not statistically significant. Meanwhile, the differences in attention shifting score between FMG and FNMG ($p = 0.772$), FMG and FCMG ($p = 0.430$), FMG and FCNMG (p = 0.422), FNMG and FCMG (p = 0.374); FNMG and FCNMG (p = 0.366), FCMG and FCNMG (p = 0.916) in post-test 1 were not statistically significant. On the other hand, the differences in attention shifting score between FMG and FCMG (p = 0.392); FMG and FCNMG (p = 0.180); FNMG and FCNMG (p = 0.864); FCMG and FCNMG (p = 0.077) in post-test 2 were not statistically significant, but statistically significant between FMG and FNMG ($p < 0.05$); FNMG and FCMG ($p < 0.05$). Effect size results indicated the large effect size between FMG and FNMG (d = 0.704) and FNMG and FCMG (d = 0.790) in post-test 2.

Table 4.14 : Pairwise Comparison of Attention Focusing and Attention Shifting Score (between groups)

		Comparison	MD	SE	P value	95% CI		Effect size (d)
						Lower	Upper	
Attention focusing	Baseline test	FMG VS FNMG	1.500	0.978	0.125	-0.417	3.417	0.525
		FMG VS FCMG	-0.125	1.063	0.906	-2.209	1.959	0.040
		FMG VS FCNMG	0.438	1.274	0.731	-2.060	2.935	0.118
		FNMG VS FCMG	-1.625	0.924	0.079	-3.435	0.185	0.602
		FNMG VS FCNMG	-1.063	1.160	0.360	-3.337	1.212	0.313
		FCMG VS FCNMG	0.563	1.233	0.648	-1.854	2.979	0.156
	Post test 1	FMG VS FNMG	0.875	1.033	0.397	-1.150	2.900	0.290
		FMG VS FCMG	-0.438	1.084	0.687	-2.563	1.688	0.138
		FMG VS FCNMG	-1.438	1.294	0.267	-3.975	1.100	0.365
		FNMG VS FCMG	-1.313	0.792	0.097	-2.864	0.239	0.568
		FNMG VS FCNMG	-2.313*	1.061	0.029	-4.393	-0.232	0.746
		FCMG VS FCNMG	-1.000	1.111	0.368	-3.178	1.178	0.308
	Post-test 2	FMG VS FNMG	1.813*	0.828	0.029	0.189	3.436	0.749
		FMG VS FCMG	-0.188	0.960	0.845	-2.068	1.693	0.067
		FMG VS FCNMG	0.375	0.970	0.699	-1.526	2.276	0.132

Table 4.14 : Continued

		FNMG VS FCMG	-2.000*	0.789	0.011	-3.547	-0.453	0.867
		FNMG VS FCNMG	-1.438	0.802	0.073	-3.010	0.135	0.614
		FCMG VS FCNMG	0.563	0.937	0.548	-1.274	2.399	0.206
Attention shifting	**Baseline**	FMG VS FNMG	-0.188	0.828	0.821	-1.811	1.436	0.077
		FMG VS FCMG	-1.188	0.960	0.216	-3.068	0.693	0.424
		FMG VS FCNMG	-0.625	0.970	0.519	-2.526	1.276	0.221
		FNMG VS FCMG	-1.000	0.789	0.205	-2.547	0.547	0.434
		FNMG VS FCNMG	-0.438	0.802	0.585	-2.010	1.135	0.187
		FCMG VS FCNMG	0.563	0.937	0.548	-1.274	2.399	0.206
	Post-test 1	FMG VS FNMG	0.250	0.865	0.772	-1.445	1.945	0.099
		FMG VS FCMG	-0.688	0.871	0.430	-2.395	1.020	0.270
		FMG VS FCNMG	-0.813	1.013	0.422	-2.797	1.172	0.346
		FNMG VS FCMG	-0.938	1.055	0.374	-3.004	1.129	0.304
		FNMG VS FCNMG	-1.063	1.174	0.366	-3.364	1.239	0.310
		FCMG VS FCNMG	-0.125	1.179	0.916	-2.436	2.186	0.036
	Post-test 2	FMG VS FNMG	1.563*	0.760	0.040	0.074	3.051	0.704
		FMG VS FCMG	-0.813	0.949	0.392	-2.673	1.048	0.293
		FMG VS FCNMG	1.375	1.025	0.180	-0.633	3.383	0.459
		FNMG VS FCMG	-2.375*	1.029	0.021	-4.391	-0.359	0.790
		FNMG VS FCNMG	-0.188	1.099	0.864	-2.341	1.966	0.058
		FCMG VS FCNMG	2.188	1.237	0.077	-0.238	4.613	0.605

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Figure 4.4 illustrates the mean attention focusing scores over time. At post-test 1, all groups exhibited a decline in attention focusing, with FCNMG showing a less pronounced decrease. However, at post-test 2, FMG and FCMG groups experienced an increase in attention focusing levels, while FNMG and FCNMG groups maintained a stable status.

Figures 4.5 depict the mean attention-shifting scores over time. All groups experienced a decline in attention-shifting at post-test 1. However, at post-test 2, the FMG and FCMG groups demonstrated an increase in attention-shifting levels, while the FNMG and FCNMG groups maintained a stable status.

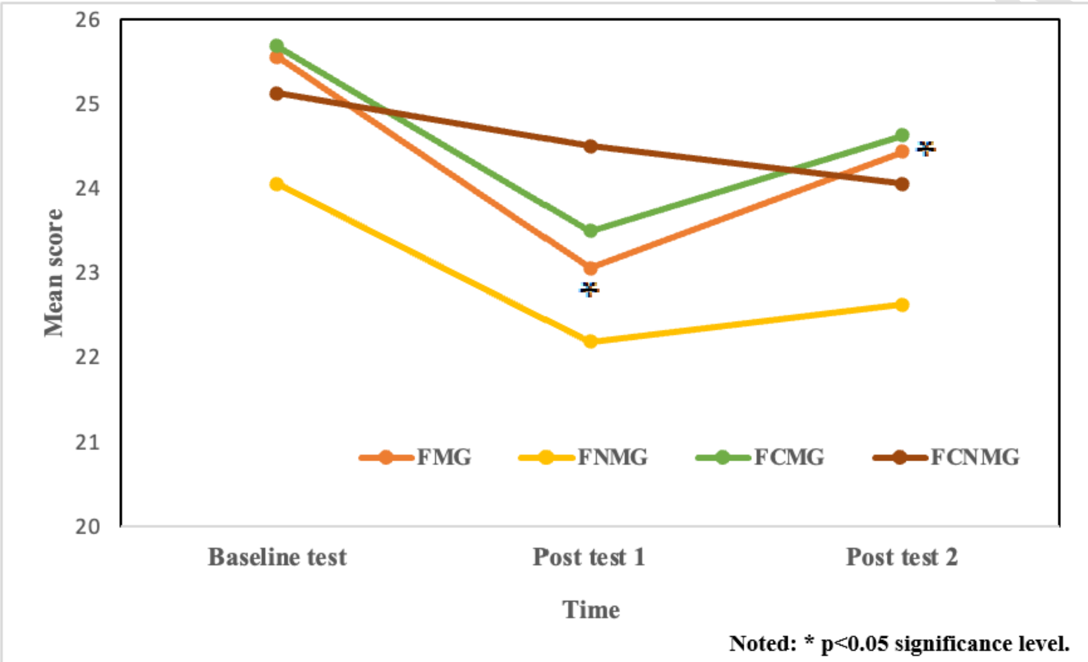


Figure 4.4 : The Mean Scores Changes of Attention Focusing across the Times among Groups

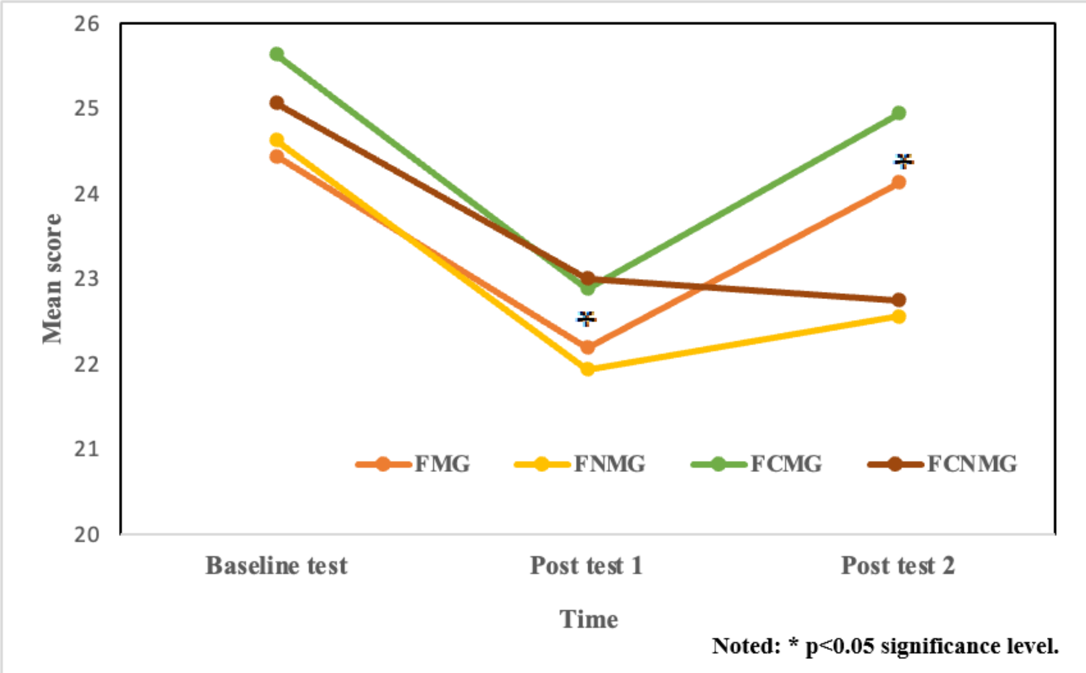


Figure 4.5 : The Mean Scores Changes of Attention Shifting across the Times among Groups

4.3.4 Fourth Objective of the Scope of Attention

The fourth objective of the current study was to examine the effects of mental fatigue and music recovery on the scope of attention among university table tennis players.

a) Null hypothesis 11: there were no significant differences in MF on table tennis scope of attention.

b) Null hypothesis 12: there were no significant differences in music on the recovery of table tennis scope of attention.

The GEE was used to determine whether there was a difference in the scope of attention among groups. Table 4.15 presents descriptive statistics on the scope of attention for four groups at baseline test, post-test 1, and post-test 2.

Table 4.15 : Descriptive Statistics (Mean, SE) for Scope of Attention

Variable	Time	FMG	FNMG	FCMG	FCNMG
Scope of attention	Baseline	5.19 (0.453)	4.94 (0.496)	5.06 (0.272)	4.81 (0.407)
	Post-test 1	3.44 (0.364)	3.50 (0.415)	3.94 (0.225)	3.94 (0.446)
	Post-test 2	4.50 (0.476)	3.88 (0.363)	4.88 (0.174)	4.00 (0.424)

Concerning the impact of MF on the scope of attention (Table 4-16), the GEE analysis revealed a significant change over time ($\chi^2 = 33.697$, $p < 0.001$), but no significant difference between the groups ($\chi^2 = 0.652$, $p = 0.885$), nor an interaction effect between group and time ($\chi^2 = 2.763$, $p = 0.430$). The results indicate that both the MF intervention and control groups experienced similar reductions in the scope of attention over time. Still, the MF intervention group did not show a significantly greater reduction than the control group. Similarly, for the effect of music on the scope of attention, the GEE analysis revealed a significant main effect of time ($\chi^2 = 11.474$, $p < 0.05$) but no significant main effect of group ($\chi^2 = 5.775$, $p = 0.123$). nor an interaction effect between group and time (group*time, $\chi^2 = 7.494$, $p = 0.058$). The results indicate that both the music intervention and control groups experienced similar improvements in scope of attention over time, but the music intervention groups did not show a significantly greater improvement than the control groups.

Table 4.16 : Results of GEE on the Scope of Attention Score

Variable	Intervention	Source	Wald Chi-Square	df	p value
Scope of attention	Mental fatigue	Group	0.652	3	0.885
		time	33.697*	1	< 0.001
		Group * time	2.763	3	0.430
	Music recovery	Group	5.775	3	0.123
		time	11.474*	1	< 0.05
		Group * time	7.494	3	0.058

*: Significant difference at 0.05 level, df: degree of freedom.

The post hoc test (LSD) was utilised to evaluate the differences in the scope of attention on the comparison within the group (baseline test vs post-test 1, post-test 1 vs post-test 2, baseline test vs post-test 2) and the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4-17), the differences in scope of attention between the baseline test and post-test 1 in FMG ($p < 0.01$), FNMG ($p < 0.05$), FCMG ($p < 0.01$) and FCNMG ($p < 0.05$) were statistically significant. The results of effect size indicated that there was a large effect size in FMG ($d = 1.031$), FNMG ($d = 0.761$) and FCMG ($d = 1.091$), and a medium effect size in FCMG ($d = 0.496$). Meanwhile, the differences in scope of attention between post-test 1 and post-test 2 in FNMG ($p = 0.395$) and FCNMG ($p = 0.781$) were not statistically significant, but statistically significant in FMG ($p < 0.01$) and FCMG ($p < 0.01$). The effect size results indicated a large effect size in FCMG ($d = 1.129$) and a medium effect size in FMG ($d = 0.607$) in post-test 2 compared to post-test 1. On the other hand, the differences in the scope of attention between the baseline test and post-test 2 in FMG ($p = 0.118$) and FCMG ($p = 0.619$) were not statistically significant but statistically significant in FNMG ($p < 0.01$) and FCNMG ($p < 0.05$). The effect size results indicated a medium effect size in the FNMG ($d = 0.592$) and FCNMG ($d = 0.473$) between post-test 2 compared to the baseline test.

Table 4.17 : Pairwise Comparison of Scope of Attention (within group)

Comparison			Group	MD	SE	P value	95% CI		Effect size (d)
							Lower	Upper	
Scope of attention	Baseline VS	Post-test 1	FMG	1.750*	0.390	< 0.001	0.985	2.515	1.031
			FNMG	1.438*	0.606	0.018	0.250	2.625	0.761
			FCMG	1.125*	0.352	0.001	0.435	1.815	1.091
			FCNMG	0.875*	0.394	0.026	0.103	1.647	0.496
	Post-test 1 VS	Post-test 2	FMG	-1.063*	0.410	0.009	-1.865	-0.260	0.607
			FNMG	-0.375	0.441	0.395	-1.239	0.489	0.233
			FCMG	-.9375*	0.324	0.004	-1.573	-0.302	1.129
			FCNMG	-0.063	0.225	0.781	-0.503	0.378	0.035

Regarding the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4-18), the differences in scope of attention score between FMG and FNMG ($p = 0.710$), FMG and FCMG ($p = 0.813$), FMG and FCNMG ($p = 0.538$), FNMG and FCMG ($p = 0.825$), FNMG and FCNMG ($p = 0.846$), FCMG and FCNMG ($p = 0.610$) in the baseline test were not statistically significant. Meanwhile, the differences in scope of attention score between FMG and FNMG ($p = 0.910$), FMG and FCMG ($p = 0.243$), FMG and FCNMG ($p = 0.385$), FNMG and FCMG ($p = 0.354$), FNMG and FCNMG ($p = 0.472$), FCMG and FCNMG ($p = 1.000$) in post-test 1 were also not statistically significant. On the other hand, the differences in scope of attention between FMG and FNMG (p = 0.296), FMG and FCMG (p = 0.459), FMG and FCNMG (p = 0.433), FNMG and FCNMG (p = 0.823), FCMG and FCNMG (p = 0.056) in post-test 2 were not statistically significant, but statistically significant between FNMG and FCMG ($p < 0.05$). The effect size results indicated a large effect size between FNMG and FCMG (d = 0.850) in the post-test 2.

Table 4.18 : Pairwise Comparison of Scope of Attention (between groups)

		Comparison	MD	SE	P value	95% CI		Effect size (d)
						Lower	Upper	
Scope of attention	Baseline test	FMG VS FNMG	0.250	0.671	0.710	-1.066	1.566	0.127
		FMG VS FCMG	0.125	0.528	0.813	-0.910	1.160	0.081
		FMG VS FCNMG	0.375	0.609	0.538	-0.818	1.568	0.211
		FNMG VS FCMG	-0.125	0.566	0.825	-1.233	0.983	0.076
		FNMG VS FCNMG	0.125	0.642	0.846	-1.133	1.383	0.067
		FCMG VS FCNMG	0.250	0.490	0.610	-0.710	1.210	0.175
	Post-test 1	FMG VS FNMG	-0.063	0.552	0.910	-1.144	1.019	0.039
		FMG VS FCMG	-0.500	0.428	0.243	-1.339	0.339	0.400
		FMG VS FCNMG	-0.500	0.576	0.385	-1.629	0.629	0.313
		FNMG VS FCMG	-0.438	0.472	0.354	-1.362	0.487	0.318
		FNMG VS FCNMG	-0.438	0.609	0.472	-1.631	0.756	0.246
		FCMG VS FCNMG	0.000	0.500	1.000	-0.979	0.979	0.000
	Post-test 2	FMG VS FNMG	0.625	0.599	0.296	-0.548	1.798	0.357
		FMG VS FCMG	-0.375	0.507	0.459	-1.368	0.618	0.253
		FMG VS FCNMG	0.500	0.637	0.433	-0.749	1.749	0.269
		FNMG VS FCMG	-1.000*	0.403	0.013	-1.789	-0.211	0.850
		FNMG VS FCNMG	-0.125	0.558	0.823	-1.219	0.969	0.077
		FCMG VS FCNMG	0.875	0.458	0.056	-0.023	1.773	0.654

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Figure 4-6 depicts the mean scope of attention scores over time. All groups exhibited a decline in the scope of attention at post-test 1, with FMG and FNMG experiencing a more pronounced decrease compared to FCMG and FCNMG. At post-test 2, FMG and FCMG groups demonstrated an increased scope of attention, while FNMG and FCNMG groups maintained a stable status.

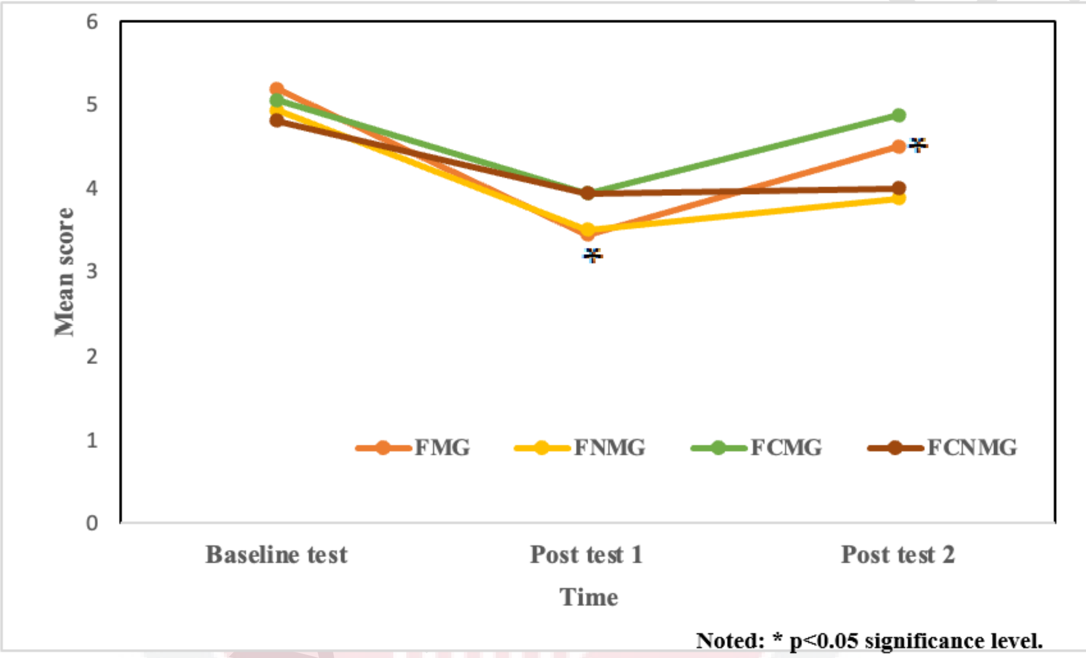


Figure 4.6 : The Mean Scores Changes of Scope of Attention across the Times among Groups

4.3.5 Fifth Objective of Thought-Action Repertoire

The fifth objective of the current study was to examine the effects of mental fatigue and music recovery on thought-action repertoire among university table tennis players.

a) Null hypothesis 13: there were no significant differences in MF on the table tennis players' thought-action repertoire.

b) Null hypothesis 14: there were no significant differences in music on the recovery of table tennis players' thought-action repertoire.

The GEE was utilised to determine the differences in thought-action repertoire scores among groups. Table 4.19 presents descriptive statistics of thought-action repertoire scores for four groups at the baseline, post-test 1, and post-test 2.

Table 4.19 : Descriptive Statistics (Mean, SE) for Thought-Action Repertoire

Variable	Time	FMG	FNMG	FCMG	FCNMG
Thought-action repertoire	Baseline	6.50 (0.750)	6.63 (1.049)	6.31 (0.823)	6.75 (0.583)
	Post-test 1	4.94 (0.519)	4.63 (0.870)	5.44 (0.593)	5.06 (0.676)
	Post-test 2	6.31 (0.498)	4.88 (0.706)	6.06 (0.687)	4.63 (0.432)

Concerning the impact of MF on the thought-action repertoire (Table 4.20), the GEE analysis revealed a significant change over time ($\chi^2 = 31.068$, $p < 0.001$), but no significant difference between the groups ($\chi^2 = 0.105$, $p = 0.991$), nor an interaction effect between group and time ($\chi^2 = 2.948$, $p = 0.400$). The results indicate that both the MF intervention and control groups experienced similar reductions in thought-action repertoire over time. Still, the MF intervention group did not show a significantly more significant reduction than the control groups. In contrast, for the effect of music recovery on thought-action repertoire, the GEE analysis revealed a significant main effect of time ($\chi^2 = 2.428$, $p = 0.119$), but no significant main effect of group ($\chi^2 = 2.554$, $p = 0.466$), nor an interaction effect between group and time ($\chi^2 = 6.965$, $p = 0.073$). The results indicate that the groups did not demonstrate distinct patterns or changes in the thought-action repertoire over time.

Table 4.20 : Results of GEE on Thought-Action Repertoire Score

Variable	Intervention	Source	Wald Chi-Square	df	p value
Thought-action repertoire	Mental fatigue	Group	0.105	3	0.991
		time	31.068*	1	< 0.001
		Group * time	2.948	3	0.400
	Music recovery	Group	2.554	3	0.466
		time	2.428	1	0.119
		Group * time	6.965	3	0.073

*: Significant difference at 0.05 level, df: degree of freedom.

The post hoc test (LSD) was utilised to evaluate the differences in the score of thought-action repertoire on the comparison within the group (baseline test vs post-test 1, post-test 1 vs post-test 2, baseline test vs post-test 2) and the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4.22), the differences in the score of thought-action repertoire between baseline test and post-test 1 in FMG ($p < 0.01$), FNMG ($p < 0.01$), FCMG ($p < 0.05$), FCNMG ($p < 0.01$) was statistically significant. The results of effect size indicated there were medium effect sizes in FMG ($d = 0.586$), FNMG ($d = 0.502$), FCNMG ($d = 0.647$), and small effect sizes in FCMG ($d = 0.295$) in the post-test 1 compared to the baseline test. Meanwhile, the differences in the score of thought-action repertoire between post-test 1 and post-test 2 in FNMG ($p = 0.762$), FCMG ($p = 0.139$), FCNMG ($p = 0.434$) were not statistically significant, but statistically significant in FMG ($p < 0.01$). The effect size results indicated a large effect size in FMG ($d = 0.655$) in post-test 1 compared to post-test 2. On the other hand, the differences in the score of thought-action repertoire between the baseline test and post-test 2 in FMG ($p = 0.724$), FNMG (p = 0.084), and FCMG (p = 0.682) were not statistically significant, but statistically significant in FCNMG (p < 0.01). Results of the effect size indicated that FCNMG (d = 1.003) had a large effect size in the baseline test compared to post-test 2.

Table 4.21 : Pairwise Comparison of Thought-Action Repertoire (within group)

Comparison			Group	MD	SE	P value	95% CI		Effect size (d)
							Lower	Upper	
Thought-action	Baseline VS	Post-test 1	FMG	1.563*	0.492	0.001	0.598	2.527	0.586
			FNMG	2.000*	0.612	0.001	0.800	3.200	0.502
			FCMG	0.875*	0.404	0.030	0.084	1.667	0.295
			FCNMG	1.688*	0.654	0.010	0.406	2.969	0.647
	Post-test 1 VS	Post-test 2	FMG	-1.375*	0.423	0.001	-2.204	-0.546	0.655
			FNMG	-0.250	0.827	0.762	-1.871	1.371	0.076
			FCMG	-0.625	0.423	0.139	-1.454	0.204	0.236
			FCNMG	0.438	0.559	0.434	-0.658	1.533	0.187
	Baseline VS	Post-test 2	FMG	0.188	0.532	0.724	-0.8551	1.2301	0.071
			FNMG	1.750	1.014	0.084	-0.237	3.737	0.474
			FCMG	0.250	0.609	0.682	-0.944	1.444	0.080
			FCNMG	2.125*	0.618	0.001	0.914	3.336	1.003

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Regarding the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4.23), the differences in the score of thought-action repertoire between FMG and FNMG (p = 0.923); FMG and FCMG (p = 0.866); FMG and FCNMG (p = 0.792); FNMG and FCMG (p = 0.815); FNMG and FCNMG (p = 0.917); FCMG and FCNMG (p = 0.664) in baseline test were not statistically significant. Meanwhile, the differences in the score of thought-action repertoire between FMG and FNMG (p = 0.758); FMG and FCMG (p = 0.526); FMG and FCNMG (p = 0.883); FNMG and FCMG (p = 0.440); FNMG and FCNMG (p = 0.691); FCMG and FCNMG (p = 0.677) were in post-test 1 were not statistically significant. On the other hand, the differences in the score of thought-action repertoire between FMG and FNMG (p = 0.096), FMG and FCMG (p = 0.768); FNMG and FCMG (p = 0.228), FNMG and FCNMG (p = 0.763); FCMG and FCNMG (p = 0.077) in post-test 2 were not statistically significant, but statistically significant between FMG and FCNMG ($p < 0.05$). Results of effect size indicated a large effect size between FMG and FCNMG (d = 0.877) in post-test 2.

Table 4.22 : Pairwise Comparison of Thought-Action Repertoire (between groups)

		Comparison	MD	SE	P value	95% CI		Effect size (d)
						Lower	Upper	
Thought-action repertoire	Baseline test	FMG VS FNMG	-0.125	1.290	0.923	-2.653	2.403	0.033
		FMG VS FCMG	0.188	1.114	0.866	-1.995	2.370	0.058
		FMG VS FCNMG	-0.250	0.950	0.792	-2.112	1.612	0.090
		FNMG VS FCMG	0.313	1.333	0.815	-2.301	2.926	0.080
		FNMG VS FCNMG	-0.125	1.200	0.917	-2.477	2.227	0.036
		FCMG VS FCNMG	-0.438	1.009	0.664	-2.414	1.539	0.148
	Post-test 1	FMG VS FNMG	0.313	1.013	0.758	-1.673	2.298	0.106
		FMG VS FCMG	-0.500	0.788	0.526	-2.044	1.044	0.217
		FMG VS FCNMG	-0.125	0.852	0.883	-1.795	1.545	0.055
		FNMG VS FCMG	-0.813	1.053	0.440	-2.876	1.251	0.264
		FNMG VS FCNMG	-0.438	1.102	0.691	-2.597	1.722	0.136
		FCMG VS FCNMG	0.375	0.899	0.677	-1.387	2.137	0.143

Table 4.22 : Continued

Post-test 2	FMG VS FNMG	1.438	0.864	0.096	-0.256	3.131	0.569
	FMG VS FCMG	0.250	0.849	0.768	-1.413	1.913	0.101
	FMG VS FCNMG	1.688*	0.659	0.010	0.396	2.979	0.877
	FNMG VS FCMG	-1.188	0.986	0.228	-3.119	0.744	0.412
	FNMG VS FCNMG	0.250	0.828	0.763	-1.373	1.873	0.103
	FCMG VS FCNMG	1.438	0.812	0.077	-0.154	3.029	0.606

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Figure 4.7 illustrates the mean thought-action repertoire scores over time. All groups experienced a decline in thought-action repertoire at post-test 1. However, at post-test 2, FMG and FCMG groups demonstrated increased thought-action repertoire levels, while FNMG and FCNMG groups maintained a stable status.

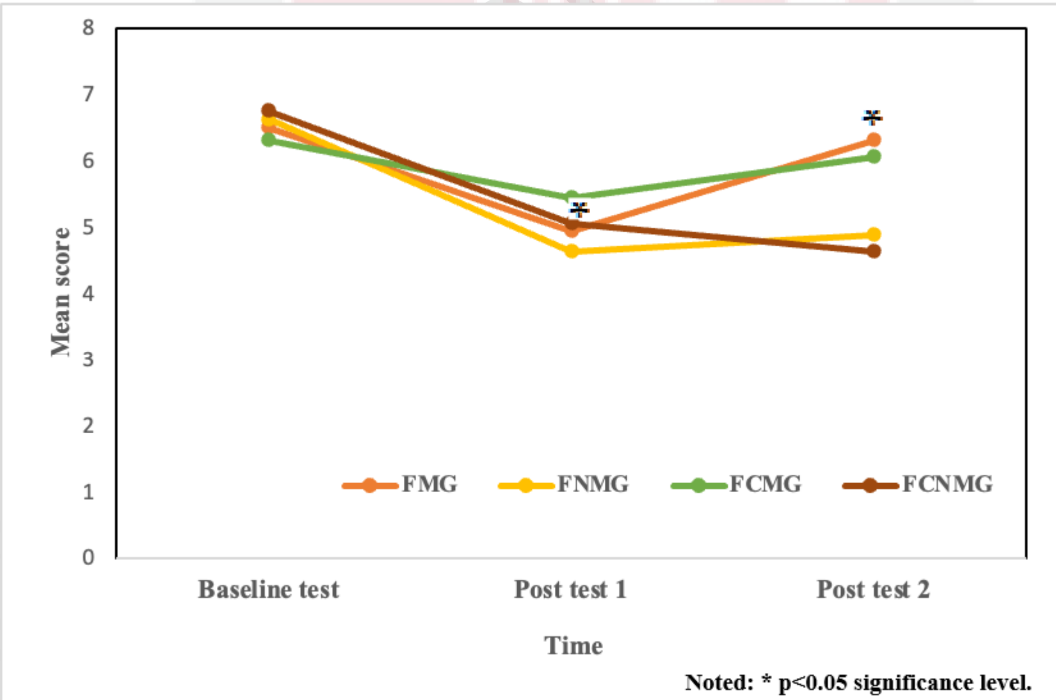


Figure 4.7 : The Mean Scores Changes of Thought-Action Repertoire across the Times among Groups

4.3.6 Sixth Objective of Stroke Accuracy

The sixth objective of the current study was to evaluate the effects of mental fatigue and music recovery on stroke accuracy in terms of accuracy numbers, fault numbers and total score among university table tennis players.

a) Null hypothesis 15: there were no significant differences in MF on table tennis players' stroke accuracy numbers.

b) Null hypothesis 16: there were no significant differences in music on the recovery of table tennis players' stroke accuracy numbers.

c) Null hypothesis 17: there were no significant differences in MF on table tennis players' stroke fault numbers.

d) Null hypothesis 18: there were no significant differences in music on the recovery of table tennis players' stroke fault numbers.

e) Null hypothesis 19: there were no significant differences in MF on table tennis players' stroke total score.

f) Null hypothesis 20: there were no significant differences in music on the recovery of table tennis players' stroke total score.

The GEE was used to determine whether table tennis players' stroke accuracy, faults, and total scores differed among the four groups. Table 4.23 presents descriptive statistics of accuracy, faults, and total scores for four groups at baseline test, post-test 1, and post-test 2.

Table 4.23 : Descriptive Statistics (Mean, SE) for Stroke Accuracy Numbers, Faults Numbers and Total Score

Variable	Time	FMG	FNMG	FCMG	FCNMG
Accuracy numbers	Baseline	18.00 (1.392)	17.75 (1.055)	19.00 (1.202)	17.25 (1.501)
	Post-test 1	14.50 (1.712)	13.38 (1.034)	17.75 (1.014)	18.31 (1.316)
	Post-test 2	18.69 (1.583)	14.25 (1.276)	20.69 (1.178)	17.75 (1.557)
Fault numbers	Baseline	6.50 (0.515)	5.63 (0.278)	6.13 (0.499)	6.63 (0.672)
	Post-test 1	9.06 (0.603)	8.56 (0.330)	7.13 (0.618)	7.63 (0.785)
	Post-test 2	5.69 (0.482)	7.25 (0.556)	5.81 (0.283)	7.31 (0.543)
Total score	Baseline	56.50 (1.770)	57.13 (1.057)	57.88 (1.403)	55.63 (1.807)
	Post-test 1	50.44 (2.093)	49.81 (1.222)	55.63 (1.308)	55.69 (1.853)
	Post-test 2	58.00 (1.936)	52.00 (1.728)	59.88 (1.205)	55.44 (1.918)

Concerning the impact of MF on accuracy numbers (Table 4.24), GEE analysis revealed no significant main effect of group ($\chi^2 = 5.108$, $p = 0.164$), but a significant main effect of time ($\chi^2 = 15.384$, $p < 0.001$). The significant interaction effect between group and time ($\chi^2 = 22.678$, $p < 0.001$) suggests that the groups exhibited varying patterns and changes in accuracy numbers over time. Similarly, for the effect of music on accuracy numbers, GEE analysis revealed a significant main effect of group ($\chi^2 = 15.043$, $p < 0.05$) and a significant main effect of time ($\chi^2 = 14.858$, $p < 0.001$). The significant interaction effect (group*time, $\chi^2 = 15.521$, $p < 0.05$) indicates that the groups demonstrated distinct patterns and changes in accuracy numbers over time.

Regarding the impact of MF on fault numbers (Table 4.24), GEE analysis revealed no significant main effect of group ($\chi^2 = 3.334$, $p = 0.343$), but a significant main effect of time ($\chi^2 = 37.415$, $p < 0.001$). The significant interaction effect between group and time ($\chi^2 = 9.756$, $p < 0.05$) suggests that the groups exhibited varying patterns and changes in fault numbers over time. Similarly, for the effect of music on fault numbers, GEE analysis revealed no significant main effect of group ($\chi^2 = 7.285$, $p = 0.063$), but a significant main effect of time ($\chi^2 = 27.867$, $p < 0.001$). The significant interaction effect (group*time, $\chi^2 = 13.821$, $p < 0.05$) indicates that the groups demonstrated distinct patterns and changes in fault numbers over time.

As for the impact of MF on total score (Table 4.24), GEE analysis revealed no significant main effect of group ($\chi^2 = 6.152$, $p = 0.104$), but a significant main effect of time ($\chi^2 = 30.329$, $p < 0.001$). The significant interaction effect between group and time ($\chi^2 = 25.622$, $p < 0.001$) suggests that the groups exhibited varying patterns and changes in total score over time. Similarly, for the effect of music on total score, GEE analysis revealed a significant main effect of group ($\chi^2 = 16.852$, $p < 0.05$) and a significant main effect of time ($\chi^2 = 24.714$, $p < 0.001$). The significant interaction effect (group*time, $\chi^2 = 17.710$, $p < 0.05$) indicates that the groups demonstrated distinct patterns and changes in total score over time.

Table 4.24 : Results of GEE on Accuracy Numbers, Fault Numbers and Total Score

Variable	Intervention	Source	Wald Chi-Square	df	p value
Accuracy numbers	Mental fatigue	Group	5.108	3	0.164
		time	15.384*	1	< 0.001
		Group * time	22.678*	3	< 0.001
	Music recovery	Group	15.043*	3	< 0.05
		time	14.858*	1	< 0.001
		Group * time	15.521*	3	< 0.05

Table 4.24 : Continued

Fault numbers	Mental fatigue	Group	3.334	3	0.343
		time	37.415*	1	< 0.001
		Group * time	9.756*	3	< 0.05
	Music recovery	Group	7.285	3	0.063
		time	27.867*	1	< 0.001
		Group * time	13.821*	3	< 0.05
Total score	Mental fatigue	Group	6.152	3	0.104
		time	30.329*	1	< 0.001
		Group * time	25.622*	3	< 0.001
	Music recovery	Group	16.852*	3	< 0.05
		time	24.714*	1	< 0.001
		Group * time	17.710*	3	< 0.05

*: Significant difference at 0.05 level, df: degree of freedom.

The post hoc test (LSD) was utilised to evaluate the differences in table tennis players' stroke accuracy performance of the accuracy numbers, faults numbers and total score on the comparison within the group (baseline test vs post-test 1, post-test 1 vs post-test 2, baseline test vs post-test 2) and the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4.25), the differences in accuracy numbers between the baseline test and post-test 1 in FCMG ($p = 0.304$) and FCNMG ($p = 0.199$) were not statistically significant but statistically significant in FMG ($p < 0.01$) and FNMG ($p < 0.01$). The effect size results indicated a large effect size in FNMG ($d = 1.014$) and a medium effect size in FMG ($d = 0.543$). Meanwhile, the differences in accuracy numbers between post-test 1 and post-test 2 in FNMG ($p = 0.412$) and FCNMG ($p = 0.509$) were not statistically significant, but statistically significant in FMG ($p < 0.01$) and FCMG ($p < 0.01$). The effect size results indicated that there was medium effect size in FMG ($d = 0.615$) and FCMG ($d = 0.647$) in post-test 1 compared to post-test 2. On the other hand, the differences in accuracy numbers between baseline test and post-test 2 in FMG ($p = 0.615$); FCMG ($p = 0.216$) and FCNMG ($p = 0.668$) were not statistically significant, but statistically significant in FNMG ($p < 0.01$). The effect size results indicated a large effect size in FNMG ($d = 0.724$) in the post-test 2 compared to the baseline test.

Regarding the results of fault numbers (Table 4.25), the differences in fault numbers between the baseline test and post-test 1 in FCMG ($p = 0.194$) and FCNMG ($p = 0.137$) were not statistically significant but statistically significant in FMG ($p < 0.01$) and FNMG ($p < 0.01$). The effect size results indicated a large effect size in FMG ($d = 1.106$) and FNMG ($d = 2.330$). Meanwhile, the differences in faults between post-test 1 and post-test 2 in FCMG ($p = 0.660$) were not statistically significant, but statistically significant in FMG ($p < 0.01$); FNMG ($p < 0.05$) and FCNMG ($p < 0.01$). The results of effect size indicated that there was a large effect size in FMG ($d = 1.498$) and a medium effect size in FNMG ($d = 0.695$) and FCMG ($d = 0.661$) in the post-test 1 compared to the post-test 2. On the other hand, the differences in faults between baseline test and post-test 2 in FMG ($p = 0.094$), FCMG ($p = 0.626$) and FCNMG ($p = 0.392$) were not statistically significant, but statistically significant in FNMG ($p < 0.01$). The effect size results indicated a large effect size in FNMG ($d = 0.896$) in the post-test 2 compared to the baseline test.

Regarding the result of the total score (Table 4.25), the differences in total score between the baseline test and post-test 1 in FCMG ($p = 0.214$) and FCNMG ($p = 0.956$)

were not statistically significant but statistically significant in FMG ($p < 0.01$) and FNMG ($p < 0.01$). The effect size results indicated a large effect size in FMG ($d = 0.757$) and FNMG ($d = 1.549$) in post-test 1 compared to the baseline test. Meanwhile, the differences in total score between post-test 1 and post-test 2 in FNMG ($p = 0.143$) and FCNMG ($p = 0.848$) were not statistically significant, but statistically significant in FMG ($p < 0.01$) and FCMG ($p < 0.01$). The effect size indicated a large effect size in FMG ($d = 0.908$) and FCMG ($d = 0.818$) in post-test 1 compared to post-test 2. On the other hand, the differences in total score between the baseline test and post-test 2 in FMG ($p = 0.386$), FCMG ($p = 0.246$) and FCNMG ($p = 0.913$) were not statistically significant, but statistically significant in FNMG ($p < 0.01$). The effect size indicated the large effect size in FNMG ($d = 0.866$) in post-test 2 compared to the baseline test.

Table 4.25 : Pairwise Comparison of Accuracy Numbers, Faults Numbers and Total Score (within group)

Comparison		Group	MD	SE	P value	95% CI Lower	95% CI Upper	Effect size (d)
Accuracy numbers	Baseline VS Post-test 1	FMG	3.500*	1.118	0.002	1.309	5.691	0.543
		FNMG	4.375*	0.901	<0.001	2.609	6.141	1.014
		FCMG	1.250	1.217	0.304	-1.135	3.635	0.272
		FCNMG	-1.063	0.827	0.199	-2.683	0.558	0.182
	Post-test 1 VS Post-test 2	FMG	-4.188*	1.013	<0.001	-6.172	-2.203	0.615
		FNMG	-0.875	1.068	0.412	-2.967	1.217	0.182
		FCMG	-2.938*	0.912	0.001	-4.725	-1.150	0.647
		FCNMG	0.563	0.852	0.509	-1.108	2.233	0.094
	Baseline VS Post-test 2	FMG	-0.688	1.3685	0.615	-3.3697	1.9947	0.112
		FNMG	3.500*	1.179	0.003	1.189	5.811	0.724
		FCMG	-1.688	1.363	0.216	-4.359	0.984	0.343

Table 4.25 : Continued

			FCNMG	-0.500	1.166	0.668	-2.785	1.785	0.079
Faults numbers	Baseline VS	Post-test 1	FMG	-2.563*	0.566	<0.001	-3.671	-1.454	1.106
			FNMG	-2.938*	0.369	<0.001	-3.662	-2.213	2.330
			FCMG	-1.000	0.771	0.194	-2.510	0.510	0.431
			FCNMG	-1.000	0.673	0.137	-2.319	0.319	0.331
	Post-test 1 VS	Post-test 2	FMG	3.375*	0.558	<0.001	2.281	4.469	1.498
			FNMG	1.313*	0.598	0.028	0.141	2.484	0.695
			FCMG	1.313*	0.506	0.009	0.322	2.303	0.661
			FCNMG	0.313	0.711	0.660	-1.081	1.706	0.112
	Baseline VS	Post test 2	FMG	0.813	0.486	0.094	-0.1398	1.7648	0.394
			FNMG	-1.625*	0.491	0.001	-2.588	-0.662	0.896
			FCMG	0.313	0.642	0.626	-0.945	1.570	0.187
			FCNMG	-0.688	0.804	0.392	-2.263	0.888	0.272
Total score	Baseline VS	Post-test 1	FMG	6.063*	1.527	<0.001	3.070	9.055	0.757
			FNMG	7.313*	1.041	<0.001	5.272	9.353	1.549
			FCMG	2.250	1.810	0.214	-1.298	5.798	0.402
			FCNMG	-0.063	1.137	0.956	-2.291	2.166	0.008
	Post-test 1 VS	Post-test 2	FMG	-7.563*	1.400	<0.001	-10.307	-4.818	0.908
			FNMG	-2.188	1.493	0.143	-5.113	0.738	0.354
			FCMG	-4.250*	1.324	0.001	-6.846	-1.654	0.818
			FCNMG	0.250	1.307	0.848	-2.311	2.811	0.032
	Baseline VS	Post-test 2	FMG	-1.500	1.730	0.386	-4.890	1.8903	0.196
			FNMG	5.125*	1.546	0.001	2.095	8.155	0.866
			FCMG	-2.000	1.723	0.246	-5.377	1.377	0.370
			FCNMG	0.188	1.719	0.913	-3.182	3.557	0.024

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Regarding the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of post hoc test (LSD) (Table 4.26), the differences in accuracy numbers between FMG and FNMG ($p = 0.886$), FMG and FCMG ($p = 0.587$), FMG and FCNMG ($p = 0.714$), FNMG and FCMG ($p = 0.435$); FNMG and FCNMG ($p = 0.785$), FCMG and FCNMG ($p = 0.363$) in the baseline test were not statistically significant. Meanwhile, the differences in accuracy score between FMG and FNMG ($p = 0.574$); FMG and FCMG ($p = 0.102$); FMG and FCNMG ($p = 0.077$); FCMG and FCNMG ($p = 0.735$) at post-test 1 were not statistically significant, but statistically significant between FNMG and FCMG ($p < 0.01$); FNMG and FCNMG ($p < 0.01$). Effect size results indicated a large effect between FNMG and FCMG ($d = 1.034$) and FNMG and FCNMG ($d = 1.010$) in post-test 1. On the other hand, the differences in accuracy score between FMG and FCMG ($p = 0.311$); FMG and FCNMG ($p = 0.673$); FNMG and FCNMG ($p = 0.082$); FCMG and FCNMG ($p = 0.133$) at post-test 2 were not statistically significant, but statistically significant between FMG and FNMG ($p < 0.05$); FNMG and FCMG ($p < 0.01$) in the post-test 2. The results of effect size indicated that there was a large effect size between FMG and FNMG ($d = 0.747$) and FNMG and FCMG ($d = 1.269$) in the post-test 2.

Regarding the results for the number of faults (Table 4.26), the differences in the numbers of faults between FMG and FNMG ($p = 0.135$), FMG and FCMG ($p = 0.601$), FMG and FCNMG ($p = 0.883$), FNMG and FCMG ($p = 0.381$), FNMG and FCNMG ($p = 0.169$), FCMG and FCNMG ($p = 0.550$) at baseline test were not statistically significant. Meanwhile, the differences in the numbers of faults between FMG and FNMG ($p = 0.467$); FMG and FCNMG ($p = 0.146$); FNMG and FCNMG ($p = 0.271$);

FCMG and FCNMG ($p = 0.617$) at post-test 1 were not statistically significant, but statistically significant between FMG and FCMG ($p < 0.05$); FNMG and FCMG ($p < 0.05$). The effect size results indicated a large effect size between FMG and FCMG ($d = 0.768$) and FNMG and FCMG ($d = 0.702$) in the post-test 1. On the other hand, the differences in the numbers of faults between FMG and FCMG ($p = 0.823$); FNMG and FCNMG ($p = 0.936$) at post-test 2 were not statistically significant, but statistically significant between FMG and FNMG ($p < 0.05$); FMG and FCNMG ($p < 0.05$); FNMG and FCMG ($p < 0.05$); FCMG and FCNMG ($p < 0.05$). The results of effect size indicated that there was a large effect size between FMG and FNMG ($d = 0.727$); FMG and FCNMG ($d = 0.766$); FNMG and FCMG ($d = 0.790$); FCMG and FCNMG ($d = 0.839$) in the post-test 2.

As to the results for the total score (Table 4.26), the differences in the total score between FMG and FNMG ($p = 0.762$), FMG and FCMG ($p = 0.543$), FMG and FCNMG ($p = 0.729$), FNMG and FCMG ($p = 0.669$), FNMG and FCNMG ($p = 0.474$), FCMG and FCNMG ($p = 0.325$) at baseline test were not statistically significant. Meanwhile, the differences in the total score between FMG and FNMG ($p = 0.797$); FMG and FCNMG ($p = 0.060$); FCMG and FCNMG ($p = 0.978$) at post-test 1 were not statistically significant, but statistically significant between FMG and FCMG ($p < 0.05$); FNMG and FCMG ($p < 0.01$); FNMG and FCNMG ($p < 0.01$). The results of effect size indicated that there was a large effect size between FMG and FCMG ($d = 0.719$), FNMG and FCMG ($d = 1.112$), and FNMG and FCNMG ($d = 0.906$). On the other hand, the differences in total score between FMG and FCMG ($p = 0.411$); FMG and FCNMG ($p = 0.347$); FNMG and FCNMG ($p = 0.183$) at post-test 2 were not statistically significant, but statistically significant between FMG and FNMG ($p <$

0.05); FNMG and FCMG ($p < 0.01$); FCMG and FCNMG ($p = 0.05$). The results of effect size indicated that there was a large effect size between FMG and FNMG ($d = 0.791$), FNMG and FCMG ($d = 1.280$), and FCMG and FCNMG ($d = 0.671$) in the post-test 2.

Table 4.26 : Pairwise Comparison of Accuracy Numbers, Faults Numbers and Total Numbers (between Groups)

		Comparison	MD	SE	P value	95% CI Lower	95% CI Upper	Effect size (d)
Accuracy numbers	Baseline test	FMG VS FNMG	0.250	1.747	0.886	-3.173	3.673	0.049
		FMG VS FCMG	-1.000	1.839	0.587	-4.605	2.605	0.186
		FMG VS FCNMG	0.750	2.047	0.714	-3.263	4.763	0.125
		FNMG VS FCMG	-1.250	1.600	0.435	-4.385	1.885	0.268
		FNMG VS FCNMG	0.500	1.835	0.785	-3.097	4.097	0.093
		FCMG VS FCNMG	1.750	1.923	0.363	-2.020	5.520	0.311
	Post test 1	FMG VS FNMG	1.125	2.000	0.574	-2.794	5.044	0.193
		FMG VS FCMG	-3.250	1.989	0.102	-7.149	0.649	0.559
		FMG VS FCNMG	-3.813	2.159	0.077	-8.044	0.419	0.573
		FNMG VS FCMG	-4.375*	1.448	0.003	-7.213	-1.537	1.034
		FNMG VS FCNMG	-4.938*	1.674	0.003	-8.218	-1.657	1.010
		FCMG VS FCNMG	-0.563	1.661	0.735	-3.818	2.693	0.116
	Post test 2	FMG VS FNMG	4.438	2.033	0.029	0.452	8.423	0.747
		FMG VS FCMG	-2.000	1.973	0.311	-5.868	1.868	0.347
		FMG VS FCNMG	0.938	2.221	0.673	-3.415	5.290	0.145
		FNMG VS FCMG	-6.438*	1.737	<0.001	-9.842	-3.033	1.269
		FNMG VS FCNMG	-3.500	2.014	0.082	-7.447	0.447	0.595
		FCMG VS FCNMG	2.938	1.953	0.133	-0.890	6.765	0.515

Table 4.26 : Continued

Faults numbers	Baseline test	FMG VS FNMG	0.875	0.585	0.135	-0.273	2.023	0.512
		FMG VS FCMG	0.375	0.717	0.601	-1.031	1.781	0.179
		FMG VS FCNMG	-0.125	0.847	0.883	-1.786	1.536	0.051
		FNMG VS FCMG	-0.500	0.571	0.381	-1.619	0.619	0.300
		FNMG VS FCNMG	-1.000	0.728	0.169	-2.426	0.426	0.471
		FCMG VS FCNMG	-0.500	0.837	0.550	-2.141	1.141	0.204
	Post-test 1	FMG VS FNMG	0.500	0.687	0.467	-0.847	1.847	0.249
		FMG VS FCMG	1.938*	0.863	0.025	0.246	3.629	0.768
		FMG VS FCNMG	1.438	0.990	0.146	-0.502	3.377	0.545
		FNMG VS FCMG	1.438*	0.701	0.040	0.064	2.811	0.702
		FNMG VS FCNMG	0.938	0.852	0.271	-0.732	2.607	0.377
		FCMG VS FCNMG	-0.500	0.999	0.617	-2.458	1.458	0.171
	Post test 2	FMG VS FNMG	-1.563*	0.735	0.034	-3.004	-0.121	0.727
		FMG VS FCMG	-0.125	0.559	0.823	-1.220	0.970	0.077
		FMG VS FCNMG	-1.625*	0.726	0.025	-3.048	-0.202	0.766
		FNMG VS FCMG	1.438*	0.623	0.021	0.216	2.659	0.790
		FNMG VS FCNMG	-0.063	0.777	0.936	-1.585	1.460	0.028
		FCMG VS FCNMG	-1.500*	0.612	0.014	-2.699	-0.301	0.839
Total score	Baseline test	FMG VS FNMG	-0.625	2.061	0.762	-4.665	3.415	0.104
		FMG VS FCMG	-1.375	2.258	0.543	-5.802	3.052	0.208
		FMG VS FCNMG	0.875	2.529	0.729	-4.082	5.832	0.118
		FNMG VS FCMG	-0.750	1.756	0.669	-4.192	2.692	0.146
		FNMG VS FCNMG	1.500	2.093	0.474	-2.602	5.602	0.245
		FCMG VS FCNMG	2.250	2.287	0.325	-2.233	6.733	0.337
	Post-test 1	FMG VS FNMG	0.625	2.424	0.797	-4.126	5.376	0.088
		FMG VS FCMG	-5.188*	2.468	0.036	-10.025	-0.350	0.719
		FMG VS FCNMG	-5.250	2.796	0.060	-10.730	0.230	0.650
		FNMG VS FCMG	-5.813*	1.790	0.001	-9.321	-2.304	1.112

Table 4.26 : Continued

	FNMG VS FCNMG	-5.875*	2.220	0.008	-10.227	-1.524	0.906
	FCMG VS FCNMG	-0.063	2.268	0.978	-4.508	4.383	0.009
Post test 2	FMG VS FNMG	6.000*	2.595	0.021	0.914	11.086	0.791
	FMG VS FCMG	-1.875	2.281	0.411	-6.345	2.595	0.281
	FMG VS FCNMG	2.563	2.726	0.347	-2.780	7.905	0.322
	FNMG VS FCMG	-7.875*	2.106	<0.001	-12.003	-3.747	1.280
	FNMG VS FCNMG	-3.438	2.581	0.183	-8.497	1.622	0.456
	FCMG VS FCNMG	4.438	2.265	0.050	-0.002	8.877	0.671

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Figure 4-8 depicts the mean accuracy numbers over time. At post-test 1, the FMG and FNMG groups experienced a decline in accuracy numbers, while the FCMG and FCNMG groups maintained a stable status. However, at post-test 2, the FMG and FCMG groups demonstrated an increase in accuracy numbers, while the FNMG and FCNMG groups remained stable.

Figure 4-9 depicts the mean fault numbers over time. All groups exhibited an increase in fault numbers at post-test 1, with FMG and FNMG demonstrating a more pronounced increase than FCMG and FCNMG. However, at post-test 2, FMG and FCMG groups experienced a decline in fault numbers, while FNMG and FCNMG groups maintained a stable status.

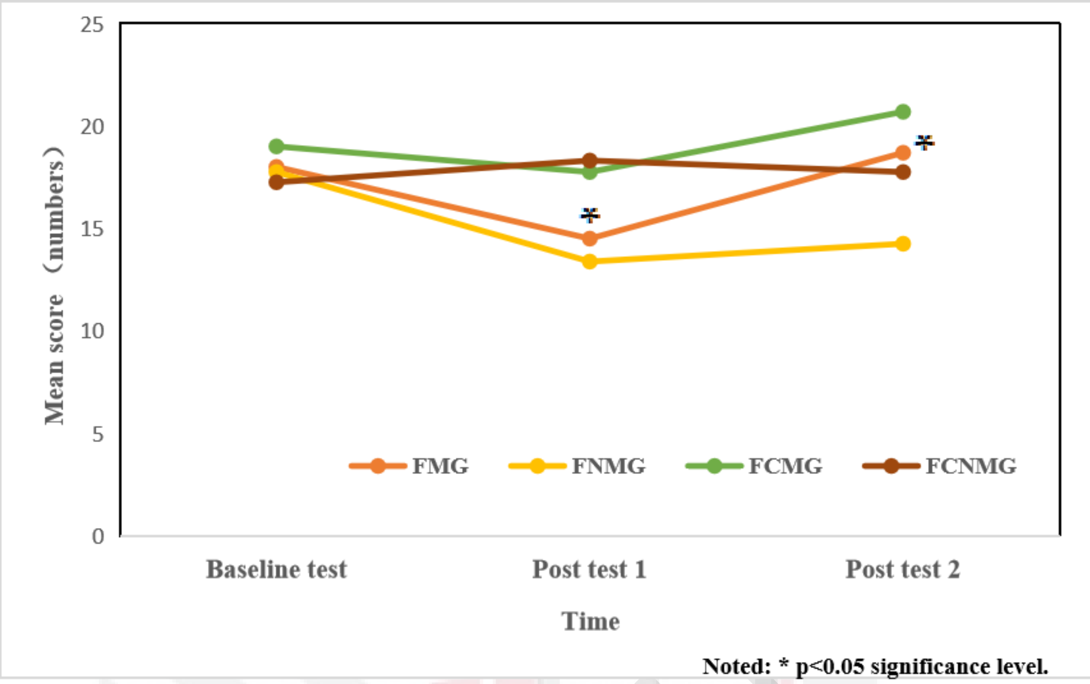


Figure 4.8 : The Mean Scores Changes of Accuracy Numbers across the Times among Groups

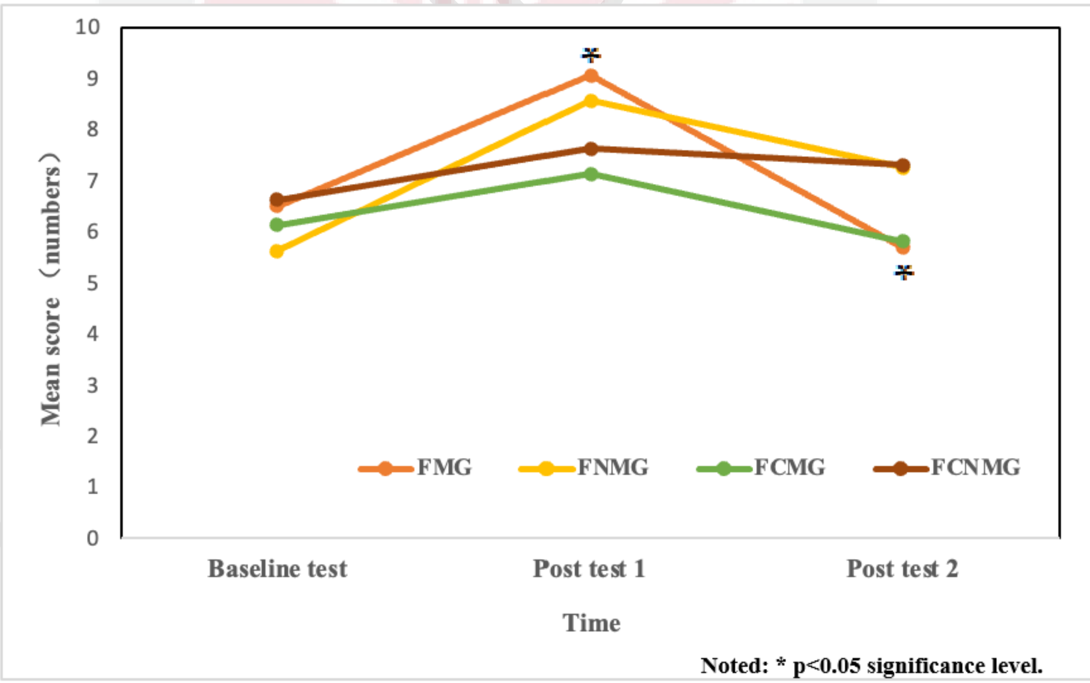


Figure 4.9 : The Mean Scores Changes of Fault Numbers across the Times among Groups

Figure 4-10 depicts the mean total scores over time. At post-test 1, FMG and FNMG groups experienced a decline in total scores, while FCMG and FCNMG groups maintained a stable status. However, at post-test 2, FMG and FCMG groups demonstrated an increase in total scores, while FNMG and FCNMG groups remained stable.

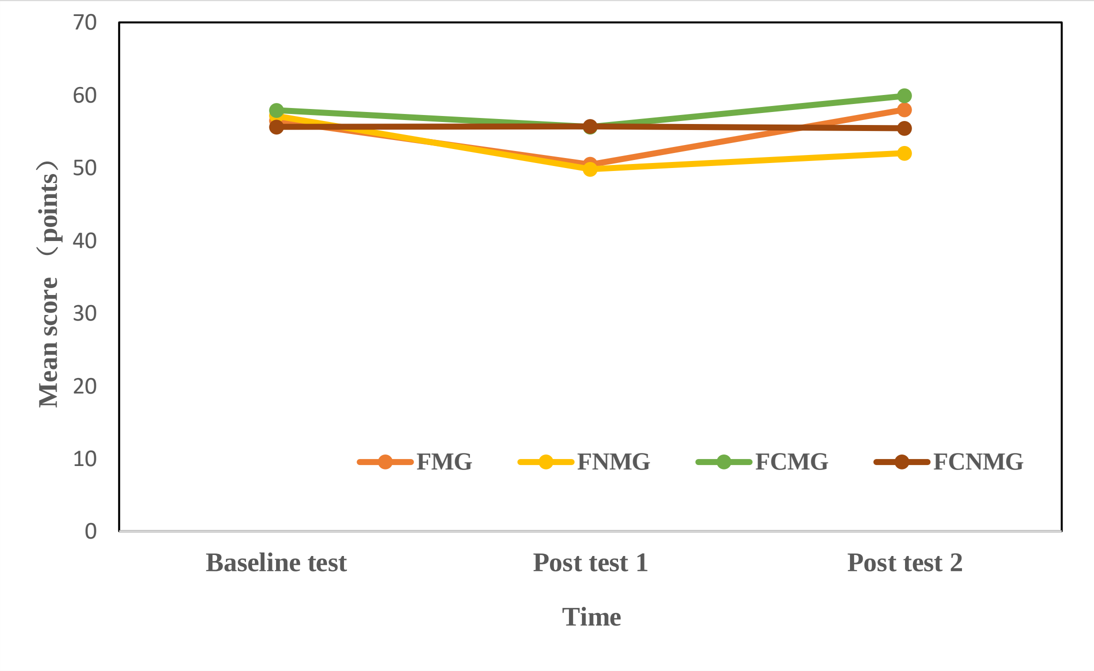


Figure 4.10 : The Mean Scores Changes of Total Scores across the Times among Groups

4.3.7 Seventh Objective of Ball Speed

The seven objectives of the current study were to examine the effects of MF on table tennis players' ball speed and music on their recovery of ball speed.

a) Null hypothesis 21: there were no significant differences in MF on table tennis players' ball speed.

b) Null hypothesis 22: there were no significant differences in music on the recovery of table tennis players' ball speed.

The GEE was utilised to determine if there was a difference in ball speed among groups. Descriptive statistics of ball speed for four groups at baseline test, post-test 1 and post-test 2 are presented at Table 4.27.

Table 4.27 : Descriptive Statistics (Mean, SE) for Ball Speed

Variable	Time	FMG	FNMG	FCMG	FCNMG
	Baseline	47.36 (0.734)	46.26 (1.549)	45.73 (0.759)	46.99 (1.064)
Speed	Post-test 1	46.69 (1.206)	45.09 (1.851)	46.13 (1.229)	45.91 (1.063)
	Post-test 2	45.58 (1.303)	43.47 (1.242)	44.20 (1.560)	45.57 (1.582)

Concerning the impact of MF on ball speed (Table 4.28), GEE analysis revealed no significant main effect of group ($\chi^2 = 0.957$, $p = 0.812$) and no significant main effect of time ($\chi^2 = 1.926$, $p = 0.165$). The non-significant interaction effect between group and time ($\chi^2 = 1.678$, $p = 0.624$) suggests that the groups did not exhibit varying patterns or changes in ball speed over time. In contrast, for the effect of music on ball speed, GEE analysis revealed no significant main effect of group ($\chi^2 = 1.075$, $p = 0.783$), but a significant main effect of time ($\chi^2 = 6.803$, $p < 0.05$). The non-significant interaction effect (group*time, $\chi^2 = 1.694$, $p = 0.638$) indicates that the groups demonstrate slightly changes in ball speed over time.

Table 4.28 : Results of GEE on Table Tennis Players' Ball Speed

Variable	Intervention	Source	Wald Chi-Square	df	p value
ball speed	Mental fatigue	Group	0.957	3	0.812
		time	1.926	1	0.165
		Group * time	1.678	3	0.624
	Music recovery	Group	1.075	3	0.783
		time	6.803*	1	< 0.05
		Group * time	1.694	3	0.638

*: Significant difference at 0.05 level, df: degree of freedom.

The post hoc post hoc test (LSD) was utilised to evaluate the differences in ball speed on the comparison within the group (baseline test vs post-test 1, post-test 1 vs post-test 2, baseline test vs post-test 2) and the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4-30), the differences in ball speed between the baseline test and post-test 1 in FMG (P = 0.412), FNMG (P = 0.288), FCMG (P = 0.704), FCNMG (P = 0.076) were not statistically significant. Meanwhile, the differences in ball speed between post-test 1 and post-test 2 in FMG (P = 0.088), FNMG (P = 0.203) and FCNMG (P = 0.707) were not statistically significant, but statistically significant in FCMG ($p < 0.05$) with small effect size (d = 0.336). On the other hand, the differences in ball speed between the baseline test and post-test 2 in FCMG (p = 0.314) and FCNMG (p = 0.201) were not statistically significant, but statistically significant in FMG ($p < 0.05$) and FNMG ($p < 0.05$). The effect size results indicated a medium effect size in FMG (d = 0.410) and FNMG (d = 0.478) in the post-test 2 compared to the baseline test.

Table 4.29 : Pairwise Comparison of Ball Speed (within Group)

	Comparison		Group	MD	SE	P value	95% CI		Effect size (d)
							Lower	Upper	
ball speed	Baseline VS	Post-test 1	FMG	0.663	0.807	0.412	-0.919	2.244	0.161
			FNMG	1.163	1.094	0.288	-0.982	3.307	0.165
			FCMG	-0.394	1.035	0.704	-2.423	1.635	0.098
			FCNMG	1.088	0.613	0.076	-0.113	2.288	0.242
	Post-test 1 VS	Post-test 2	FMG	1.113	0.652	0.088	-0.165	2.390	0.218
			FNMG	1.625	1.277	0.203	-0.877	4.127	0.247
			FCMG	1.925*	0.903	0.033	0.155	3.695	0.336
			FCNMG	0.338	0.897	0.707	-1.422	2.097	0.062
	Baseline VS	Post-test 2	FMG	1.775	0.892	0.047	0.0267	3.5233	0.410
			FNMG	2.788*	1.221	0.022	0.394	5.181	0.478
			FCMG	1.531	1.519	0.314	-1.447	4.509	0.303
			FCNMG	1.425	1.115	0.201	-0.760	3.610	0.253

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

Regarding the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of post hoc test (LSD) (Table 4.31), the differences of ball speed between FMG and FNMG (P = 0.521), FMG and FCMG (P = 0.124), FMG and FCNMG (P = 0.779), FNMG and FCMG (P = 0.761), FNMG and FCNMG (P = 0.695), FCMG and FCNMG (P = 0.334) in baseline test were not statistically significant. Meanwhile, the differences in ball speed between FMG and FNMG (P = 0.469), FMG and FCMG (P = 0.741), FMG and FCNMG (P = 0.624), FNMG and FCMG (P = 0.643), FNMG and FCNMG (P = 0.703), FCMG and FCNMG (P = 0.893) in post-test 1 were also not statistically significant. On the other hand, the differences in ball speed between FMG and FNMG (P = 0.241), FMG and FCMG (P = 0.497), FMG and FCNMG (P = 0.995), FNMG and FCMG (P = 0.714), FNMG and FCNMG (P = 0.296), FCMG and FCNMG (P = 0.538) at post-test 2 were not statistically significant as well.

Table 4.30 : Pairwise Comparison of Ball Speed (between Groups)

		Comparison	MD	SE	P value	95% CI		Effect size (d)
						Lower	Upper	
Speed	Baseline test	FMG VS FNMG	1.100	1.714	0.521	-2.260	4.460	0.223
		FMG VS FCMG	1.625	1.055	0.124	-0.443	3.693	0.533
		FMG VS FCNMG	0.363	1.293	0.779	-2.171	2.896	0.103
		FNMG VS FCMG	0.525	1.725	0.761	-2.856	3.906	0.104
		FNMG VS FCNMG	-0.738	1.879	0.695	-4.421	2.946	0.133
		FCMG VS FCNMG	-1.263	1.307	0.334	-3.824	1.299	0.329
	Post-test 1	FMG VS FNMG	1.600	2.209	0.469	-2.729	5.929	0.251
		FMG VS FCMG	0.569	1.722	0.741	-2.807	3.944	0.112
		FMG VS FCNMG	0.788	1.607	0.624	-2.363	3.938	0.168
		FNMG VS FCMG	-1.031	2.222	0.643	-5.386	3.323	0.163
		FNMG VS FCNMG	-0.813	2.134	0.703	-4.995	3.370	0.134
		FCMG VS FCNMG	0.219	1.625	0.893	-2.966	3.404	0.047
	Post-test 2	FMG VS FNMG	2.113	1.800	0.241	-1.415	5.640	0.399
		FMG VS FCMG	1.381	2.032	0.497	-2.602	5.364	0.233
		FMG VS FCNMG	0.013	2.049	0.995	-4.004	4.029	0.000
		FNMG VS FCMG	-0.731	1.994	0.714	-4.639	3.176	0.123
		FNMG VS FCNMG	-2.100	2.011	0.296	-6.042	1.842	0.358
		FCMG VS FCNMG	-1.369	2.221	0.538	-5.723	2.985	0.213

Figure 4.11 illustrates the mean ball speed over time. While there were slight declines in ball speed for FMG, FNMG, and FCNMG groups at post-test 1, these changes were

not statistically significant. FCMG experienced a less pronounced decrease. At post-test 2, all groups exhibited a decline in ball speed, but these decreases were also not statistically significant.

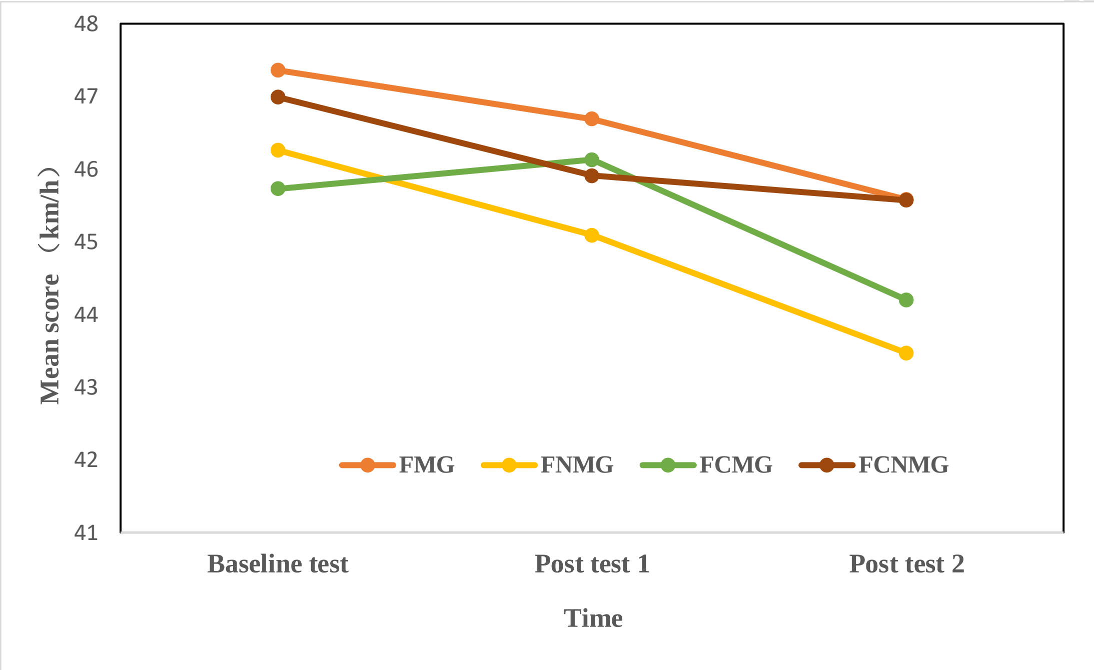


Figure 4.11 : The Mean Scores Changes of Ball Speed across the Times among Groups

4.3.8 Checking Secondary Outcome of RPE and Motivation

Based on the current study's theoretical framework, RPE and motivation were the two secondary variables analysed in the following section.

i. Rating Perception of Exertion (RPE)

The GEE was used to evaluate whether there was a difference in the RPE scores among groups. Descriptive statistics of RPE scores for four groups in the baseline test, post-test 1, and post-test 2 are presented in Table 4.31.

Table 4.31 : Descriptive Statistics (Mean, SE) for RPE Score

Variable	Time	FMG	FNMG	FCMG	FCNMG
	Baseline	8.31 (0.327)	8.19 (0.268)	7.88 (0.248)	8.18 (0.182)
RPE	Post-test 1	9.69 (0.303)	9.44 (0.342)	9.06 (0.257)	9.38 (0.248)
	Post-test 2	7.88 (0.341)	8.06 (0.400)	8.25 (0.207)	8.56 (0.216)

Concerning the impact of MF on RPE (Table 4-32), the GEE analysis revealed a significant change over time ($\chi^2 = 217.822$, $p < 0.001$), but no significant difference between the groups ($\chi^2 = 2.772$, $p = 0.428$), nor an interaction effect between group and time ($\chi^2 = 36.919$, $p = 0.897$). The results indicate that both the MF intervention and control groups experienced similar improvements in RPE over time, but the MF intervention group did not show a significantly greater reduction than the control groups. In contrast, for the effect of music recovery on the RPE, the GEE analysis revealed a significant main effect of time ($\chi^2 = 79.988$, $p < 0.001$), an interaction effect between group and time ($\chi^2 = 10.231$, $p < 0.05$). But no significant main effect of group ($\chi^2 = 1.699$, $p = 0.637$). The results indicates that the groups demonstrate distinct patterns or changes in the RPE over time.

Table 4.32 : Results of GEE on RPE Score

Variable	Intervention	Source	Wald Chi-Square	df	p value
RPE score	Mental fatigue	Group	2.772	3	0.428
		time	217.822*	1	< 0.001
		Group * time	36.919*	3	0.897
	Music recovery	Group	1.699	3	0.637
		time	78.988*	1	< 0.001
		Group * time	10.231*	3	< 0.05

*: Significant difference at 0.05 level, df: degree of freedom.

The post hoc test (LSD) was utilised to evaluate the differences in RPE score on the comparison within the group (baseline test vs post-test 1, post-test 1 vs post-test 2, baseline test vs post-test 2) and the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4-34), the differences in RPE score between the baseline test and post-test 1 in FMG ($p < 0.01$), FNMG ($p < 0.01$), FCMG ($p < 0.01$) and FCNMG ($p < 0.01$) were statistically significant. Results of effect size indicated that there was a small effect in FMG ($d = 0.101$), FCMG ($d = 0.299$), and FCNMG ($d = 0.143$), with a large effect in FNMG ($d = 1.455$) between the baseline test to post-test 1. Meanwhile, the differences in RPE scores between post-test 1 and post-test 2 in FMG ($p < 0.01$), FNMG ($p < 0.01$), FCMG ($p < 0.01$) and FCNMG ($p < 0.05$) were statistically significant. Results of effect size indicated that there was a small effect of RPE score in FMG ($d = 0.293$) and FNMG ($d = 0.187$), with a medium effect in FCNMG ($d = 0.357$) and a large effect in FCMG ($d = 1.218$) and between post-test 1 and post-test 2. On the other hand, the differences in RPE score between the baseline test and post-test 2 in FNMG ($p = 0.843$), FCMG ($p = 0.332$) and FCNMG ($p = 0.106$) were not statistically significant, but statistically significant in FMG ($p < 0.05$) with the medium effect size ($d = 0.377$) in baseline test compared to post-test 2.

Regarding the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4.35), the differences in the RPE

Table 4.33 : Pairwise Comparison of RPE (within Group)

	Comparison	Group	MD	SE	P value	95% CI Lower	95% CI Upper	Effect size (d)
RPE	Baseline VS Post-test 1	FMG	-1.375*	0.174	<0.001	-1.716	-1.034	0.101
		FNMG	-1.250*	0.400	0.002	-2.034	-0.466	1.455
		FCMG	-1.188*	0.321	<0.001	-1.817	-0.558	0.299
		FCNMG	-1.188*	0.202	<0.001	-1.583	-0.792	0.143
	Post-test 1 VS Post-test 2	FMG	1.813*	0.220	<0.001	1.381	2.245	0.293
		FNMG	1.375*	0.214	<0.001	0.955	1.795	0.187
		FCMG	0.813*	0.309	0.009	0.207	1.418	1.218
		FCNMG	0.8125*	0.321	0.011	0.183	1.442	0.357
	Baseline VS Post-test 2	FMG	0.438*	0.216	0.043	0.014	0.861	0.365
		FNMG	0.125	0.450	0.781	-0.756	1.006	1.105
		FCMG	-0.375	0.305	0.218	-0.972	0.222	0.952
		FCNMG	-0.375	0.232	0.106	-0.829	0.079	0.377

*: Significant difference at 0.05 level, MD: Mean difference, SE: Standard error

scores between FMG and FNMG (p = 0.768), FMG and FCMG (p = 0.287); FMG and FCNMG (p = 0.738), FNMG and FCMG (p = 0.392), FNMG and FCNMG (p = 1.000) FCMG and FCNMG (p = 0.309) in baseline test were not statistically significant. Meanwhile, the differences in the RPE score between FMG and FNMG (p = 0.584), FMG and FCMG (p = 0.116); FMG and FCNMG (p = 0.424), FNMG and FCMG (p = 0.381), FNMG and FCNMG (p = 0.882); FCMG and FCNMG (p = 0.382) in post-test 1 were also not statistically significant. On the other hand, the differences in the RPE score between FMG and FNMG (p = 0.721), FMG and FCMG (p = 0.347); FMG and FCNMG (p = 0.088), FNMG and FCMG (p = 0.677), FNMG and FCNMG (p =

0.271); FCMG and FCNMG (p = 0.296) in post-test 2 were not statistically significant as well.

Table 4.34 : Pairwise Comparison of RPE (between Groups)

		Comparison	MD	SE	P value	95% CI Lower	95% CI Upper	Effect size (d)
RPE	**Baseline test**	FMG VS FNMG	0.125	0.423	0.768	-0.705	0.955	0.114
		FMG VS FCMG	0.438	0.411	0.287	-0.368	1.243	0.617
		FMG VS FCNMG	0.125	0.374	0.738	-0.609	0.859	0.166
		FNMG VS FCMG	0.313	0.365	0.392	-0.404	1.029	0.951
		FNMG VS FCNMG	0.000	0.324	1.000	-0.635	0.635	0.097
		FCMG VS FCNMG	-0.313	0.307	0.309	-0.915	0.290	0.720
	Post-test 1	FMG VS FNMG	0.250	0.457	0.584	-0.645	1.145	1.270
		FMG VS FCMG	0.625	0.397	0.116	-0.153	1.403	1.112
		FMG VS FCNMG	0.313	0.391	0.424	-0.454	1.079	0.063
		FNMG VS FCMG	0.375	0.428	0.381	-0.464	1.214	0.273
		FNMG VS FCNMG	0.063	0.422	0.882	-0.766	0.891	1.342
		FCMG VS FCNMG	-0.313	0.357	0.382	-1.013	0.388	1.191
	Post-test 2	FMG VS FNMG	-0.188	0.525	0.721	-1.217	0.842	1.266
		FMG VS FCMG	-0.375	0.399	0.347	-1.157	0.407	0.000
		FMG VS FCNMG	-0.688	0.404	0.088	-1.478	0.103	0.716
		FNMG VS FCMG	-0.188	0.450	0.677	-1.070	0.695	1.108
		FNMG VS FCNMG	-0.500	0.454	0.271	-1.391	0.391	0.741
		FCMG VS FCNMG	-0.313	0.299	0.296	-0.899	0.274	0.583

Figure 4.12 depicts the mean RPE scores over time. All groups exhibited an increase in RPE scores at post-test 1. However, at post-test 2, all groups experienced a decline in RPE scores.

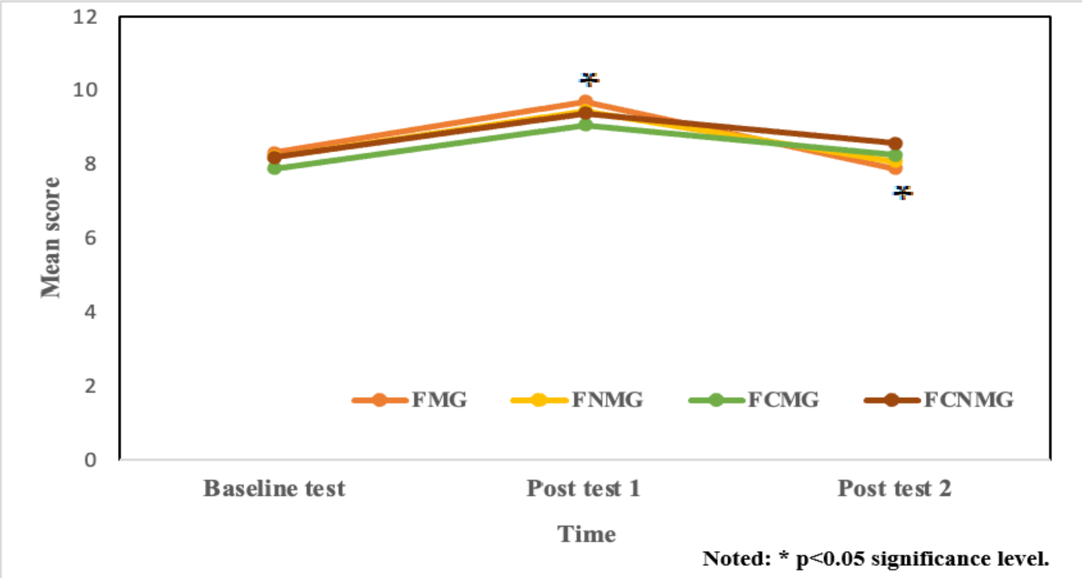


Figure 4.12 : The Mean Scores Changes of RPE across the Times among Groups

i. Motivation

The GEE was used to determine if there was a difference in motivation scores among groups. Table 4.35 presents descriptive statistics of motivation scores for four groups in the baseline test, post-test 1, and post-test 2.

Table 4.35 : Descriptive Statistics (Mean, SE) for Motivation

Variable	Time	FMG	FNMG	FCMG	FCNMG
	Baseline	7.76 (0.259)	7.53 (0.430)	7.04 (0.384)	7.29 (0.360)
Motivation	Post-test 1	6.59 (0.436)	6.29 (0.351)	6.11 (0.392)	6.35 (0.310)
	Post-test 2	7.36 (0.406)	6.16 (0.329)	6.93 (0.414)	6.73 (0.281)

Concerning the impact of MF on motivation (Table 4.36), the GEE analysis revealed a significant change over time ($\chi^2 = 40.448$, $p < 0.001$), but no significant difference between the groups (χ^2 = 1.659, p = 0.646), nor an interaction effect between group and time (χ^2 = 0.624, p = 0.891). The results indicate that both the MF intervention and control groups experienced similar reductions in the motivation over time, but the MF intervention group did not show a significantly greater reduction than the control group. In contrast, for the effect of music on the motivation, the GEE analysis revealed a significant main effect of time (χ^2 = 13.890, $p < 0.001$), and an interaction effect between group and time (χ^2 = 7.907, $p < 0.05$). But no significant main effect of group (χ^2 = 2.284, p = 0.516). The results indicates that the groups demonstrated distinct patterns and changes in motivation over time.

Table 4.36 : Results of GEE on Motivation

Variable	Intervention	Source	Wald Chi-Square	df	p value
Motivation	Mental fatigue	Group	1.659	3	0.646
		time	40.448	1	< 0.001
		Group * time	0.624	3	0.891
	Music recovery	Group	2.284	3	0.516
		time	13.890	1	< 0.001
		Group * time	7.907	3	< 0.05

*: Significant difference at 0.05 level, df: degree of freedom.

The post hoc test (LSD) was utilised to evaluate the differences of the motivation score on the comparison within the group (baseline test vs post-test 1, post-test 1 vs post-test 2, baseline test vs post-test 2) and the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4-38), the differences in the motivation score between the baseline test and post-test 1 in

FMG ($p < 0.01$); FNMG ($p < 0.01$); FCMG ($p < 0.05$) and FCNMG ($p < 0.01$) was statistically significant. Results of effect size indicated that there was a medium effect in FNMG (d = 0.581) and a large effect size in FMG (d = 0.785) and FCMG (d = 0.764) and FCNMG (d = 0.680) between the baseline test and post-test 1. Meanwhile, the differences in the motivation score between post-test 1 and post-test 2 in FNMG (p = 0.694) and FCNMG (p = 0.092) were not statistically significant, but statistically significant in FMG ($p < 0.01$) and FCMG ($p < 0.01$). The effect size results indicated a medium effect size in FMG (d = 0.442) and FCMG (d = 0.495) between post-tests 1 and 2. On the other hand, the differences in the motivation score between the baseline test and post-test 2 were not statistically significant in FMG (p = 0.153), FCMG (p = 0.784), and FCNMG (p = 0.095) were not statistically significant, but statistically significant in FNMG ($p < 0.01$). The effect size results indicated a large effect size in FNMG (d = 0.866) between post-test 2 and the baseline test.

Table 4.37 : Pairwise Comparison of Motivation (within group)

Comparison			Group	MD	SE	P value	95% CI Lower	95% CI Upper	Effect size
Motivation	Baseline VS	Post-test 1	FMG	1.163*	0.257	<0.001	0.658	1.667	0.785
			FNMG	1.238*	0.373	0.001	0.506	1.969	0.764
			FCMG	0.931*	0.391	0.017	0.165	1.698	0.581
			FCNMG	0.944*	0.306	0.002	0.345	1.543	0.680
	Post-test 1 VS	Post-test 2	FMG	-0.769*	0.221	<0.001	-1.201	-0.336	0.442
			FNMG	0.131	0.334	0.694	-0.523	0.785	0.093
			FCMG	-0.825*	0.183	<0.001	-1.184	-0.466	0.495
			FCNMG	-0.375	0.222	0.092	-0.811	0.061	0.307

Table 4.37 : Continued

Baseline VS	Post-test 2	FMG	0.394	0.275	0.153	-0.146	0.934	0.280
		FNMG	1.369*	0.425	0.001	0.537	2.201	0.866
		FCMG	0.106	0.388	0.784	-0.655	0.867	0.064
		FCNMG	0.569	0.341	0.095	-0.099	1.237	0.426

*: Significant difference at 0.05 level. MD: Mean difference, SE: Standard error

Regarding the comparison between groups (FMG vs FNMG, FMG vs FCMG, FMG vs FCNMG, FNMG vs FCMG, FNMG vs FCNMG, and FCMG vs FCNMG). Based on the results of the post hoc test (LSD) (Table 4-38), the differences in the motivation score between FMG and FNMG ($p = 0.645$), FMG and FCMG ($p = 0.120$), FMG and FCNMG ($p = 0.297$), FNMG and FCMG ($p = 0.398$), FNMG and FCNMG ($p = 0.680$), FCMG and FCNMG ($p = 0.626$) in baseline test were not statistically significant. Meanwhile, the differences in the motivation score between FMG and FNMG ($p = 0.584$), FMG and FCMG ($p = 0.406$), FMG and FCNMG ($p = 0.649$), FNMG and FCMG ($p = 0.730$), FNMG and FCNMG ($p = 0.894$), FCMG and FCNMG ($p = 0.626$) in the post-test 1 were not statistically significant. On the other hand, the differences in the motivation score between FMG and FCMG ($p = 0.457$); FMG and FCNMG ($p = 0.196$), FNMG and FCMG ($p = 0.143$), FNMG and FCNMG ($p = 0.189$), and FCMG and FCNMG ($p = 0.680$) in the post-test 2 were not statistically significant, but statistically significant between FMG and FNMG ($p < 0.05$). The effect size results indicated a large effect size between FMG and FNMG ($d = 0.791$) in the post-test 2.

Table 4.38 : Pairwise Comparison of Motivation (between groups)

		Comparison	MD	SE	P value	95% CI		Effect size (d)
						Lower	Upper	
Motivation	Baseline test	FMG VS FNMG	0.231	0.502	0.645	-0.752	1.214	0.158
		FMG VS FCMG	0.719	0.463	0.120	-0.188	1.626	0.532
		FMG VS FCNMG	0.463	0.443	0.297	-0.407	1.332	0.357
		FNMG VS FCMG	0.488	0.576	0.398	-0.642	1.617	0.290
		FNMG VS FCNMG	0.231	0.561	0.680	-0.868	1.331	0.141
		FCMG VS FCNMG	-0.256	0.526	0.626	-1.288	0.776	0.167
	Post-test 1	FMG VS FNMG	0.306	0.560	0.584	-0.791	1.403	0.187
		FMG VS FCMG	0.488	0.586	0.406	-0.662	1.637	0.285
		FMG VS FCNMG	0.244	0.535	0.649	-0.805	1.293	0.156
		FNMG VS FCMG	0.181	0.526	0.730	-0.849	1.212	0.118
		FNMG VS FCNMG	-0.063	0.468	0.894	-0.980	0.855	0.046
		FCMG VS FCNMG	-0.244	0.500	0.626	-1.223	0.735	0.167
	Post-test 2	FMG VS FNMG	1.206*	0.522	0.021	0.183	2.230	0.791
		FMG VS FCMG	0.431	0.580	0.457	-0.705	1.568	0.255
		FMG VS FCNMG	0.638	0.494	0.196	-0.330	1.605	0.442
		FNMG VS FCMG	-0.775	0.529	0.143	-1.812	0.262	0.502
		FNMG VS FCNMG	-0.569	0.433	0.189	-1.417	0.279	0.450
		FCMG VS FCNMG	0.206	0.501	0.680	-0.775	1.188	0.141

*: Significant difference at 0.05 level. MD: Mean difference, SE: Standard error

Figure 4.13 illustrates the mean motivation scores over time. All groups experienced a decline in motivation at post-test 1. However, at post-test 2, all groups demonstrated an increase in motivation levels.

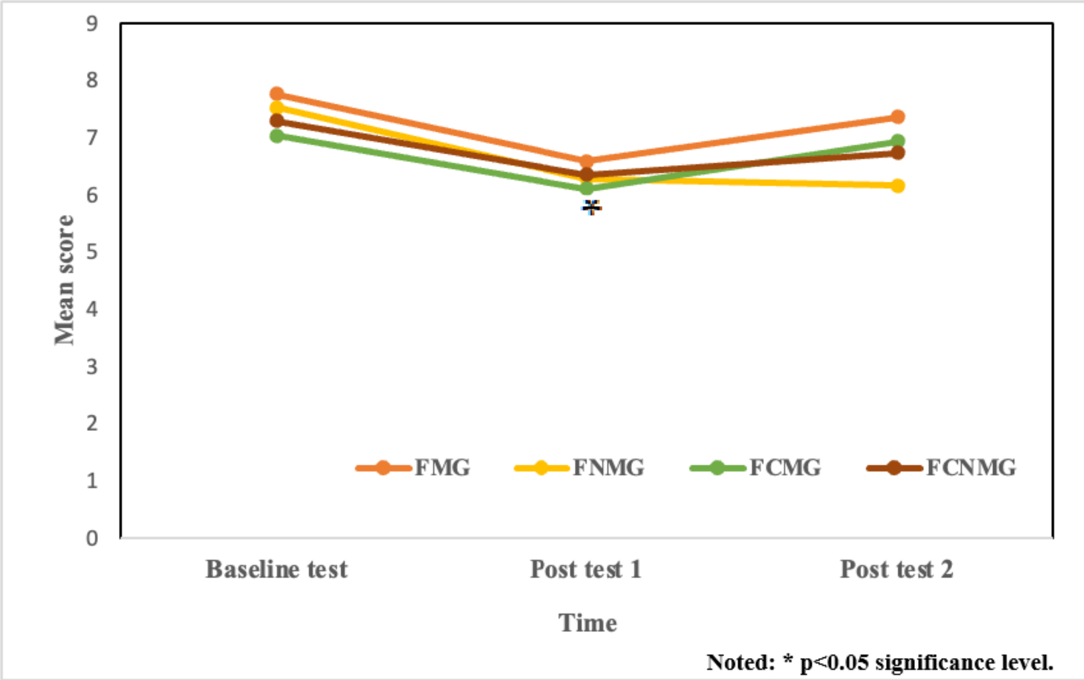


Figure 4.13 : The Mean Scores Changes of Motivation across the Times among Groups

4.4 Summary of the Result

The results of this study showed that mental fatigue impaired university table tennis players' mental fatigue feeling; negative emotion; attention focusing; attention shifting; scope of attention; thought-action repertoire; RPE; motivation; accuracy numbers; faults numbers; and total score. However, positive emotions and ball speed were not impaired by mental fatigue among university table tennis players. On the other hand, listening to music aided the recovery of mentally fatigued university table tennis players by counteracting feelings of mental fatigue; positive emotions; negative emotion; attention focusing; attention shifting; scope of attention; thought-action repertoire; RPE; motivation; accuracy numbers; faults numbers; and total score. However, there was little effect of music on the recovery of ball speed among mentally fatigued university table tennis players.

CHAPTER 5

DISCUSSION, CONCLUSION, IMPLICATION, AND RECOMMENDATION FOR FUTURE STUDY

5.1 Introduction

The chapter discusses the results of this study and consists of four sections. 5.1 Section presented the discussions based on the seven objectives of this study. 5.2 Section highlights the conclusions of the findings of this study. 5.3 Section comprises the implications on both theoretical and practical aspects. And 5.4 section presented the recommendations for future studies.

5.2 Discussion

The discussion section was based on the seven objectives of this study. Each objective discussed the effect of mental fatigue on the corresponding variable and the effect of music on the recovery of each dependent variable. Specifically, 5.1.1 discussed the Stroop task inducing mental fatigue and music recovery on mental fatigue feelings. 5.1.2 Discussed mental fatigue on the positive and negative emotions and the effects of music on the recovery of the positive and negative emotions. 5.1.3 discusses the mental fatigue on attention focusing, attention shifting, and music on the recovery of attention focusing and attention shifting. 5.1.4 Discussed mental fatigue and music on recovery of the scope of attention. 5.1.5 Discussed mental fatigue on the thought-action repertoire and music on recovery of the thought-action repertoire. 5.1.6 Discussed mental fatigue on stroke accuracy of accuracy numbers, faults, total score, and music on the recovery of stroke accuracy of accuracy faults and total score. 5.1.7 Discussed mental fatigue on ball speed and music on recovery of ball speed.

5.2.1 Discussion on Mental Fatigue Feeling

i. Stroop Task Inducing Mental Fatigue

The first objective of this study is to examine the Stroop task for inducing mental fatigue. This study found that the 45-minute Stroop task induced mental fatigue successfully in all four groups. Meanwhile, FMG and FNMG applied the incongruent Stroop task, which induced more mental fatigue than FCMG and FCNMG applied the congruent Stroop task. The successfully induced mental fatigue by the Stroop task is aligned with previous studies. For example, Kosack et al. (2020) instructed badminton players to exert a 60-minute Stroop task, which induced mental fatigue successfully (Kosack et al., 2020). Filipas et al. (2023) instructed tennis players to experience a 30-minute Stroop task inducing mental fatigue successfully (Filipas et al., 2024). Besides the Stroop task, Mansec et al. (2018) successfully applied AX-CPT cognitive task inducing mental fatigue (Mansec et al., 2018). The successfully inducing mental fatigue is aligned with the nature of mental fatigue, which is the psychobiological state induced by prolonged cognitive demanding tasks. This prolonged cognitive involvement leads participants to mental fatigue. Smith et al. (2019) examine the Stroop task. AX-CPT and Psychomotor Vigilance Task (PVT) are three cognitive tasks that induce mental fatigue; they reported that all three cognitive tasks effectively induce mental fatigue (Smith et al., 2019).

Meanwhile, they suggested that cognitive tasks require sustained attention, and inhibition processes could induce mental fatigue successfully (Smith et al., 2019). In contrast, the task involved in the inhibition process would lead participants to mental fatigue (Smith et al., 2019). This finding is aligned with the Ego Depletion Theory. This theory posits that self-control and cognitive regulation rely on limited mental resources (Baumeister & Vohs, 2016; Baumeister et al., 2016). The task required substantial cognitive control, depleted these resources, and led the participant into a mental fatigue condition (Baumeister & Vohs, 2016; Baumeister et al., 2016). Meanwhile, the incongruent task involving continuous suppression of automatic responses and this inhibition involvement led to more mental fatigue than the congruent Stroop task (Smith et al., 2019).

ii. Music on the Recovery Mental Fatigue Feeling

The other aspect of the first objective is to examine music to recover from mental fatigue. The finding of this study shows that players in FMG and FCMG listening to music reduce mental fatigue feelings significantly, while FNMG and FCNMG also reduce mental fatigue feelings. However, it is much less than listening to music groups. Listening to music recovers mental fatigue is aligned with previous studies; for example, Guo et al. (2015) instructed university students to listen to relaxing music while conducting cognitive tasks; participants in the listening to music group significantly reduced mental fatigue than the control group without music (Guo et al., 2015). Jacquet et al. (2021) instructed participants to listen to self-selected music after a 32-minute cognitive task, and participants' subjective feeling of mental fatigue was significantly less than without the music condition (Jacquet et al., 2021). Listening to music reduces mental fatigue, which might trigger the release of dopamine, a neurotransmitter associated with pleasure and reward; this elevated dopamine reduces perceived mental fatigue feelings (Ferreri et al., 2019).

Meanwhile, dopamine interacts with adenosine in the brain, where an increased dopamine level reduces adenosine activity (Ferré et al., 1997; Fuxe et al., 2010). As the psychobiological model of endurance performance proposed, the higher perception of effort is attributed to mental fatigue, triggering the elevated adenosine transmission (Marcora et al., 2009; Martin et al., 2018); this reduction of adenosine activity led to the psychophysical benefits of reduced rating of perceived exertion (Samuele M Marcora et al., 2009; Martin et al., 2018), subsequently reducing the feeling of mental fatigue.

5.2.2 Discussion on Positive and Negative Emotions

i. Mental Fatigue on Positive and Negative Emotion

The second objective of this study is to examine the effects of mental fatigue on positive and negative emotions. This study found that mental fatigue did not decrease positive emotions and, interestingly, was associated with decreased negative emotions in four groups. The psychobiological model of endurance performance suggests mental fatigue activates the ACC in the brain, leading to elevated adenosine transmission, which correspondingly inhibits dopamine transmission (Marcora et al., 2009; Martin et al., 2018). Since this inhibition, dopamine transmission might lead to positive emotions being less affected. Interestingly, this study found that mental fatigue was associated with a decrease in negative emotion in four groups. This is consistent with Dimitri van der Linden & Paul Eling (2006) finding that mental fatigue participants decreased the tension from 9.0 (2.6) to 8.58 (3.7) (Van Der Linden & Eling, 2006).

Some negative emotions, for example, anxiety and fear. Anxiety is a complex emotional state where people feel anxious, disturbed, worried, and annoyed in the face of impending danger or threat (Gutiérrez-García & Contreras, 2013). Fear is an emotion that is often related to anxiety. While anxiety arises from exception or concern about the occurrence of a fearful situation, fear is an affective reaction to actual exposure to threats (Foa & Kozak, 1986; Zhang et al., 2018). As the participants of this study are university table tennis players, they might quickly feel anxiety and fear when facing a challenging task. When they conduct the Stroop task, the players might enter the flow state, a psychological state of complete immersion and focused engagement in an activity, where individuals experience a profound sense of enjoyment and fulfilment (Jackson, 2000; Koehn & Díaz-Ocejo, 2022). The flow state decreases the attention from anxiety and fear to the focus on the task itself, subsequently decreasing the negative emotion (Rogatko, 2009).

ii. Music on the Positive and Negative Emotion

The second objective is to examine the effect of music on inducing positive and negative emotions. The finding of this study is that listening to music increases positive emotions and decreases negative emotions. The finding that listening to music increases positive emotions is aligned with previous studies; for example, Stefan Koelsch et al. (2021) suggested music can evoke a wide variety of emotions, such as positive emotions of joy, amusement, and amazement (Koelsch et al., 2021). As the conceptual framework for the benefits of music in exercise and sports suggested, listening to music could enhance the affective response (Terry et al., 2020). Meanwhile, listening to music as a reward triggers dopamine transmission (Ferreri et al., 2019), and the elevated dopamine transmission leads to increased positive emotion.

Meanwhile, listening to music also decreased the negative emotion; the finding of this study is aligned with Guo et al. (2015) Study, which instructed participants to listen to folk music to decrease anxiety ($F(1,34) = 19.13$, $p < 0.01$, $\eta p2 = 0.36$) (Guo et al., 2015b). The conceptual framework for the benefits of music in exercise and sports also suggests listening to music reduces anxiety (Terry et al., 2020) Meanwhile, listening to music triggers dopamine transmission, which might lead to a decrease in negative emotions (Ferreri et al., 2019).

5.2.3 Discussion on Attention Control of Attention Focusing and Attention Shifting

i. Mental Fatigue on Attention Focusing and Attention Shifting

This study's third objective is to examine mental fatigue's effect on attention focusing and shifting. The finding of this study is that mental fatigue leads to decreased attention focusing and attention shifting in four groups. This finding aligns with previous studies; Leung (2016) examined the attention of 47 undergraduate students during mental fatigue; subjective, EEG, pupil, and eye-tracking data suggest cognitive processing of attention-focusing efficiency declined over time (Hopstaken et al., 2016). Meanwhile, van der Linden and Eling found that mental fatigue impaired attention during local-global tasks, and mental fatigue impairs both the global and local shape of attention ability (Van Der Linden & Eling, 2006). The impairment of attention focusing and attention shifting were aligned with the strength model of self-regulation (Baumeister & Vohs, 2018). Cognitive resources are finite and depleted with cognitive activity, leading to a reduction of attention ability (Baumeister & Vohs, 2018; Baumeister et al., 2016). Mental fatigue depletes cognitive resources, leading to cognitive control deficits and a decrease in attention performance.

ii. Music on the Recovery of the Attention Focusing and Attention Shifting

The other aspect of the third objective is to examine the music on the recovery of attention focusing and attention shifting; the finding of this study is that FMG after music intervention, the attention focusing and attention shifting were significantly increased compared to FNMG sit and relaxing, which impaired by mental fatigue. This finding aligns with previous studies. For example, Guo et al. (2015) applied music counter mental fatigue; university students listening to music performed better in cognitive performance compared to those students who were not listening to music students (Guo et al., 2015). Their study suggested music helps regulate attention resources, which led to cognitive performance being less affected by mental fatigue (Guo et al., 2015). Attention resources are also indicated to be significant in cognitive tasks (Kok et al., 2006).

Meanwhile, Kiss & Linnell (2020) reported students listening to music could enhance their attention and improve their performance (Kiss & Linnell, 2021). On the other hand, music modulates perception in ACC. At the same time, the ACC is a critical brain region involving attention control and cognitive processes (Stevens et al., 2011). This overlapping and music-modulated perception might affect attention focusing and attention shifting. This finding is also aligned with attention restoration theory, which suggests exposure to certain stimuli, such as music, can help restore attention capacities by providing a break from focused attention tasks, subsequently increasing attention performance (Basu et al., 2019).

5.2.4 Discussion on the Scope of Attention

i. Mental Fatigue on the Scope of Attention

The fourth objective of this study is to examine the scope of attention. The finding of this study is that mental fatigue impaired the scope of attention; in this study, the scope of attention was measured by a global-local visual processing task; this measurement relies more on attention selection to examine participants under mental fatigue conditions, the selection of attention on the global or local aspect (Iglesias-Fuster et al., 2018). The finding of this study is that participants under mental fatigue conditions prefer to put attention on the simulated driven attention (bottom-up). This finding aligns with a previous study; for example, Boksen et al. 2005 examined mental fatigue on attention; they found that 3 hours without rest on mental fatigue tasks increased the reaction time and error rates in cognitive tasks, as well as an inability to inhibit automatic attention to irrelevant stimuli (Boksem et al., 2005). This also indicated that mental fatigue decreased the efficiency of goal-directed attention (top-down), made the participants more reliant on stimulus-driven (bottom-up) processes, and reduced the scope of attention. On the other hand, this finding is aligned with the strength model of self-regulation, the depleted cognitive resource deficit on exerting the cognitive control on the top-down process and transfer to the bottom-up method (Baumeister & Vohs, 2018; Baumeister et al., 2016). This might be the reason that mental fatigue impairs the scope of attention.

ii. Music on the Recovery of the Scope of Attention

The fourth objective is to examine music with the recovery of the scope of attention. This study found that FMG listening to music increased the scope of attention compared to FNMG sitting and relaxing. This finding was aligned with previous studies; for example, Putkinen et al. (2017) applied music-induced positive emotion, broadening the scope of auditory attention (Putkinen et al., 2017). On the other hand, global-local visual tasks measured the scope of attention and relied on attention selection (Iglesias-Fuster et al., 2018).

Nadon et al. (2021) suggested that relaxing music had a decreased error rate for congruent trials, while stimulating music similarly affects selective attention (Nadon et al., 2021). This finding could confirm that listening to music induces positive emotions and helps recover the attention impaired by mental fatigue. Due to mental fatigue, impaired attention and transferred the attention from goal-directed (top-down) to stimulus-driven (bottom-up) fashion (Boksem et al., 2005). Based on the scope of attention finding, attention selection transferred from stimulus-driven (bottom-up) attention to goal-directed (top-down) attention after listening to music. This indicates that listening to music helps recover attention impaired by mental fatigue. Moreover, this finding was aligned with the theory of the Broaden-and-build (Fredrickson & Branigan, 2005). Individual listening to music induced positive emotion, the successful positive emotion leads to broadening the scope of attention and effect the subsequent performance.

5.2.5 Discussion on Thought-Action Repertoire

i. Mental Fatigue on the Thought-Action Repertoire

This study's fifth objective is to examine mental fatigue's effect on thought-action repertoire. This study found that mental fatigue impaired thought-action repertoire in all four groups. Limited studies examined the effect of mental fatigue on the thought-action repertoire. The thought-action repertoire is the cognitive activity of "action tendencies'' from positive psychology (Fredrickson & Branigan, 2005). Although there is little study examining mental fatigue and thought-action repertoire, as Fredrickson et al. (2012) suggested, individuals under negative emotion state narrowed the momentary thought-action repertoire by calling forth specific action tendencies (e.g. attack, flee) (Fredrickson & Branigan, 2005). As the participants are under mental fatigue, the particular action tendencies might be rest or relaxation-related activity due to the definition of mental fatigue referring to the psychobiological state with a subjective feeling of tiredness and lack of energy (Marcora et al., 2009).

The finding aligns with the theory of the strength model of self-regulation; individuals exert self-control with depleted mental resources, and as the cognitive resources are depleted, the subsequent self-control process is more effortful (Baumeister & Vohs, 2016; Baumeister et al., 2016). Hence, the thought-action repertoire is decreased. Meanwhile, as the psychobiological model of endurance performance suggested, mental fatigue activated the ACC, leading to an elevated perception of effort and reduced motivation (Marcora et al., 2009; Martin et al., 2018). This decrease in motivation might be related to reduced thought-action repertoire.

ii. Music on the Recovery of the Thought-Action Repertoire

The fifth objective is to examine the effects of music on the recovery of the thought-action repertoire. The finding of this study is the thought-action repertoire was increased in FMG after listening to music. This finding is aligned with Fredrickson 2013, who proposed positive emotion broadens the thought-action repertoire (Fredrickson & Branigan, 2005). Although the Fredrickson study instructed participants to view some pictures to induce positive emotion, this study instructed the participants to listen to music to induce positive emotion (Fredrickson & Branigan, 2005). Putkinen et al. reported music could successfully induce mental fatigue (Vesa Putkinen et al., 2017).

As music modulates the perception of ACC, ACC is a critical brain region involving cognitive processes, which might be why music improves the thought-action repertoire (Stevens et al., 2011). On the other hand, this finding aligns with the broaden-and-build theory, in which positive emotion broadens the cognitive activity of the thought-action repertoire (Fredrickson & Branigan, 2005). Furthermore, this finding supported that mental fatigue was recovered by positive emotion induced by listening to music.

5.2.6 Discussion on Stroke Accuracy

i. Mental Fatigue on the Stroke Accuracy

This study's sixth objective is to evaluate mental fatigue's effect on stroke accuracy performance, supported by accuracy numbers, faults numbers and total scores. The finding of this study is accuracy number; the total score was significantly decreased in FMG and FNMG while less affected in FCMG and FCNMG. Meanwhile, the number of faults increased dramatically in the FMG and FNMG but was less affected in FCMG and FCNMG. This finding is aligned with Mansec et al. (2018) examined AX-CPT-induced mental fatigue on stroke accuracy in elite table tennis players; players stroke accuracy was decreased after mental fatigue inducement, with an increase in the fault numbers (Mansec et al., 2018).

Similarly, Filipas et al. applied the Stroop task inducing mental fatigue to examine its effect on tennis stroke accuracy; they found that mental fatigue impaired second serve accuracy (Filipas et al., 2024). The stroke accuracy performance aligns with the theory of the improved psychobiological model of endurance performance (Sun et al., 2022). This theory, based on the psychobiological model of endurance performance, proposes that RPE and motivation are two factors that mediate physical performance (Marcora et al., 2009; Martin et al., 2018).

The psychobiological model of exercise performance suggests that attention is also a significant factor that affects performance (Sun et al., 2022); by this theory, the effect of mental fatigue on performance from the physical aspect extent to the skill performance domain (Sun et al., 2022) and attention control and mental fatigue overlap in ACC (Faber et al., 2012; Lorist et al., 2005). Thus, stroke accuracy performance impaired by mental fatigue might be attributed to the player's exerted attention on the task due to table tennis being an eye-hand coordination sport (Haryanto & Amra, 2020; Paul et al., 2011). The deficit of attention control affected by mental fatigue decreases stroke accuracy performance. On the other hand, as the theory of the strength of self-regulation suggested, the self-control process depleted the *finite* and *universal* mental resource (Baumeister & Vohs, 2018; Baumeister et al., 2016); as the mental resource depleted, the subsequent attention control was deficit, consequently leading to stroke accuracy performance decrement.

ii. Music on the Recovery of Stroke Accuracy

The other aspect of the sixth objective is to evaluate the effects of music on the recovery of stroke accuracy impaired by mental fatigue. The finding of this study is mentally fatigued table tennis players increased the accuracy numbers and total score and decreased the faults number in FMG and FCMG compared to FNMG and FCNMG after listening to music recovery. The finding of this study aligns with Jacquet et al. (2021) applied self-selected music recovery to motor-control performance (Jacquet et al., 2021). Meanwhile, Guo et al. (2015) used folk music to counteract mental fatigue successfully, and participants under music conditions performed better cognitively than the control group without music (Guo et al., 2015. As their study suggested, music helps regulate the attention resource (Guo et al., 2015; Kok et al., 2006). This attention regulation led to performance being less affected by mental fatigue.

On the other hand, the finding of music on the recovery of attention suggested music improved attention after listening to music among mentally fatigued university table tennis players (see. 5.2.3 discussion on attention control). Attention control and mental fatigue overlapped in ACC, and this activation of ACC led to elevated adenosine and dopamine, correspondingly increasing the RPE and decreasing motivation and attention control (Marcora et al., 2009; Martin et al., 2018). However, the music stimulates and mediates the perception of the ACC (Antioch et al., 2020), leading to mentally fatigued players regulating their attention, subsequently helping recovery of stroke accuracy performance.

5.2.7 Discussion on Ball Speed

i. Mental Fatigue on the Ball Speed

This study's seventh objective is to examine mental fatigue's effect on ball speed. This study found that mental fatigue did not affect ball speed among university table tennis players. This finding is aligned with Filipas et al. (2023), who examined mental fatigue in the serve performance of tennis; they found mental fatigue did not affect the serve speed in the first and second serve speed (Filipas et al., 2024). However, this study's findings contrast with the study of Mansec et al. (2018), they suggesting mental fatigue impaired the ball speed in elite players. This inconsistency might be attributed to the difference in the duration of mental fatigue inducement (Mansec et al., 2018). In their study, they applied a 90-minute AX-CPT task for inducing mental fatigue, while this study induced mental fatigue with 45-minute Stroop task; the duration of mental fatigue inducement in Mansec et al.'s study is twice compared to this study, and the players might experience extreme mental fatigue.

Meanwhile, this study applied a 45-minute Stroop task to induce less mental fatigue, while a previous study suggested that a 30-minute Stroop task had already successfully induced mental fatigue (Sun et al., 2021). Mansec et al. players experienced extreme mental fatigue might be the reason for this inconsistency. On the other hand, in the Mansec et al. (2018) study, they recruited elite players. While this study recruited university table tennis players, the elite players might be more sensitive to speed. In contrast, university table tennis players are less, which might also be the reason for this inconsistency. This inconsistency is suggested in further studies investigating the effect of mental fatigue on ball speed among athletes and the effect of varying duration of mental fatigue on ball speed among athletes.

ii. Music on the Recovery of Ball Speed

The other aspect of the seventh objective is to examine the effect of music on ball speed among mentally fatigued university table tennis players. This study found that music did not affect ball speed among mentally fatigued university table tennis players. For one aspect, mental fatigue does not affect the ball speed among mentally fatigued university table tennis players. Hence, the music did not affect the ball speed. On the other hand, considering the speed-and-accuracy trade-off, the speed-accuracy trade-off is the inverse relationship between the speed at which players execute a stroke and the accuracy of the stroke (Sudo et al., 2024). The university table tennis players focused on stroke accuracy to earn higher points while less focused on ball speed. This might be the reason the ball speed was less affected by music.

5.3 Conclusion

Overall, mental fatigue impaired university table tennis players' mental fatigue feelings, negative emotion, attention control, scope of attention, thought-action repertoire, and stroke accuracy, while positive emotions and ball speed were less affected. On the other hand, listening to music aided the recovery of mentally fatigued university table tennis players by counteracting mental fatigue feelings, positive and negative emotions, attention control, scope of attention, thought-action repertoire, and stroke accuracy. However, music had little effect on the recovery of ball speed among mentally fatigued university table tennis players.

5.4 Implications

The findings of this study were implicated theoretically and practically. Detailed explains were presented as follows:

5.4.1 Theoretical Implication

The three theories of this study are the strength model of self-regulation (Baumeister & Vohs, 2018; Baumeister et al., 2016), the improved psychobiological model of endurance performance (Marcora et al., 2009; Martin et al., 2018; Sun, Soh, et al., 2022b) and broaden-and-build theory (Fredrickson & C. Branigan, 2005). The psychobiological model of endurance performance was a prominent theory in mental fatigue literature. This theory elaborately provides the mechanism of mental fatigue on physical performance. However, the skill performance should have been covered. However, the skill performance was also impaired in soccer (Smith et al., 2016), basketball (Cao et al., 2022; Fortes et al., 2020) table tennis (Mansec et al., 2018) and tennis (Filipas et al., 2024). This skill performance impaired by mental fatigue could not explained by the psychobiological model of endurance performance proposed as two mediators of RPE and motivation. Hence, the psychobiological model of endurance performance improved due to mental fatigue and attention control overlapping in the ACC (Faber et al., 2012; Lorist et al., 2005). This improvement might extend the effects of mental fatigue on the performance from the physical to the skill domain (Sun et al., 2022). However, the improved psychobiological model of endurance performance is still naïve and needs more empirical studies to confirm it. Thus, the results of this study could prove the improved psychobiological model of endurance performance suggested that attention is a significant factor mediating mental fatigue and skill performance.

On the other hand, the psychobiological model of exercise performance suggested the role of attention in mental fatigue literature. Attention can be divided into goal-directed attention (top-down) and stimulus-driven attention (bottom-up) (Katsuki &

Constantinidis, 2014; Pinto et al., 2013); goal-directed attention is impaired by mental fatigue and decreased focus (Boksem et al., 2005). Meanwhile, mentally fatigued players diverted their attention from global to local stimulus, indicating the goal-directed attention transfer to stimulus-driven attention. This finding also suggested that attention focusing was impaired by mental fatigue. Thus, attention focusing might mediate mental fatigue and skill performance. However, the attention focus incorporated into the psychobiological model of endurance performance still needs further empirical studies to confirm it.

For the broaden-and-build theory, this study is the first tested music-induced positive emotion under mental fatigue conditions in a sports context. However, this study preliminarily examined the broad effect, that is, music induced positive emotion increased the scope of attention and thought-action repertoire. Based on the psychobiological model of exercise performance suggests that attention is another factor that mediates mental fatigue and skill performance (Sun et al., 2022). This study found that music-induced positive emotion recovery in the scope of attention and thought-action repertoire attenuated the skill performance impaired by mental fatigue. Therefore, the broaden-and-build theory could be applied to positive emotion to counteract mental fatigue-induced performance decrement for future study investigation.

5.4.2 Practical Implication

Based on the results of the current study, mental fatigue impaired the performance of table tennis players. These findings have practical implications for table tennis players and coaches. Previous studies have demonstrated that long travel times to competition venues, prolonged mobile phone use, and extended video game play (Forte et al., 2019) can induce mental fatigue, which in turn adversely affects competitive performance, thus minimise the inducing mental fatigue task might contribute the table tennis players achieve the optimal performance. Moreover, if the opponent's mental fatigue occurred, the coaches and table tennis players could modulate the tactics, for example, focusing on accuracy to design the tactics to earn the competition and achieve optimal performance. On the other hand, music could be an effective recovery strategy for counteracting mental fatigue and subsequent performance decrement; hence, when table tennis players are under mental fatigue, listening to music could counteract mental fatigue feelings and counteract the stroke performance decrement impaired by mental fatigue.

5.5 Recommendations for Future Study

The findings of this study have suggested three significant recommendations for future studies. Details of recommendation are as follows:

i. The limitation of this study is mental fatigue inducement in the laboratory, which is a 45-minute Stroop Task for inducing mental fatigue; table tennis players conducted the Stroop task required sustained attention and inhibition control, which are common phenomena in fierce table tennis competition. However, table tennis players generally only experience this task after the competition. Notably, as the previous study reported, long travelling away to the competition and the long duration of smartphone use also caused mental fatigue, and as this study presented, mental fatigue impaired stroke performance in table tennis players. In real-game scenarios, athletes not only experience mental fatigue but also physiological fatigue due to the physical demands of the sport—both factors that can significantly affect performance. Therefore, future studies should investigate mental fatigue in table tennis performance and assess the effects of recovery interventions, such as music, in field settings that include real-world factors like extended travel and prolonged smartphone use. Additionally, incorporating measures of both physiological and mental fatigue would provide a more comprehensive understanding of how these factors interact to influence performance. Investigating fatigue and recovery strategies in field settings could yield more definitive conclusions and practical benefits for coaches and players.

ii. This study focused on music-induced mental fatigue in table tennis stroke performance, as previous studies suggested mental fatigue impaired performance in table tennis players. However, diverse sports performance (e.g., soccer, basketball, and tennis) were impaired by mental fatigue, and counteracting the mental fatigue-induced performance has not been examined. Hence, future studies should investigate music intervention on recovering these sports' performance impaired by mental fatigue.

iii. The study investigated music-induced positive emotion on mentally fatigued table tennis players' stroke performance; the context of stroke performance was based on table tennis players reversing the ball sent by the robot. However, as fierce table tennis competition rapidly increases, Table tennis players may not reverse the ball with a robot in real competition, so future studies should investigate the effects of mental fatigue-induced table tennis stroke performance decrement based on real competition and examine the effects of music recovery on the performance decrement.

REFERENCES

Akhshabi, M., & Rahimi, M. (2021). The impact of music on sports activities: a scoping review.

Alarcón, F., Ureña, N., & Cárdenas, D. (2017). Mental fatigue impairs the basketball free-throw performance [Article]. *Revista De Psicologia Del Deporte*, *26*, 33-36. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85018697659&partnerID=40&md5=3591283606336f676007f689f33dfbb0

Altenmüller, E., Wiesendanger, M., & Kesselring, J. (2006). *Music, motor control and the brain*. Oxford University Press Oxford.

Antioch, I., Furuta, T., Uchikawa, R., Okumura, M., Otogoto, J., Kondo, E., Sogawa, N., Ciobica, A., & Tomida, M. (2020). Favorite music mediates pain-related responses in the anterior cingulate cortex and skin pain thresholds. *Journal of Pain Research*, 2729-2737.

Arazi, H., Asadi, A., & Purabed, M. (2015). Physiological and psychophysical responses to listening to music during warm-up and circuit-type resistance exercise in strength trained men. *Journal of sports medicine*, *2015*(1), 389831.

Axelsen, J. L., Kirk, U., & Staiano, W. (2020). On-the-Spot Binaural Beats and Mindfulness Reduces the Effect of Mental Fatigue. *Journal of Cognitive Enhancement*, *4*(1), 31-39. https://doi.org/10.1007/s41465-019-00162-3

Ayres, L. P. (1911). The influence of music on speed in the six day bicycle race. *American Physical Education Review*, *16*(5), 321-324.

Ballmann, C. G. (2021). The influence of music preference on exercise responses and performance: a review. *J Funct Morphol Kinesiol*, *6*(2), 33.

Bartlett, F. C. (1943). Ferrier Lecture-Fatigue following highly skilled work. *Proceedings of the Royal Society of London. Series B-Biological Sciences*, *131*(864), 247-257.

Basu, A., Duvall, J., & Kaplan, R. (2019). Attention restoration theory: Exploring the role of soft fascination and mental bandwidth. *Environment and Behavior*, *51*(9-10), 1055-1081.

Baumeister, R. E., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego Depletion: Is the Active Self a Limited Resource?

Baumeister, R. F., & Heatherton, T. F. J. P. i. (1996). Self-regulation failure: An overview. *7*(1), 1-15.

Baumeister, R. F., & Steinhilber, A. (1984). Paradoxical effects of supportive audiences on performance under pressure: The home field disadvantage in sports championships. *Journal of Personality and Social Psychology*, *47*(1), 85-93. https://doi.org/10.1037/0022-3514.47.1.85

Baumeister, R. F., & Vohs, K. D. (2016). Strength Model of Self-Regulation as Limited Resource. In (pp. 67-127). https://doi.org/10.1016/bs.aesp.2016.04.001

Baumeister, R. F., & Vohs, K. D. (2018). Strength model of self-regulation as limited resource: Assessment, controversies, update. In *Self-regulation and self-control* (pp. 78-128). Routledge.

Baumeister, R. F., Vohs, K. D., & Tice, D. M. (2016). The Strength Model of Self-Control. *Current Directions in Psychological Science*, *16*(6), 351-355. https://doi.org/10.1111/j.1467-8721.2007.00534.x

Belli, T., Misuta, M. S., de Moura, P. P. R., Tavares, T. D. S., Ribeiro, R. A., Dos Santos, Y. Y. S., Sarro, K. J., & Galatti, L. R. (2019). Reproducibility and Validity of a Stroke Effectiveness Test in Table Tennis Based on the Temporal Game Structure. *Front Psychol*, *10*, 427. https://doi.org/10.3389/fpsyg.2019.00427

Boksem, M. A., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on attention: an ERP study. *Cognitive Brain Research*, *25*(1), 107-116.

Boksem, M. A., Meijman, T. F., & Lorist, M. M. (2006). Mental fatigue, motivation and action monitoring. *Biol Psychol*, *72*(2), 123-132. https://doi.org/10.1016/j.biopsycho.2005.08.007

Boksem, M. A., & Tops, M. (2008). Mental fatigue: costs and benefits. *Brain Res Rev*, *59*(1), 125-139. https://doi.org/10.1016/j.brainresrev.2008.07.001

Borghini, G., Vecchiato, G., Toppi, J., Astolfi, L., Maglione, A., Isabella, R., Caltagirone, C., Kong, W., Wei, D., & Zhou, Z. (2012). Assessment of mental fatigue during car driving by using high resolution EEG activity and neurophysiologic indices. 2012 annual international conference of the IEEE engineering in medicine and biology society,

Boyas, S., & Guével, A. (2011). Neuromuscular fatigue in healthy muscle: underlying factors and adaptation mechanisms. *Annals of physical and rehabilitation medicine*, *54*(2), 88-108.

Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology*, *74*(5), 1252-1265.

Bray, S. R., Graham, J. D., Ginis, K. A. M., & Hicks, A. L. (2012). Cognitive task performance causes impaired maximum force production in human hand flexor muscles. *Biological psychology*, *89*(1), 195-200.

Brown, D. M., & Bray, S. R. (2017). Effects of mental fatigue on physical endurance performance and muscle activation are attenuated by monetary incentives. *Journal of Sport and Exercise Psychology*, *39*(6), 385-396.

Campbell, M. K., Fayers, P. M., & Grimshaw, J. M. (2005). Determinants of the intracluster correlation coefficient in cluster randomized trials: the case of implementation research. *Clinical Trials*, *2*(2), 99-107.

Cao, S., Geok, S. K., Roslan, S., Sun, H., Lam, S. K., & Qian, S. (2022). Mental Fatigue and Basketball Performance: A Systematic Review [Review]. *Frontiers in Psychology*, *12*, Article 819081. https://doi.org/10.3389/fpsyg.2021.819081

Chen, H., Chin, K. L., & Tan, C. B. (2021). Selection and validation of emotional videos: Dataset of professional and amateur videos that elicit basic emotions. *Data in Brief*, *34*, 106662.

Chen, L., Sugi, T., Shirakawa, S., Zou, J., & Nakamura, M. (2008). Comfortable environments for mental work by suitable work-rest schedule: Mental fatigue and relaxation. 2008 6th IEEE International Conference on Industrial Informatics,

Chen, Y.-W., Tan, T.-C., & Lee, P.-C. (2015). The Chinese government and the globalization of table tennis: A case study in local responses to the globalization of sport. *The international journal of the history of sport*, *32*(10), 1336-1348.

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Academic press.

Cohen, J. D., Botvinick, M., & Carter, C. S. (2000). Anterior cingulate and prefrontal cortex: who's in control? *Nature neuroscience*, *3*(5), 421-423.

Cooper, A. (2021). An investigation into the factors affecting player development within each phase of the academy pathway in english football academies. *Soccer & Society*, *22*(5), 429-441.

Cox, R. H., Martens, M. P., & Russell, W. D. (2003). Measuring Anxiety in Athletics: The Revised Competitive State Anxiety Inventory–2 %J Journal of Sport and Exercise Psychology. *25*(4), 519-533. https://doi.org/10.1123/jsep.25.4.519

Daniell, W. E., Swan, S. S., McDaniel, M. M., Stebbins, J. G., Seixas, N. S., & Morgan, M. S. (2002). Noise exposure and hearing conservation practices in an industry with high incidence of workers' compensation claims for hearing loss. *American journal of industrial medicine*, *42*(4), 309-317.

Davis, W. B., & Thaut, M. H. (1989). The influence of preferred relaxing music on measures of state anxiety, relaxation, and physiological responses. *Journal of music therapy*, *26*(4), 168-187.

Derryberry, D., & Tucker, D. M. (1994). Motivating the focus of attention.

Desai, S., & Patel, N. (2021). Development and validity of questionnaire for healthy adult human participants of early phase bioequivalence pharmacokinetic endpoint study. *Research Journal of Pharmacology and Pharmacodynamics*, *13*(4), 111-117.

Díaz-García, J., García-Calvo, T., Manzano-Rodríguez, D., López-Gajardo, M. Á., Parraca, J. A., & Ring, C. (2023). Brain endurance training improves shot speed and accuracy in grassroots padel players. *Journal of Science and Medicine in Sport*, *26*(7), 386-393.

Díaz-García, J., González-Ponce, I., López-Gajardo, M., Van Cutsem, J., Roelands, B., & García-Calvo, T. (2021). How Mentally Fatiguing Are Consecutive World Padel Tour Matches? *Int J Environ Res Public Health*, *18*(17). https://doi.org/10.3390/ijerph18179059

Díaz-García, J., Habay, J., Rubio-Morales, A., De Wachter, J., García-Calvo, T., Roelands, B., & Van Cutsem, J. (2024). Mental fatigue impairs padel-specific psychomotor performance in youth-elite male players. *European Journal of Sport Science, 24(4), 508-517.*

Ding, C., Soh, K. G., Sun, H., Roslan, S., Cao, S., & Zhao, Y. (2024). Does mental fatigue affect performance in racket sports? A systematic review. *BMC Sports Science, Medicine and Rehabilitation*, *16*(1), 179.

Dorris, D. C., Power, D. A., & Kenefick, E. (2012). Investigating the effects of ego depletion on physical exercise routines of athletes. *Psychology of Sport and Exercise*, *13*(2), 118-125.

Eliakim, M., Bodner, E., Eliakim, A., Nemet, D., & Meckel, Y. (2012). Effect of motivational music on lactate levels during recovery from intense exercise. *The Journal of Strength & Conditioning Research*, *26*(1), 80-86.

Englert, C., & Wolff, W. (2015). Ego depletion and persistent performance in a cycling task. *International Journal of Sport Psychology*, *46*(2), 137-151.

Faber, I. R. (2016). Diamonds in the rough: searching for high potential in youth table tennis players.

Faber, L. G., Maurits, N. M., & Lorist, M. M. (2012). Mental fatigue affects visual selective attention. *Plos One*, *7*(10), e48073.

Fernández-Domínguez, J. C., Sesé-Abad, A., Morales-Asencio, J. M., Sastre-Fullana, P., Pol-Castañeda, S., & de Pedro-Gómez, J. E. (2016). Content validity of a health science evidence-based practice questionnaire (HS-EBP) with a web-based modified Delphi approach. *International Journal for Quality in Health Care*, *28*(6), 764-773.

Ferré, S., Fuxe, K., Fredholm, B. B., Morelli, M., & Popoli, P. (1997). Adenosine–dopamine receptor–receptor interactions as an integrative mechanism in the basal ganglia. *Trends in neurosciences*, *20*(10), 482-487.

Ferreri, L., Mas-Herrero, E., Zatorre, R. J., Ripollés, P., Gomez-Andres, A., Alicart, H., Olivé, G., Marco-Pallarés, J., Antonijoan, R. M., & Valle, M. (2019). Dopamine modulates the reward experiences elicited by music. *Proceedings of the National Academy of Sciences*, *116*(9), 3793-3798.

Filipas, L., Ferioli, D., Banfi, G., La Torre, A., & Vitale, J. A. (2021). Single and combined effect of acute sleep restriction and mental fatigue on basketball free-throw performance. *International Journal of Sports Physiology and Performance*, *16*(3), 415-420.

Filipas, L., Rossi, C., Codella, R., & Bonato, M. (2024). Mental Fatigue Impairs Second Serve Accuracy in Tennis Players. *Research Quarterly for Exercise and Sport*, *95*(1), 190-196.

Foa, E. B., & Kozak, M. J. (1986). Emotional processing of fear: exposure to corrective information. *Psychological Bulletin*, *99*(1), 20.

Fortes, L. S., Berriel, G. P., Faro, H., Freitas-Júnior, C. G., & Peyré-Tartaruga, L. A. (2022). Can Prolongate Use of Social Media Immediately Before Training Worsen High Level Male Volleyball Players' Visuomotor Skills? *Percept Mot Skills*, 315125221123635. https://doi.org/10.1177/00315125221123635

Fortes, L. S., de Lima, D., Gantois, P., Nasicmento, J. R. A., & Fonseca, F. S. (2021). Smartphone Use Among High Level Swimmers Is Associated With Mental Fatigue and Slower 100-and 200-but Not 50-Meter Freestyle Racing. *Perceptual and Motor Skills*, *128*(1), 390-408, Article 0031512520952915. https://doi.org/10.1177/0031512520952915

Fortes, L. S., De Lima-Junior, D., Fiorese, L., Nascimento-Júnior, J. R. A., Mortatti, A. L., & Ferreira, M. E. C. (2020). The effect of smartphones and playing video games on decision-making in soccer players: A crossover and randomised study. *J Sports Sci*, *38*(5), 552-558. https://doi.org/10.1080/02640414.2020.1715181

Fortes, L. S., Lima, D., Barbosa, B. T., Faro, H. K. C., Ferreira, M. E. C., & Almeida, S. S. Effect of mental fatigue on decision-making skill and visual search behaviour in basketball players: an experimental and randomised study. *International Journal of Sport and Exercise Psychology*. https://doi.org/10.1080/1612197x.2022.2058055

Fredrickson, B. L. (2004). The broaden–and–build theory of positive emotions. *Philosophical transactions of the royal society of London. Series B: Biological Sciences*, *359*(1449), 1367-1377.

Fredrickson, B. L., & Branigan, C. (2005). Positive emotions broaden the scope of attention and thought-action repertoires. *Cognition & emotion*, *19*(3), 313-332.

Fuxe, K., Marcellino, D., Borroto-Escuela, D., Guescini, M., Fernandez-Duenas, V., Tanganelli, S., Rivera, A., Ciruela, F., & Agnati, L. (2010). Adenosine–dopamine interactions in the pathophysiology and treatment of CNS disorders. *CNS neuroscience & therapeutics*, *16*(3), e18-e42.

Gandevia, S. C. (2001). Spinal and supraspinal factors in human muscle fatigue. *Physiological reviews*, *81*(4), 1725-1789.

Girard, O., & Millet, G. P. (2009). Neuromuscular fatigue in racquet sports. *Physical Medicine and Rehabilitation Clinics of North America*, *20*(1), 161-173.

Griffin, N. (2014). *Ping-pong diplomacy: the secret history behind the game that changed the world*. Simon and Schuster.

Guglielmi, D., Panari, C., & Simbula, S. (2012). The determinants of teachers' well-being: The mediating role of mental fatigue. *European Journal of Mental Health*, *7*(2), 204-220.

Guo, W., Ren, J., Wang, B., & Zhu, Q. (2015). Effects of Relaxing Music on Mental Fatigue Induced by a Continuous Performance Task: Behavioral and ERPs Evidence. *Plos One*, *10*(8), e0136446. https://doi.org/10.1371/journal.pone.0136446

Gutiérrez-García, A. G., & Contreras, C. M. (2013). Anxiety: an adaptive emotion. *New insights into anxiety disorders*, 21-37.

Guyon, A. J., Hildebrandt, H., Güsewell, A., Horsch, A., Nater, U. M., & Gomez, P. (2022). How audience and general music performance anxiety affect classical music students' flow experience: a close look at its dimensions. *Frontiers in Psychology*, *13*, 959190.

Habay, J., Proost, M., De Wachter, J., Diaz-Garcia, J., De Pauw, K., Meeusen, R., Van Cutsem, J., & Roelands, B. (2021). Mental Fatigue-Associated Decrease in Table Tennis Performance: Is There an Electrophysiological Signature? *International Journal of Environmental Research and Public Health*, *18*(24), Article 12906. https://doi.org/10.3390/ijerph182412906

Habay, J., Van Cutsem, J., Verschueren, J., De Bock, S., Proost, M., De Wachter, J., Tassignon, B., Meeusen, R., & Roelands, B. (2021). Mental Fatigue and Sport-Specific Psychomotor Performance: A Systematic Review. *Sports Medicine*, *51*(7), 1527-1548. https://doi.org/10.1007/s40279-021-01429-6

Hammond, N. (2012). Vuvuzelas, pop stars and back-up dancers: the politics of rhythm and noise at the 2010 soccer World Cup in South Africa. *SAMUS: South African Music Studies*, *32*(1), 37-58.

Hardin, J. W., & Hilbe, J. M. (2002). *Generalized estimating equations*. chapman and hall/CRC.

Haryanto, J., & Amra, F. (2020). The relationship of concentration and eye-hand coordination with accuracy of backhand backspin serve in table tennis. *International Journal of Technology, Innovation and Humanities*, *1*(1), 51-56.

Hayashi, M., Chikazawa, Y., & Hori, T. (2004). Short nap versus short rest: recuperative effects during VDT work. *Ergonomics*, *47*(14), 1549-1560. https://doi.org/10.1080/00140130412331293346

Hodges, D. A. (2009). Bodily responses to music. *The Oxford handbook of music psychology*, *2009*, 121-130.

Holtzer, R., Shuman, M., Mahoney, J. R., Lipton, R., & Verghese, J. (2010). Cognitive fatigue defined in the context of attention networks. *Aging, Neuropsychology,* *and Cognition*, *18*(1), 108-128.

Hommel, B., Ridderinkhof, K. R., & Theeuwes, J. (2002). Cognitive control of attention and action: Issues and trends. *Psychological research*, *66*(4), 215-219.

Hong, Z., & Sun, Y. (2000). The butterfly effect and the making of'ping-pong diplomacy'. *Journal of Contemporary China*, *9*(25), 429-448.

Hopstaken, J. F., Van Der Linden, D., Bakker, A. B., & Kompier, M. A. (2015). A multifaceted investigation of the link between mental fatigue and task disengagement. *Psychophysiology*, *52*(3), 305-315.

Hopstaken, J. F., van der Linden, D., Bakker, A. B., Kompier, M. A. J., & Leung, Y. K. (2016). Shifts in attention during mental fatigue: Evidence from subjective, behavioral, physiological, and eye-tracking data. *J Exp Psychol Hum Percept Perform*, *42*(6), 878-889. https://doi.org/10.1037/xhp0000189

Huang, Q., Mao, X., Shi, J., Pan, J., & Li, A. (2024). Enhanced Cognitive Inhibition in Table Tennis Athletes: Insights from Color-Word and Spatial Stroop Tasks. *Brain Sciences*, *14*(5), 443.

Iglesias-Fuster, J., Piña-Novo, D., Ontivero-Ortega, M., Lage-Castellanos, A., & Valdés-Sosa, M. (2018). Recurrent activation of neural circuits during attention to global and local visual information. *Span J Psychol*, *21*, E17.

Iino, Y., & Kojima, T. (2016). Effect of the racket mass and the rate of strokes on kinematics and kinetics in the table tennis topspin backhand. *Journal of Sports Sciences*, *34*(8), 721-729.

Ishii, A., Tanaka, M., & Watanabe, Y. (2014). Neural mechanisms of mental fatigue. *Reviews in the Neurosciences*, *25*(4), 469-479. https://doi.org/10.1515/revneuro-2014-0028

Iso-Ahola, S. E. (2013). Exercise: Why It is a Challenge for Both the Nonconscious and Conscious Mind. *Review of General Psychology*, *17*(1), 93-110. https://doi.org/10.1037/a0030657

Iso-Ahola, S. E. (2024). A theory of the skill-performance relationship. *Frontiers in Psychology*, *15*, 1296014.

Itao, K., Komazawa, M., & Kobayashi, H. (2018). A study into blood flow, heart rate variability, and body surface temperature while listening to music. *Health*, *10*(2), 181-188.

Jackson, S. A. (2000). Joy, fun, and flow state in sport.

Jacquet, T., Poulin-Charronnat, B., Bard, P., Perra, J., & Lepers, R. (2021). Physical Activity and Music to Counteract Mental Fatigue. *Neuroscience*, *478*, 75-88. https://doi.org/10.1016/j.neuroscience.2021.09.019

Jiménez-Olmedo, J. M., Penichet-Tomás, A., Villalón-Gasch, L., & Pueo, B. (2021). Validity and reliability of smartphone high-speed camera and Kinovea for velocity-based training measurement.

Jones, L., Karageorghis, C. I., & Ekkekakis, P. (2014). Can high-intensity exercise be more pleasant? Attentional dissociation using music and video. *Journal of Sport and Exercise Psychology*, *36*(5), 528-541.

Juslin, P. N. (2016). Emotional reactions to music. *The Oxford handbook of music psychology*, 197-213.

Juslin, P. N., Liljeström, S., Västfjäll, D., Barradas, G., & Silva, A. (2008). An experience sampling study of emotional reactions to music: listener, music, and situation. *Emotion*, *8*(5), 668.

Juslin, P. N., & Västfjäll, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. *Behavioral and brain sciences*, *31*(5), 559-575.

Karageorghis, C. I. (2020). Music-Related Interventions in the Exercise Domain: A Theory-Based Approach. *Handbook of sport psychology*, 929-949.

Karageorghis, C. I., Cheek, P., Simpson, S. D., & Bigliassi, M. (2018). Interactive effects of music tempi and intensities on grip strength and subjective affect. *Scandinavian Journal of Medicine & Science in Sports*, *28*(3), 1166-1175.

Karageorghis, C. I., Hutchinson, J. C., Jones, L., Farmer, H. L., Ayhan, M. S., Wilson, R. C., Rance, J., Hepworth, C. J., & Bailey, S. G. (2013). Psychological, psychophysical, and ergogenic effects of music in swimming. *Psychology of Sport and Exercise*, *14*(4), 560-568.

Karageorghis, C. I., Mouzourides, D. A., Priest, D.-L., Sasso, T. A., Morrish, D. J., & Walley, C. L. (2009). Psychophysical and ergogenic effects of synchronous music during treadmill walking. *Journal of Sport and Exercise Psychology*, *31*(1), 18-36.

Katsuki, F., & Constantinidis, C. (2014). Bottom-up and top-down attention: different processes and overlapping neural systems. *The Neuroscientist*, *20*(5), 509-521.

Kemper, K. J., & Danhauer, S. C. (2005). Music as therapy. *South Med J*, *98*(3), 282-288.

Kim, J., & Seo, B. S. (2013). How to calculate sample size and why. *Clinics in orthopedic surgery*, *5*(3), 235-242.

Kim, J. K., & Kim, J. K. (2016). Glory of Beijing Olympics. *International Theatre Olympics: The Artistic and Intercultural Power of Olympism*, 117-132.

Kim, Y. E., Schmidt, E. M., Migneco, R., Morton, B. G., Richardson, P., Scott, J., Speck, J. A., & Turnbull, D. (2010). Music emotion recognition: A state of the art review. Proc. ismir, Kimchi, R., & Palmer, S. E. (1982). Form and texture in hierarchically constructed patterns. *Journal of Experimental Psychology: Human Perception and Performance*, *8*(4), 521.

Kiss, L., & Linnell, K. J. (2021). The effect of preferred background music on task-focus in sustained attention. *Psychological research*, *85*(6), 2313-2325.

Kleine, D. (1990). Anxiety and sport performance: A meta-analysis. *Anxiety research*, *2*(2), 113-131.

Koehn, S., & Díaz-Ocejo, J. (2022). Imagery intervention to increase flow state: A single-case study with middle-distance runners in the state of Qatar. *International Journal of Sport and Exercise Psychology*, *20*(3), 729-742.

Koelsch, S., Cheung, V. K., Jentschke, S., & Haynes, J.-D. (2021). Neocortical substrates of feelings evoked with music in the ACC, insula, and somatosensory cortex. *Scientific Reports*, *11*(1), 10119.

Kok, A., Ridderinkhof, K. R., & Ullsperger, M. (2006). The control of attention and actions: current research and future developments. *Brain Research*, *1105*(1), 1-6.

Kosack, M. H., Staiano, W., Folino, R., Hansen, M. B., & Lønbro, S. (2020). The Acute Effect of Mental Fatigue on Badminton Performance in Elite Players. *Int J Sports Physiol Perform*, *15*(5), 632-638. https://doi.org/10.1123/ijspp.2019-0361

Krallmann, S. (2016). *Without music, life would be a mistake.-Friedrich Nietzsche. How do music and singing affect singers lives? Reflections based on qualitative interviews with singers and choral conductors*

Kunrath, C. A., Cardoso, F. d. S. L., Calvo, T. G., & Costa, I. T. d. (2020). Mental fatigue in soccer: a systematic review. *Revista Brasileira De Medicina Do Esporte*, *26*, 172-178.

Labbé, E., Schmidt, N., Babin, J., & Pharr, M. (2007). Coping with stress: the effectiveness of different types of music. *Applied psychophysiology and biofeedback*, *32*, 163-168.

Lee, P.-C., & Tan, T.-C. (2011). Impacts of 2008 Beijing Olympic Games on national identity: Perspectives of collegiate athletes in Taiwan. *Sports & Exercise Research*, *13*(1), 10-22.

Lees, A. (2003). Science and the major racket sports: a review. *Journal of Sports Sciences*, *21*(9), 707-732.

Leggieri, M., Thaut, M. H., Fornazzari, L., Schweizer, T. A., Barfett, J., Munoz, D. G., & Fischer, C. E. (2019). Music intervention approaches for Alzheimer's disease: A review of the literature. *Frontiers in Neuroscience*, *13*, 132.

Lim, J.-H., Kim, H., Jeon, C., & Cho, S. (2018). The effects on mental fatigue and the cognitive function of mechanical massage and binaural beats (brain massage) provided by massage chairs. *Complementary therapies in clinical practice*, *32*, 32-38.

Loch, F., zum Berge, A. H., Ferrauti, A., Meyer, T., Pfeiffer, M., & Kellmann, M. (2020). Acute Effects of Mental Recovery Strategies After a Mentally Fatiguing Task. *Frontiers in Psychology*, *11*, Article 558856. https://doi.org/10.3389/fpsyg.2020.558856

Lorist, M. M., Boksem, M. A., & Ridderinkhof, K. R. (2005). Impaired cognitive control and reduced cingulate activity during mental fatigue. *Cognitive Brain Research*, *24*(2), 199-205.

MacDonald, A. W., Cohen, J. D., Stenger, V. A., & Carter, C. S. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science*, *288*(5472), 1835-1838.

MacLeod, C. M., & MacDonald, P. A. (2000). Interdimensional interference in the Stroop effect: Uncovering the cognitive and neural anatomy of attention. *Trends in cognitive sciences*, *4*(10), 383-391.

MacMahon, C., Schücker, L., Hagemann, N., & Strauss, B. (2014). Cognitive fatigue effects on physical performance during running. *Journal of Sport and Exercise Psychology*, *36*(4), 375-381.

Malagoli Lanzoni, I., Di Michele, R., & Merni, F. (2014). A notational analysis of shot characteristics in top-level table tennis players. *Eur J Sport Sci*, *14*(4), 309-317. https://doi.org/10.1080/17461391.2013.819382

Malloch, S., & Trevarthen, C. (2018). The Human Nature of Music. *Front Psychol*, *9*, 1680. https://doi.org/10.3389/fpsyg.2018.01680

Mangin, T., André, N., Benraiss, A., Pageaux, B., & Audiffren, M. (2021). No ego-depletion effect without a good control task. *Psychology of Sport and Exercise*, *57*, 102033.

Mansec, Y., Dorel, S., Nordez, A., & Jubeau, M. (2016). Sensitivity and Reliability of a Specific Test of Stroke Performance in Table Tennis. *Int J Sports Physiol Perform*, *11*(7), 678-684. https://doi.org/10.1123/ijspp.2015-0444

Mansec, Y., Pageaux, B., Nordez, A., Dorel, S., & Jubeau, M. (2018). Mental fatigue alters the speed and the accuracy of the ball in table tennis. *Journal of Sports Sciences*, *36*(23), 2751-2759. https://doi.org/10.1080/02640414.2017.1418647

Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical performance in humans. *J Appl Physiol (1985)*, *106*(3), 857-864. https://doi.org/10.1152/japplphysiol.91324.2008

Martin, K., Meeusen, R., Thompson, K. G., Keegan, R., & Rattray, B. (2018). Mental Fatigue Impairs Endurance Performance: A Physiological Explanation. *Sports Medicine*, *48*(9), 2041-2051. https://doi.org/10.1007/s40279-018-0946-9

Martin, K., Staiano, W., Menaspà, P., Hennessey, T., Marcora, S., Keegan, R., Thompson, K. G., Martin, D., Halson, S., & Rattray, B. (2016). Superior inhibitory control and resistance to mental fatigue in professional road cyclists. *Plos One*, *11*(7), e0159907.

McAfee, R. (2009). *Table tennis: Steps to success*. Human Kinetics.

McMorris, T., Barwood, M., Hale, B. J., Dicks, M., & Corbett, J. (2018). Cognitive fatigue effects on physical performance: A systematic review and meta-analysis. *Physiology & Behavior*, *188*, 103-107.

Menen, R. (2004). *The miracle of music therapy*. Pustak Mahal.

Menon, V., & Levitin, D. J. (2005). The rewards of music listening: response and physiological connectivity of the mesolimbic system. *Neuroimage*, *28*(1), 175-184.

Miell, D., MacDonald, R. A., & Hargreaves, D. J. (2005). *Musical communication*. Oxford University Press, USA.

Migliaccio, G. M., Di Filippo, G., Russo, L., Orgiana, T., Ardigò, L. P., Casal, M. Z., Peyré-Tartaruga, L. A., & Padulo, J. (2022). Effects of mental fatigue on reaction time in sportsmen. *International Journal of Environmental Research and Public Health*, *19*(21), 14360.

Milham, M. P., Banich, M. T., Claus, E. D., & Cohen, N. J. (2003). Practice-related effects demonstrate complementary roles of anterior cingulate and prefrontal cortices in attentional control. *Neuroimage*, *18*(2), 483-493.

Miller, E. K. (2000). The prefontral cortex and cognitive control. *Nature Reviews Neuroscience*, *1*(1), 59-65.

Moore, K. S. (2013). A systematic review on the neural effects of music on emotion regulation: Implications for music therapy practice. *Journal of music therapy*, *50*(3), 198-242.

Moradipanah, F., Mohammadi, E., & Mohammadil, A. (2009). Effect of music on anxiety, stress, and depression levels in patients undergoing coronary angiography. *EMHJ-Eastern Mediterranean Health Journal, 15 (3), 639-647, 2009*.

Moral-Bofill, L., López de la Llave, A., Pérez-Llantada, M. C., & Holgado-Tello, F. P. (2022). Development of flow state self-regulation skills and coping with musical performance anxiety: design and evaluation of an electronically implemented psychological program. *Frontiers in Psychology*, *13*, 899621.

Morean, M. E., DeMartini, K. S., Leeman, R. F., Pearlson, G. D., Anticevic, A., Krishnan-Sarin, S., Krystal, J. H., & O'Malley, S. S. J. P. a. (2014). Psychometrically improved, abbreviated versions of three classic measures of impulsivity and self-control. *26*(3), 1003.

Muraven, M., Collins, R. L., & Nienhaus, K. (2002). Self-control and alcohol restraint: an initial application of the self-control strength model. *Psychol Addict Behav*, *16*(2), 113-120. https://doi.org/10.1037//0893-164x.16.2.113

Muraven, M., Tice, D. M., & Baumeister, R. F. (1998). Self-Control as Limited Resource: Regulatory Depletion Patterns.

Murray, D. M., & Short, B. J. (1997). Intraclass correlation among measures related to tobacco use by adolescents: estimates, correlates, and applications in intervention studies. *Addictive behaviors*, *22*(1), 1-12.

Nadon, É., Tillmann, B., Saj, A., & Gosselin, N. (2021). The emotional effect of background music on selective attention of adults. *Frontiers in Psychology*, *12*, 729037.

Nawrot, P., Jordan, S., Eastwood, J., Rotstein, J., Hugenholtz, A., & Feeley, M. (2003). Effects of caffeine on human health. *Food Additives & Contaminants*, *20*(1), 1-30.

O'Donoghue, P., Girard, O., & Reid, M. (2013). Racket sports. *Routledge handbook of sports performance analysis*, 404-414.

O'Driscoll, S. V. (2019). The power of music: Sean Villanueva O'Driscoll.

O'Neill, Conor, Panuwatwanich, & Kriengsak. (2013). The impact of fatigue on labour productivity: Case study of dam construction project in Queensland.

Oberste, M., de Waal, P., Joisten, N., Walzik, D., Egbringhoff, M., Javelle, F., Bloch, W., & Zimmer, P. (2021). Acute aerobic exercise to recover from mental exhaustion – a randomized controlled trial. *Physiology & Behavior*, *241*, 113588. https://doi.org/https://doi.org/10.1016/j.physbeh.2021.113588

Pageaux, B., & Lepers, R. (2018). The effects of mental fatigue on sport-related performance. In S. Marcora & M. Sarkar (Eds.), *Sport and the Brain: The Science of Preparing, Enduring and Winning, Pt C* (Vol. 240, pp. 291-315). https://doi.org/10.1016/bs.pbr.2018.10.004

Pageaux, B., Lepers, R., Dietz, K. C., & Marcora, S. M. (2014). Response inhibition impairs subsequent self-paced endurance performance. *European Journal of Applied Physiology*, *114*(5), 1095-1105.

Paul, M., Biswas, S. K., & Sandhu, J. S. (2011). Role of sports vision and eye hand coordination training in performance of table tennis players. *Brazilian Journal of Biomotricity*, *5*(2), 106-116.

Pereira, A. P. S., Marinho, V., Gupta, D., Magalhães, F., Ayres, C., & Teixeira, S. (2019). Music therapy and dance as gait rehabilitation in patients with Parkinson disease: a review of evidence. *Journal of geriatric psychiatry and neurology*, *32*(1), 49-56.

Peterson, S. J., & Foley, S. (2021). Clinician's guide to understanding effect size, alpha level, power, and sample size. *Nutrition in Clinical Practice*, *36*(3), 598-605.

Pinto, Y., van der Leij, A. R., Sligte, I. G., Lamme, V. A., & Scholte, H. S. (2013). Bottom-up and top-down attention are independent. *Journal of vision*, *13*(3), 16-16.

Potteiger, J. A., Schroeder, J. M., & Goff, K. L. (2000). Influence of music on ratings of perceived exertion during 20 minutes of moderate intensity exercise. *Perceptual and Motor Skills*, *91*(3), 848-854.

Proost, M., Habay, J., De Wachter, J., De Pauw, K., Rattray, B., Meeusen, R., Roelands, B., & Van Cutsem, J. (2022). How to Tackle Mental Fatigue: A Systematic Review of Potential Countermeasures and Their Underlying Mechanisms. *Sports Medicine*, *52*(9), 2129-2158. https://doi.org/10.1007/s40279-022-01678-z

Putkinen, V., Makkonen, T., & Eerola, T. (2017). Music-induced positive mood broadens the scope of auditory attention. *Soc Cogn Affect Neurosci*, *12*(7), 1159-1168. https://doi.org/10.1093/scan/nsx038

Putkinen, V., Makkonen, T., & Eerola, T. (2017). Music-induced positive mood broadens the scope of auditory attention. *Social Cognitive and Affective Neuroscience*, *12*(7), 1159-1168.

Raab, M., Masters, R. S., & Maxwell, J. P. (2005). Improving the 'how'and 'what'decisions of elite table tennis players. *Human Movement Science*, *24*(3), 326-344.

Riskind, J. H., & Alloy, L. B. (2006). Cognitive vulnerability to psychological disorders: Overview of theory, design, and methods. *Journal of Social and Clinical Psychology*, *25*(7), 705-725.

Robinson, J. (1995). Startle. *The Journal of Philosophy*, *92*(2), 53-74.

Rodrigues, S. T., Vickers, J. N., & Williams, A. M. (2002). Head, eye and arm coordination in table tennis. *Journal of Sports Sciences*, *20*(3), 187-200.

Rogatko, T. P. (2009). The influence of flow on positive affect in college students. *Journal of happiness studies*, *10*, 133-148.

Rokushima, K., & Watanabe, Y. (2010). Effects of mild-stream bathing on recovery from mental fatigue. *Med Sci Monit*, *16*(1), 14.

RVSPK, R., Priyanath, H., & Megama, R. (2020). Methods and rules-of-thumb in the determination of minimum sample size when applying structural equation modelling: A review. *J Soc Sci Res*, *15*(2), 102-109.

Sakata12, N., Kurata12, T., Kourogi, M., & Kuzuoka, H. (2006). Situated music: An application to interactive jogging.

Santiváñez-Acosta, R., Tapia-López, E. L. N., & Santero, M. (2020). Music Therapy in Pain and Anxiety Management during Labor: A Systematic Review and Meta-Analysis. *Medicina (Kaunas)*, *56*(10). https://doi.org/10.3390/medicina56100526

Santos, P. C. R. d., Barbieri, F. A., Zijdewind, I., Gobbi, L. T. B., Lamoth, C., & Hortobágyi, T. (2019). Effects of experimentally induced fatigue on healthy older adults' gait: A systematic review. *Plos One*, *14*(12), e0226939.

Schmeichel, B. J., & Zell, A. (2007). Trait self-control predicts performance on behavioral tests of self-control. *J Pers*, *75*(4), 743-755. https://doi.org/10.1111/j.1467-6494.2007.00455.x

Sgherza, A. L., Axen, K., Fain, R., Hoffman, R. S., Dunbar, C. C., & Haas, F. (2002). Effect of naloxone on perceived exertion and exercise capacity during maximal cycle ergometry. *Journal of Applied Physiology*, *93*(6), 2023-2028.

Simpson, S. D., & Karageorghis, C. I. (2006). The effects of synchronous music on 400-m sprint performance. *Journal of Sports Sciences*, *24*(10), 1095-1102.

Sireci, S. G. (1998). The construct of content validity. *Social indicators research*, *45*, 83-117.

Smith, M. R., Chai, R., Nguyen, H. T., Marcora, S. M., & Coutts, A. J. (2019). Comparing the effects of three cognitive tasks on indicators of mental fatigue. *Journal of Psychology*, *153*(8), 759-783. https://doi.org/10.1080/00223980.2019.1611530

Smith, M. R., Coutts, A. J., Merlini, M., Deprez, D., Lenoir, M., & Marcora, S. M. (2016). Mental fatigue impairs soccer-specific physical and technical performance. *Medicine and Science in Sports and Exercise*, *48*(2), 267-276.

Smith, M. R., Zeuwts, L., Lenoir, M., Hens, N., De Jong, L. M., & Coutts, A. J. (2016). Mental fatigue impairs soccer-specific decision-making skill. *J Sports Sci*, *34*(14), 1297-1304. https://doi.org/10.1080/02640414.2016.1156241

Spieth, P. M., Kubasch, A. S., Penzlin, A. I., Illigens, B. M., Barlinn, K., & Siepmann, T. (2016). Randomized controlled trials - a matter of design. *Neuropsychiatr Dis Treat*, *12*, 1341-1349. https://doi.org/10.2147/NDT.S101938

Stevens, F. L., Hurley, R. A., & Taber, K. H. (2011). Anterior cingulate cortex: unique role in cognition and emotion. *The Journal of neuropsychiatry and clinical neurosciences*, *23*(2), 121-125.

Stubbs, R. J., Hughes, D. A., Johnstone, A. M., Rowley, E., Reid, C., Elia, M., Stratton, R., Delargy, H., King, N., & Blundell, J. (2000). The use of visual analogue scales to assess motivation to eat in human subjects: a review of their reliability and validity with an evaluation of new hand-held computerized systems for temporal tracking of appetite ratings. *British Journal of Nutrition*, *84*(4), 405-415.

Suda, M., Morimoto, K., Obata, A., Koizumi, H., & Maki, A. (2008). Emotional responses to music: towards scientific perspectives on music therapy. *Neuroreport*, *19*(1), 75-78.

Sudo, Y., Kawamoto, Y., Iino, Y., & Yoshioka, S. (2024). Mechanisms of speed-accuracy trade-off in tennis topspin forehand of college players. *Sports Biomechanics*, 1-22.

Sun, H., Soh, K. G., Roslan, S., Wazir, M., Mohammadi, A., Ding, C., & Zhao, Z. (2022). Nature exposure might be the intervention to improve the self-regulation and skilled performance in mentally fatigue athletes: A narrative review and conceptual framework. *Front Psychol*, *13*, 941299. https://doi.org/10.3389/fpsyg.2022.941299

Sun, H., Soh, K. G., Roslan, S., Wazir, M., & Soh, K. L. (2021). Does mental fatigue affect skilled performance in athletes? A systematic review. *Plos One*, *16*(10), Article e0258307. https://doi.org/10.1371/journal.pone.0258307

Sun, H., Soh, K. G., & Xu, X. (2022). Nature Scenes Counter Mental Fatigue-Induced Performance Decrements in Soccer Decision-Making. *Front Psychol*, *13*, 877844. https://doi.org/10.3389/fpsyg.2022.877844

Sun, H., Soh, K. G. G., Roslan, S., Wazir, M., Mohammadi, A., Ding, C., & Zhao, Z. J. (2022b). Nature exposure might be the intervention to improve the self-regulation and skilled performance in mentally fatigue athletes: A narrative review and conceptual framework. *Frontiers in Psychology*, *13*, Article 941299. https://doi.org/10.3389/fpsyg.2022.941299

Tan, S.-h., & Guo, Y.-y. (2008). Revision of self-control scale for Chinese college students. *Chinese Journal of Clinical Psychology*.

Tangney, J. P., Baumeister, R. F., & Boone, A. L. (2004). High Self-Control Predicts Good Adjustment, Less Pathology, Better Grades, and Interpersonal Success.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International journal of medical education*, *2*, 53.

Terry, P. C., Karageorghis, C. I., Curran, M. L., Martin, O. V., & Parsons-Smith, R. L. (2020). Effects of music in exercise and sport: A meta-analytic review. *Psychological Bulletin*, *146*(2), 91.

Thaut, M. (2013). *Rhythm, music, and the brain: Scientific foundations and clinical applications*. Routledge.

Theofanidis, D., & Fountouki, A. (2018). Limitations and delimitations in the research process. *Perioperative Nursing-Quarterly scientific, online official journal of*

GORNA, *7*(3 September-December 2018), 155-163.

Toriola, A. L., Toriola, O. M., & Igbokwe, N. U. (2004). Validity of specific motor skills in predicting table-tennis performance in novice players. *Perceptual and Motor Skills*, *98*(2), 584-586.

Torrente, F., Yoris, A., Low, D., Lopez, P., Bekinschtein, P., Vazquez, G. H., Manes, F., & Cetkovich, M. (2022). Psychological symptoms, mental fatigue and behavioural adherence after 72 continuous days of strict lockdown during the COVID-19 pandemic in Argentina. *BJPsych Open*, *8*(1), e10. https://doi.org/10.1192/bjo.2021.1065

Turino, T. (2008). *Music as social life: The politics of participation*. University of Chicago Press.

Van Belle, G. (2011). *Statistical rules of thumb* (Vol. 699). John Wiley & Sons.

Van Cutsem, J., Marcora, S., De Pauw, K., Bailey, S., Meeusen, R., & Roelands, B. (2017). The Effects of Mental Fatigue on Physical Performance: A Systematic Review. *Sports Medicine*, *47*(8), 1569-1588. https://doi.org/10.1007/s40279-016-0672-0

Van Der Linden, D., & Eling, P. (2006). Mental fatigue disturbs local processing more than global processing. *Psychological research*, *70*, 395-402.

van der Linden, D., Massar, S. A., Schellekens, A. F., Ellenbroek, B. A., & Verkes, R. J. (2006). Disrupted sensorimotor gating due to mental fatigue: preliminary evidence. *Int J Psychophysiol*, *62*(1), 168-174. https://doi.org/10.1016/j.ijpsycho.2006.04.001

van Schouwenburg, M., Aarts, E., & Cools, R. (2010). Dopaminergic modulation of cognitive control: distinct roles for the prefrontal cortex and the basal ganglia. *Current pharmaceutical design*, *16*(18), 2026-2032.

Viera, A. J., & Garrett, J. M. (2005). Understanding interobserver agreement: the kappa statistic. *Fam med*, *37*(5), 360-363.

Vink, A. C., Bruinsma, M. S., & Scholten, R. J. (2003). Music therapy for people with dementia. *Cochrane database of systematic reviews*(4).

Vogel, I., van de Looij-Jansen, P. M., Mieloo, C. L., Burdorf, A., & de Waart, F. (2012). Risky music-listening behaviors and associated health-risk behaviors. *Pediatrics*, *129*(6), 1097-1103.

Vohs, K. D., & Faber, R. J. (2007). Spent resources: Self-regulatory resource availability affects impulse buying. *Journal of consumer research*, *33*(4), 537-547.

Weikert, T., Al-Mohannadi, K., Sörling, P., Gillman, P., Hajem, C., Maehara, M., Rivera, M., Zhihao, S., America, L., & America, N. (2014). INTERNATIONAL TABLE TENNIS FEDERATION.

Weir, J. P. (2005). Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *The Journal of Strength & Conditioning Research*, *19*(1), 231-240.

Wiersma, U. J. (1992). The effects of extrinsic rewards in intrinsic motivation: A meta-analysis. *Journal of occupational and organizational psychology*, *65*(2), 101-114.

Williams, N. (2017). The Borg rating of perceived exertion (RPE) scale. *Occupational medicine*, *67*(5), 404-405.

Wilson, M. R., Vine, S. J., & Wood, G. (2013). The influence of anxiety on visual attentional control in basketball free throw shooting.

Wong, D. W.-C., Lee, W. C.-C., & Lam, W.-K. (2020). Biomechanics of table tennis: A systematic scoping review of playing levels and maneuvers. *Applied Sciences*, *10*(15), 5203.

Woodman, T., & Hardy, L. (2003). The relative impact of cognitive anxiety and self-confidence upon sport performance: A meta-analysis. *Journal of Sports Sciences*, *21*(6), 443-457.

Wright, R. A. (2008). Refining the prediction of effort: Brehm's distinction between potential motivation and motivation intensity.

Yang, w., & He, S. (2019). Factor Structure and Empirical Validation of Attentional Control Scale in Chinese Undergraduates. *The 22nd National Academic congress of Psychology.*

You, Y., Ma, Y., Ji, Z., Meng, F., Li, A., & Zhang, C. (2018). Unconscious response inhibition differences between table tennis athletes and non-athletes. *Peerj*, *6*, e5548.

Zhang, J. (2018). Analysis of culture development of Chinese table tennis.

Zhang, S., Chen, G., Wu, Q., & Li, X. (2023). The Interplay Between Table Tennis Skill Development and Sports Performance: A Comprehensive Review. *Pacific International Journal*, *6*(3), 150-156.

Zhang, S., Woodman, T., & Roberts, R. (2018). Anxiety and fear in sport and performance. In *Oxford research encyclopedia of psychology*.

Zhang, Z. (2017). *Biomechanical analysis and model development applied to table tennis forehand strokes*

Zhao, C., Zheng, C., Zhao, M., Tu, Y., & Liu, J. (2011). Multivariate autoregressive models and kernel learning algorithms for classifying driving mental fatigue based on electroencephalographic. *Expert Systems with Applications*, *38*(3), 1859-1865. https://doi.org/https://doi.org/10.1016/j.eswa.2010.07.115

Zhao, F., Manchaiah, V. K., French, D., & Price, S. M. (2010). Music exposure and hearing disorders: an overview. *International journal of audiology*, *49*(1), 54-64.

Zhou, X. (2022). *The multisensory integration of musical emotions: From behavior to neural substrate* Southwest University].

Zhu, B. (1994). The Revised Chinese Norm of The Competitive State Anxiery Inventory (CSAI-2). *Psychological Science*, *6*, 358-362. https://doi.org/10.16719/j.cnki.1671-6981.1994.06.007

Zhu, M., Pi, Y., Zhang, J., & Gu, N. (2022). The superior response speed of table tennis players is associated with proactive inhibitory control. *Peerj*, *10*, e13493.

APPENDICES

Appendix A

Systematic Review of Effects of Mental Fatigue on Racket Sports

Table 1 : Number of Hits for the Complete Strategy from Difference Databases (28/12/2023)

Databases	Complete searching string	Hits
Web of Science	(ALL=("mental fatigue" OR "mental exertion" OR "cognitive fatigue" OR "cognitive exertion" OR "mental exhaustion" OR "mental tiredness")) AND ALL=("racquet sports" OR "racket sports" OR "racket players" OR "Badminton" OR "Badminton players" OR "squash" OR "squash sport" OR padel OR "paddle tennis" OR "paddle" OR "padel players" OR "tennis" OR "Tennis player" OR "Table Tennis" OR "ping pong" OR "table tennis players")	22
PubMed	("mental fatigue"[All Fields] OR "mental exertion"[All Fields] OR "cognitive fatigue"[All Fields] OR "cognitive exertion"[All Fields] OR "mental exhaustion"[All Fields] OR "mental tiredness"[All Fields]) AND ("racquet sports"[All Fields] OR "racket sports"[All Fields] OR "racket players"[All Fields] OR "Badminton"[All Fields] OR "Badminton players"[All Fields] OR "squash"[All Fields] OR "squash sport"[All Fields] OR "padel"[All Fields] OR "paddle tennis"[All Fields] OR "paddle"[All Fields] OR "padel players"[All Fields] OR "tennis"[All Fields] OR "Tennis player"[All Fields] OR "Table Tennis"[All Fields] OR "ping pong"[All Fields] OR "table tennis players"[All Fields])	13
SCOPUS	(TITLE-ABS-KEY ("mental fatigue" OR "mental exertion" OR "cognitive fatigue" OR "cognitive exertion" OR "mental exhaustion" OR "mental tiredness") AND TITLE-ABS-KEY ("racquet sports" OR "racket sports" OR "racket players" OR "badminton" OR "badminton players" OR "squash" OR "squash sport" OR padel OR "paddle tennis" OR "paddle" OR "padel players" OR "tennis" OR "tennis player" OR "table tennis" OR "ping pong" OR "table tennis players"))	21
SPORTDiscus	("mental fatigue" OR "mental exertion" OR "cognitive fatigue" OR "cognitive exertion" OR "mental exhaustion" OR "mental tiredness") AND ("racquet sports" OR "racket sports" OR "racket players" OR "Badminton" OR "Badminton players" OR "squash" OR "squash sport" OR padel OR "paddle tennis" OR "paddle" OR "padel players" OR "tennis" OR "Tennis player" OR "Table Tennis" OR "ping pong" OR "table tennis players")	339
Psychological and Behavioral Science Collection	("mental fatigue" OR "mental exertion" OR "cognitive fatigue" OR "cognitive exertion" OR "mental exhaustion" OR "mental tiredness") AND ("racquet sports" OR "racket sports" OR "racket players" OR "Badminton" OR "Badminton players" OR "squash" OR "squash sport" OR padel OR "paddle tennis" OR "paddle" OR "padel players" OR "tennis" OR "Tennis player" OR "Table Tennis" OR "ping pong" OR "table tennis players")	38

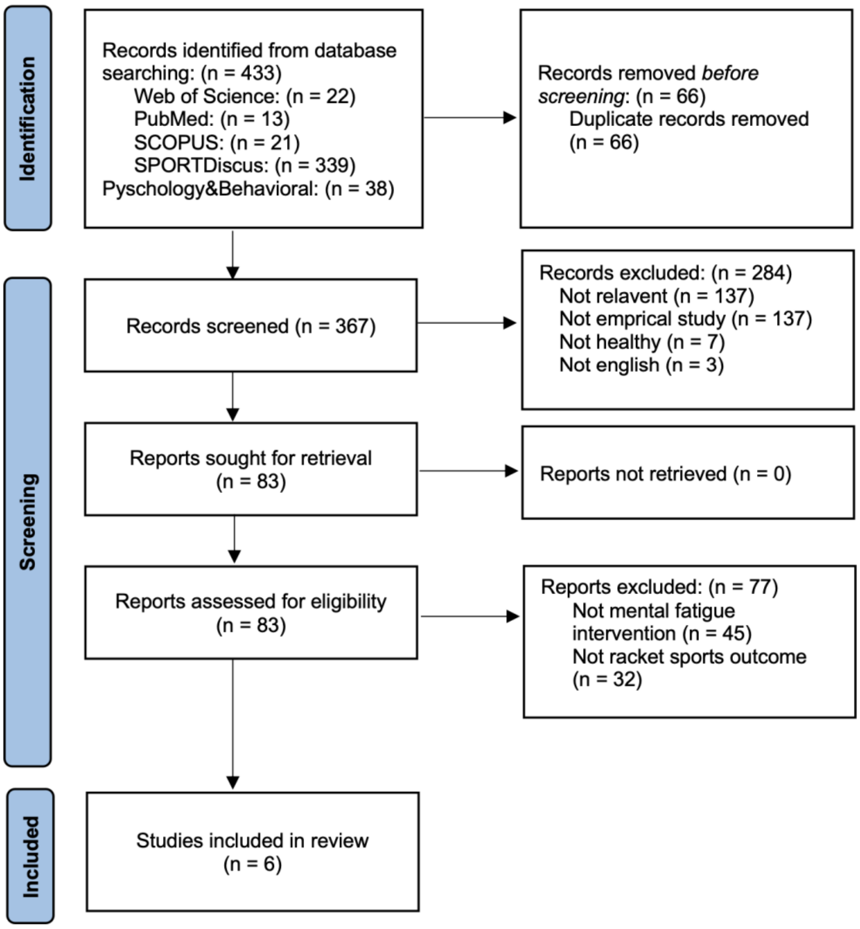


Figure 1 : Flow Diagram of the Study Selection Procedure

Table 2 : Overview of Included Publication Details

Study	Population Characteristics	Intervention			Outcomes		
		Manipulation	Duration	Markers	Type of Sports	Performance Domain	Performance outcomes
Mansec et al., 2018	22 elites Sex: 22 ♂ Age: 26.9 ± 8.9 y	EG: AX-CPT CG: Watching movie	90 mins	SE: F-VAS↑ PBM: RPE↑	Table tennis	Skill: Stroke	Ball speed↓; Accuracy↔ Faults↑; Total Score↓
Van Cutsem et al., 2019	11 experienced Sex: 5 ♂; 6 ♀ Age: 25 ± 4 y	EG: Stroop task CG: Documentary	90 mins	SE:F-VAS↑; NASA-TLX: MD↑; PD↑;TD↑; Effort↑; Frustration↑; PBM:I-MO↔; S-MO↔ PM:HR↔;BG↔	Badminton	Perceptual-cognitive: Cognitive; Visuomotor	Flanker task Response time↑ Accuracy↔ Visuomotor task Response time↑
Kosack et al., 2020	19 elite Sex: 19 ♂ Age: 20 ± 2.8 y	EG: Stroop task CG: Documentary	60 mins	SE: F-VAS↑; PBM:MO↔; Focus↔; RPE↔; PM:HR↔; BL↔	Badminton	Perceptual-cognitive: Physical; Specific skill	Countermovement jump height↔ Badminton-Specific duration↔
Habay et al., 2021	11 experienced Sex: 7♂; 4♀ Age: 24 ± 2 y	EG: Stroop task CG: Documentary	60 mins	SE: F-VAS↑; NASA-TLX: Frustration↑ PBM: I-MO↓; S-MO↔; PRE↑ PM: HR↔ EEG upper α band↓;θ band↓;	Table tennis	Perceptual-cognitive: Cognitive; Visuomotor	Flanker task Response time↔; Accuracy↔; Visuomotor task; Reaction time↑;
Díaz-García et al., 2023	61 amateurs Age: 28.71 ± 7.68 y	EG: Stroop task CG: Control condition	30 mins	SE: F-VAS↑; PM: Saccade latencies↓	Padel	Perceptual-cognitive: Cognitive;	Psychomotor vigilance task Reaction time↑
Filipas et al., 2023	10 professionals Sex: 10♂ Age: 18 ± 4 y	EG: Stroop task CG: Cognitive task	30 mins	SE: F-VAS↑;	Tennis	Skill: Serve	First serve accuracy↔; Second serve accuracy↓; First serve speed↔; Second serve speed↔

y: Years; ♂: Males; ♀: Females; ↑: Significant higher; ↓: Significant lower; ↔: No significant difference; EG: Experimental Group; CG: Control Group; AX-CPT: AX-Continuous Performance Test; mins: Minutes; SE: Subjective Evaluation; PBM: Psychobiological Markers; PM: Physiological Markers; F-VAS: Fatigue Visual Analogy Scale; NASA-TLX: National Aeronautics and Space Administration Task Load Index: Heart Rate BG: Blood Glucose; BL: Blood Lactate; EEG: Electroencephalography; I-MO: Intrinsic Motivation; S-MO: Success Motivation; MD: Mental Demand; PD: Physical Demand; TD: Temporal Demand; NA: Not Applicable

Appendix B

Systematic Review of Effects of Music on Counteract Mental Fatigue

Table 2 : Number of Hits for the Complete Search Strategy for the Different Databases (18/11/2023)

Database	Complete search string	Hits
Web of Science	(ALL=((“Music” OR “Rap Music” OR “Music, Rap” OR “Hip Hop Music” OR “Hop Music, Hip” OR “Music, Hip Hop” OR “Jazz Music” OR “Music, Jazz” OR “Classical Music” OR “Music, Classical” OR “Songs” OR “Song” OR “Vocal Melody” OR “Melodies, Vocal” OR “Melody, Vocal” OR “Vocal Melodies” OR “Rock and Roll Music”))) AND ALL=((“mental fatigue” OR “mental exertion” OR “cognitive fatigue” OR “cognitive exertion” OR “mental exhaustion” OR “mental tiredness”))	52
PubMed	((“Music” OR “Rap Music” OR “Music, Rap” OR “Hip Hop Music” OR “Hop Music, Hip” OR “Music, Hip Hop” OR “Jazz Music” OR “Music, Jazz” OR “Classical Music” OR “Music, Classical” OR “Songs” OR “Song” OR “Vocal Melody” OR “Melodies, Vocal” OR “Melody, Vocal” OR “Vocal Melodies” OR “Rock and Roll Music”)) AND ((“mental fatigue” OR “mental exertion” OR “cognitive fatigue” OR “cognitive exertion” OR “mental exhaustion” OR “mental tiredness”))	41
SCOPUS	TITLE-ABS-KEY ((“Music” OR “Rap Music” OR “Music, Rap” OR “Hip Hop Music” OR “Hop Music, Hip” OR “Music, Hip Hop” OR “Jazz Music” OR “Music, Jazz” OR “Classical Music” OR “Music, Classical” OR “Songs” OR “Song” OR “Vocal Melody” OR “Melodies, Vocal” OR “Melody, Vocal” OR “Vocal Melodies” OR “Rock and Roll Music”) AND (“mental fatigue” OR “mental exertion” OR “cognitive fatigue” OR “cognitive exertion” OR “mental exhaustion” OR “mental tiredness”))	52
SPORTSDiscus	((“Music” OR “Rap Music” OR “Music, Rap” OR “Hip Hop Music” OR “Hop Music, Hip” OR “Music, Hip Hop” OR “Jazz Music” OR “Music, Jazz” OR “Classical Music” OR “Music, Classical” OR “Songs” OR “Song” OR “Vocal Melody” OR “Melodies, Vocal” OR “Melody, Vocal” OR “Vocal Melodies” OR “Rock and Roll Music”)) AND ((“mental fatigue” OR “mental exertion” OR “cognitive fatigue” OR “cognitive exertion” OR “mental exhaustion” OR “mental tiredness”))	296
Psychological and Behavioral Sciences Collection	((“Music” OR “Rap Music” OR “Music, Rap” OR “Hip Hop Music” OR “Hop Music, Hip” OR “Music, Hip Hop” OR “Jazz Music” OR “Music, Jazz” OR “Classical Music” OR “Music, Classical” OR “Songs” OR “Song” OR “Vocal Melody” OR “Melodies, Vocal” OR “Melody, Vocal” OR “Vocal Melodies” OR “Rock and Roll Music”)) AND ((“mental fatigue” OR “mental exertion” OR “cognitive fatigue” OR “cognitive exertion” OR “mental exhaustion” OR “mental tiredness”))	286

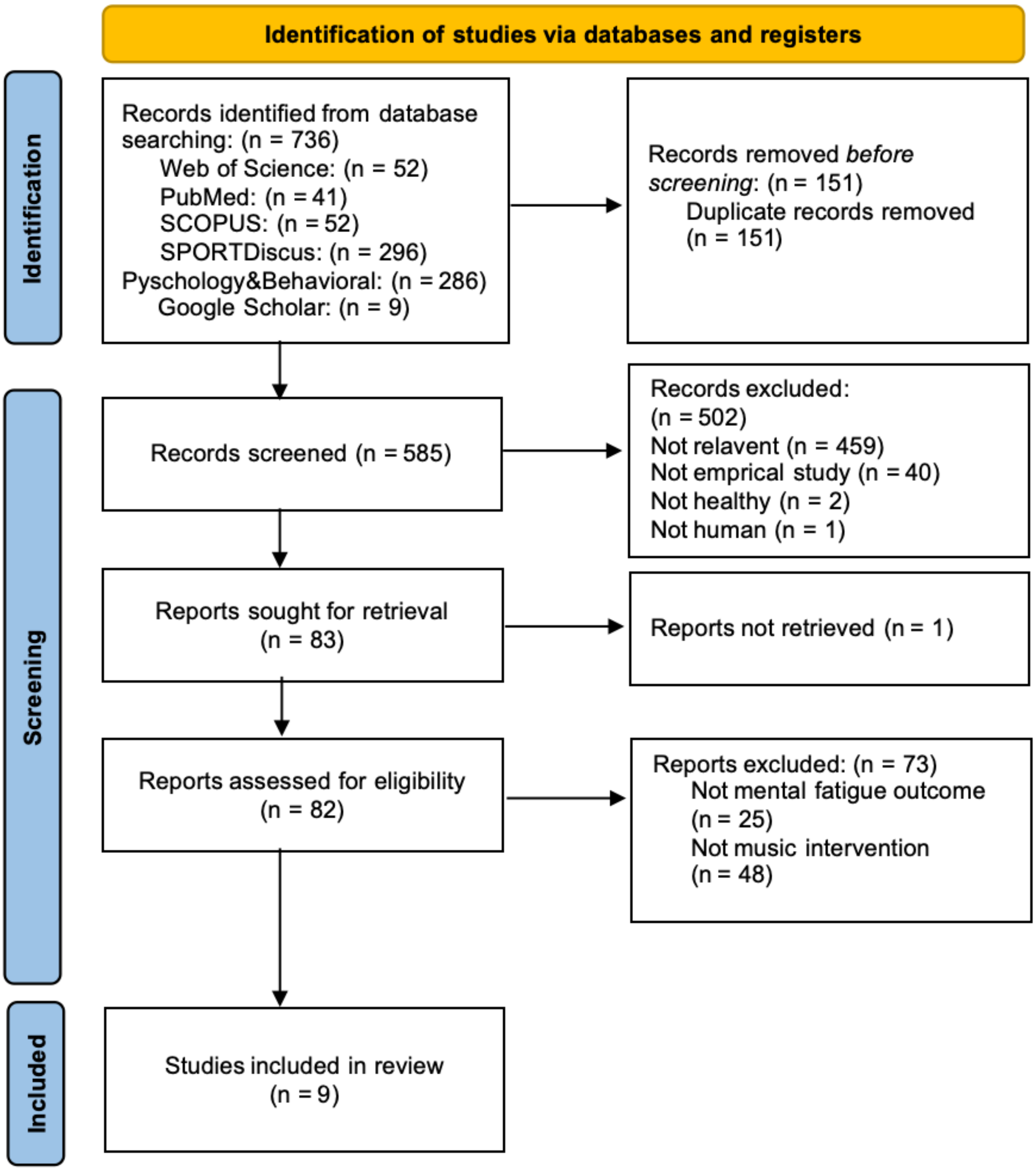


Figure 1 : Flow Diagram of the Study Selection Procedure

Table 3 : Overview of Included Publication Details

Study	Population characteristics	Intervention			Mental fatigue outcomes		
		Style	Period/ (multi)single tasking /duration	Performance domain	Performance outcome	Subjective evaluation	Physiological markers
Guo et al. (2015)	N: 36 university students; 18 ♂; 18 ♀; Age: 20.33 ± 1.26 yrs; Country: China	EG: Relaxing music CG: No music	P: $T_0 \rightarrow T_2$; music & CT D: 60 mins	Cognitive: Inhibition response	EG vs CG Reaction time↓ Accuracy↔	EG vs CG VAS↓	EG vs CG: Go-P3 and NoGo-P3 amplitudes↑
Chen et al. (2008)	N: 8 ♂ university students Age: 22 – 25 yrs; Country: Japan	EG: Relaxing music CG: no music	P: $T_{1;}$ music ◆ D: 15 mins	Cognitive: Working memory	EG vs CG Reaction time↓ Correct answers↑	EG vs CG VAS↓	EG vs CG Theta↓ Alpha↑ Beta↓
Zhou et al. (2023)	N: 8 university students 6 ♂; 2 ♀; Age: 18 - 35 yrs;	EG1: Exciting music EG2: Relaxing music CG: No music	P: $T_1 \rightarrow T_2$; music & CT D: 15 mins	Cognitive: Working memory N-back tasks	EG vs CG Reaction time↓ EG1 vs EG2 Reaction time↓	EG vs CG VAS↓ EG1 vs EG2 VAS↓	NA
Jacquet et al. (2021)	N: 37 healthy adults 7 ♂; 30 ♀; Age: 20.6 ± 0.7 yrs;	EG: Preference music CG: Conversation	P: $T_{1;}$ music ◆ D: 15 mins	Behavioral: Motor control Arm-pointing task	EG vs CG Duration↓ Errors↑	EG vs CG VAS↓	EG vs CG Theta↓ Alpha↑
Lam & Philips (2019)	N: 9 ♂ healthy adults Age: 22 ± 2.6 yrs;	EG: Preference music CG: no music	P: $T_1 \rightarrow T_2$; music & ET	Behavioral: Endurance performance YYIRTL1	EG vs CG Distance↑	NA	NA
Lam et al. (2022)a	N: 9 ♂ recreational sports participants Age: 22 ± 2.6 yrs;	EG: Preference music CG: no music	P: $T_1 \rightarrow T_2$; music & ET	Behavioral: Endurance performance YYIRTL1	EG vs CG Distance↑	EG vs CG BRUMS fatigue↓	NA

Lam et al. (2022)b	N: 9 recreational runners; 7 ♂; 2 ♀; Age: 21.1 ± 1.2yrs;	EG: Preference music CG: no music	P: $T_1 \rightarrow T_2$; music & ET	Behavioral: Endurance performance 5 km time-trail performance	EG vs CG Completion time↓	EG vs CG BRUMS fatigue↓	Heart rate↑
Gao et al. (2023)	N: 6 healthy adults; 4 ♂; 2 ♀; Age: 20 – 25 yrs;	EG1: Exciting music EG2: Relaxing music CG: No music	P: $T_0 \rightarrow T_2$; music & CT	NA	NA	NA	EG1&EG2 vs CG SSVEP amplitude↑ SNR↑ EG1 vs EG2 SSVEP amplitude↑ SNR↑
Coimbra et al. (2021)	N: 30 ♀ volleyball players; Age: < 18 yrs; Country: Brazilian	EG: Preference music CG: No music	P: after training; before bedtime;	NA	NA	EG vs CG VAS↔	NA
Seo et al. (2019)	N: 7 healthy adults; 5 ♂; 2 ♀; Age: 21 – 23 yrs;	21-23 yrs	P: $T_0 \rightarrow T_2$; music & DT	During stimulate washing task	Comfort↑ Awareness↑ vigorous↑	EG vs CG Awareness: VAS↓	EEG signal: Alpha↑ Beta↓ Theta↑

N: number of participants; ♂: males; ♀: females; P: period; D: duration; T_0:start point of the whole task; T_1: point of mental fatigue manifested T_2: end point of the task; →: from time point to time point; CT: cognitive task; ET: endurance task; DT: daily task &:listen to music simultaneous with the task; ◆: sole listening to music without any other task; EG, experimental group; CG, control group; MF, mental fatigue; ↓the value is significantly lower in experimental group/condition compare to the control group/condition; ↑the value is significantly higher in the experimental group/condition compared to control group/condition; ↔no significances between experimental and control group/condition; NA: not applicated; EEG: Electroencephalogram; YYIRTL1: Yo-Yo intermittent recovery test level 1; SDSD: standard deviation of adjacent successive heartbeat interphase difference value; TF: general frequency spectrum; LF: low-frequency power; HF: high-frequency power; HFnorm: corrected high-frequency power; SSVEP: the steady-state visually evoked potential; SNR: sign-to-noise;

Appendix C

Stroop Task

Instructions:

Welcome to participate this experimental, please ignoring the meaning of the word itself, while response the color of the word.

If the color of the word is red, please press “D” key.

If the color of the word is yellow, please press “F” key.

If the color of the word is blue, please press “J” key.

If the color of the word is green, please press “K” key.

You are encouraged to response as fast and correct as possible. Please press “space” to start!

Red　　　　Blue

Note: The left is incongruent stimuli, the right is congruent stimuli, response the color of the word, while ignoring the meaning of the word.

词色判定任务

指示：

欢迎参与本次实验，请忽略单词本身的含义，只对单词的颜色做出回应。

如果单词颜色为红色，请按”D”键。

如果单词颜色为黄色，请按”F”键。

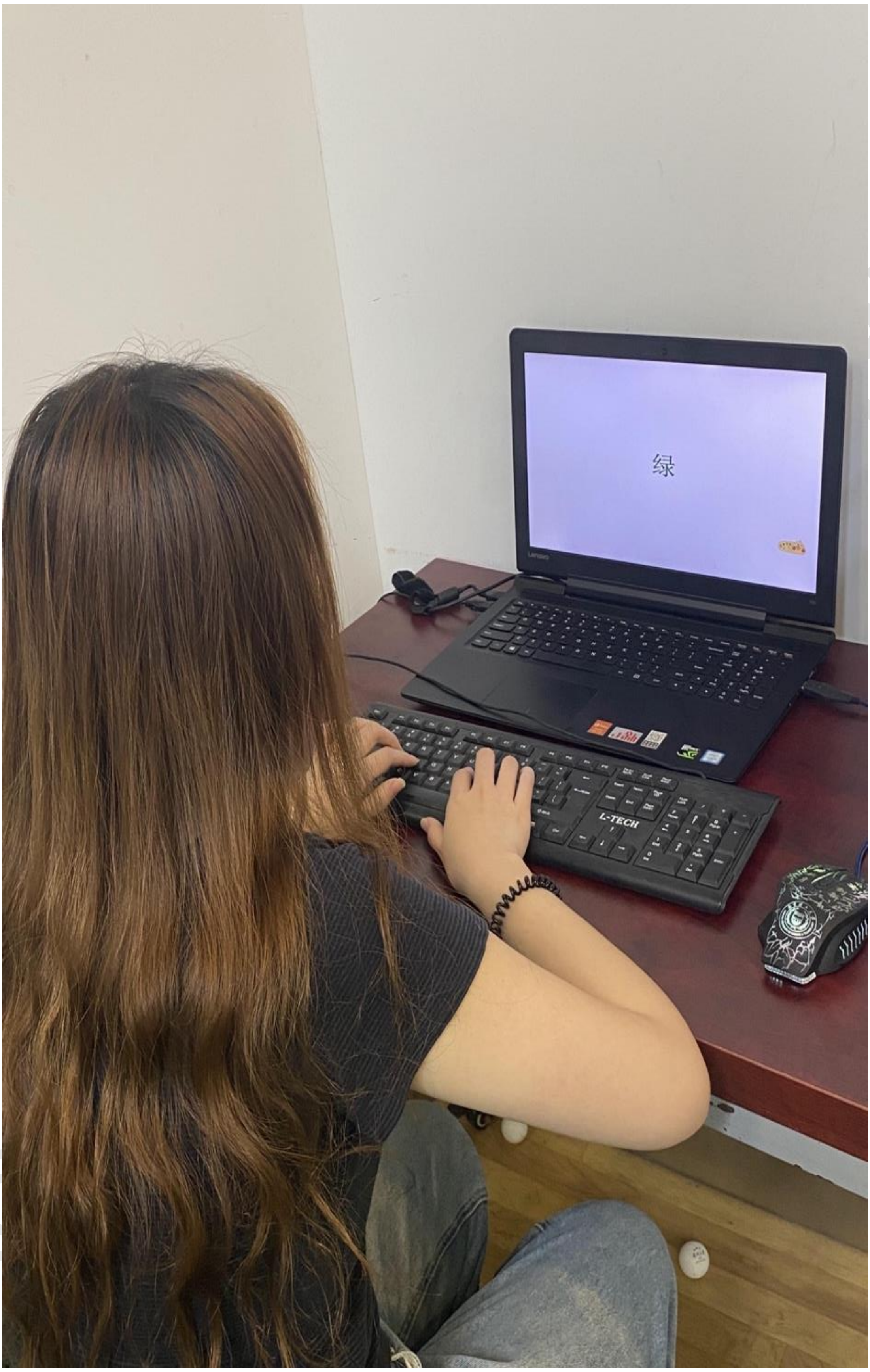
如果单词颜色为蓝色，请按”J”键。

如果单词颜色为绿色，请按”K”键。

我们希望您尽可能快速、正确地做出回应。请按”空格”开始！

红　　蓝

注：左边是不一致词色判定，右侧是一致词色判定

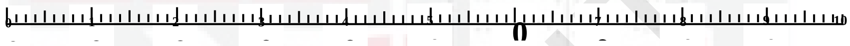

绿
L-TECH

Appendix D

Visual Analogue Scale for Mental Fatigue

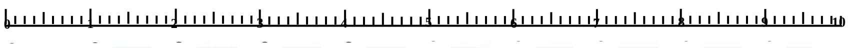
I would like to find out about your subjective evaluation of mental fatigue level, please move the single vertical line to most representative feeling of mental fatigue level.

DIRECTIONS: VAS is a 100-mm horizontal line, which “0” present “none at all”, and “100” represent the “maximal” fatigue, this is no “good” or “bad” on your marks, just move the line to the most precise and representative position to describe your current state of mental fatigue level. Thank you.



疲劳感受性任务

指导语：请花 5 秒钟感受你当下的疲劳状态，根据你当下的状态，用一条竖线画出最能准备表达你此刻疲劳状态数值，**横线最左边为 0 代表一点疲劳感觉也没有，最右边 100 代表极度疲劳。**答案没有对错之分，请尽可能准确的画出你当下的疲劳值。本次结果完全保密，请根据自己的实际情况填写。



Appendix E

Emotion Report Forms

Instructions: Please focus on your current feelings. If you do not experience a particular feeling at all, assign it a score of 0. If you feel it very strongly, assign a score of 8. The score is unrelated to personal ability and is solely intended to capture your most intuitive feelings at this moment. Each item must be scored, and all responses will remain completely confidential. Feel free to respond openly. Please ensure that no items are skipped or left unanswered.

Emotion	Intensity								
Amusement	0	1	2	3	4	5	6	7	8
Anger	0	1	2	3	4	5	6	7	8
Anxiety	0	1	2	3	4	5	6	7	8
Contentment	0	1	2	3	4	5	6	7	8
Disgust	0	1	2	3	4	5	6	7	8
Fear	0	1	2	3	4	5	6	7	8
Happiness	0	1	2	3	4	5	6	7	8
Sadness	0	1	2	3	4	5	6	7	8
Serenity	0	1	2	3	4	5	6	7	8

Note: 0=not at all, 8=a great deal

情感力任务

指导语：请集中注意去**体会一下你当下的感觉**，如果当下这种**感觉一点也没有，请打 0 分，**如果当下这种感觉非常强烈，请打 8 分。分值大小与个人能力无关，分值大小仅为统计你当下最直观的感受。每一项都要进行打分，结果完全保密，请放心作答！请勿漏答或不答。

体验	强度								
焦虑	0	1	2	3	4	5	6	7	8
愤怒	0	1	2	3	4	5	6	7	8
愉悦	0	1	2	3	4	5	6	7	8
厌恶	0	1	2	3	4	5	6	7	8
幸福	0	1	2	3	4	5	6	7	8
满足	0	1	2	3	4	5	6	7	8
恐惧	0	1	2	3	4	5	6	7	8

Appendix F

Items of the Attentional Control Scale

Instructions: The following is to understand the attention state of athletes. Read each sentence carefully, and then use "√" to mark the degree of various feelings you have at this moment. There is no right or wrong answer. You don't need to spend a lot of time thinking about each item, but you should answer the question that best suits the situation you are feeling at the moment. The numerical scale represents: (1=almost never; 2 =sometimes; 3=often; 4=always).

1	It's very hard for me to concentrate on a difficult task when there are noises around.	1	2	3	4
2	When I need to concentrate and solve a problem, I have trouble focusing my attention.	1	2	3	4
3	When I am working hard on something, I still get distracted by events around me.	1	2	3	4
4	My concentration is good even if there is music in the room around me.	1	2	3	4
5	When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me.	1	2	3	4
6	When I am reading or studying, I am easily distracted if there are people talking in the same room.	1	2	3	4
7	When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.	1	2	3	4
8	I have a hard time concentrating when I'm excited about something.	1	2	3	4
9	When concentrating I ignore feelings of hunger or thirst.	1	2	3	4
10	I can quickly switch from one task to another.	1	2	3	4
11	It takes me a while to get really involved in a new task.	1	2	3	4
12	It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures.	1	2	3	4
13	I can become interested in a new topic very quickly when I need to.	1	2	3	4
14	It is easy for me to read or write while I'm also talking on the phone.	1	2	3	4
15	I have trouble carrying on two conversations at once.	1	2	3	4
16	I have a hard time coming up with new ideas quickly.	1	2	3	4
17	After being interrupted or distracted, I can easily shift my attention back to what I was doing before.	1	2	3	4
18	When a distracting thought comes to mind, it is easy for me to shift my attention away from it.	1	2	3	4
19	It is easy for me to alternate between two different tasks.	1	2	3	4
20	It is hard for me to break from one way of thinking about something and look at it from another point of view.	1	2	3	4

注意力状态任务

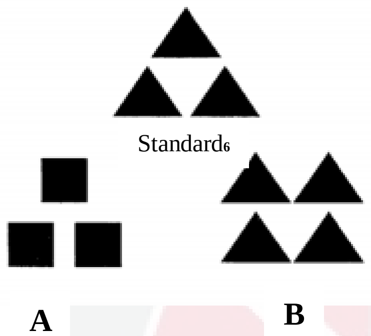
指导语：下面是了解运动员的注意力状态，仔细阅读每一句话，然后用"√"划出你**此时此刻各种感受的程度**。回答无对错之分。每条不必用大多的时间去考虑，但要回答出最符合你此时所感受到的状况。数字表示的程度为：（1=几乎从不；2=偶尔；3=经常；4=总是）。结果完全保密，请放心作答！请勿漏答或不答。

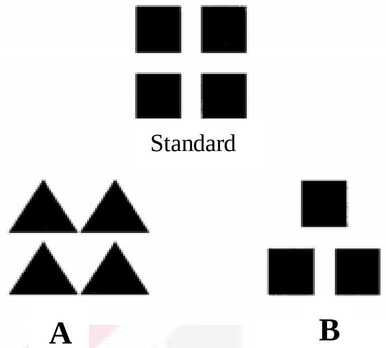
		几乎从不	偶尔	经常	总是
1	当周围有噪音时，我很难集中精力完成一项艰巨的任务。	1	2	3	4
2	当我需要集中精力解决问题时，我很难集中注意力。	1	2	3	4
3	当我努力工作的时候，我还是会被周围的事情分心。	1	2	3	4
4	即使周围有音乐，我的注意力也很集中。	1	2	3	4
5	在集中注意力时，我可以集中注意力，从而对周围发生的事情浑然不觉。	1	2	3	4
6	当我阅读或学习时，如果有人在同一个房间里说话，我就很容易分心。	1	2	3	4
7	当我试图把注意力集中在某件事情上时，我很难排除杂念。	1	2	3	4
8	当我对某件事情感到兴奋时，我很难集中注意力。	1	2	3	4
9	在集中注意力时，我会忘记饥饿或口渴的感觉。	1	2	3	4
10	我可以快速地从一项任务切换到另一项任务。	1	2	3	4
11	我需要一段时间才能真正投入到一项新任务中。	1	2	3	4
12	我很难在听课和记笔记时协调注意力。	1	2	3	4
13	在需要的时候，我可以很快对一个新话题产生兴趣。	1	2	3	4
14	对我来说，边打电话边阅读或写作很方便。	1	2	3	4
15	我很难同时进行两个对话。	1	2	3	4
16	我很难迅速想出新点子。	1	2	3	4
17	在被打断或分心后，我可以很容易地将注意力转移回之前正在做的事情上。	1	2	3	4
18	当脑海中出现杂念时，我很容易将注意力转移开。	1	2	3	4
19	对我来说，交替完成两项不同的任务很容易。	1	2	3	4
20	我很难从一种思维方式中跳出来，从另一个角度看问题。	1	2	3	4

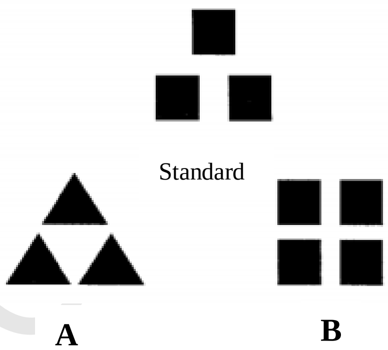
Appendix G

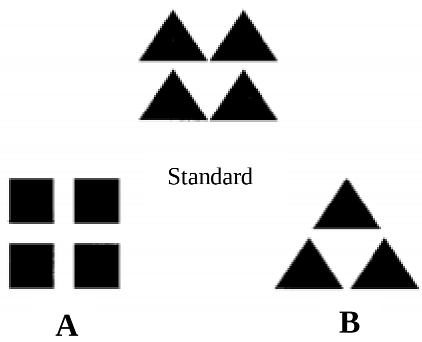
Global-Local Processing Task

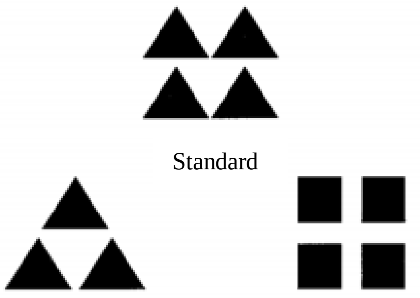
Instructions: This task consists of 8 judgment items. Each item presents a set of three figures: one standard figure at the top and two optional figures labeled A and B below. Your task is to select the figure (A or B) that, based on your initial impression, is more similar to the standard figure. You may base your decision on the overall shape or internal structure of the figures. There are no right or wrong answers. Please indicate your choice (A or B) based on your immediate intuition. All responses will remain strictly confidential. Kindly complete the task according to your genuine perception.

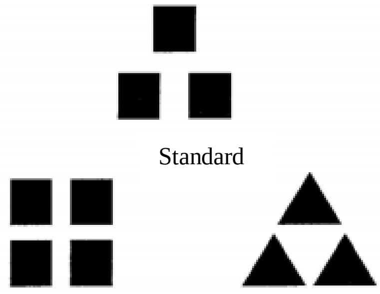


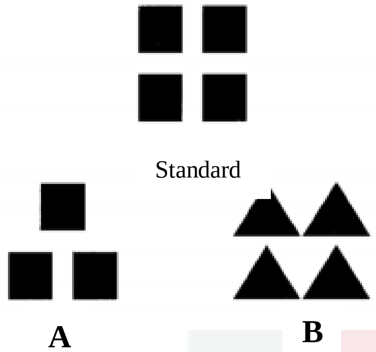


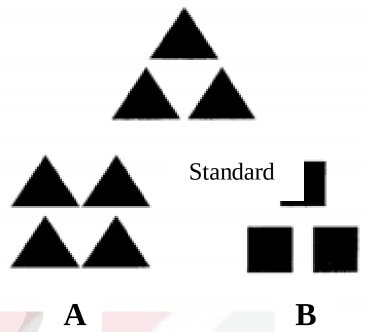





Standard

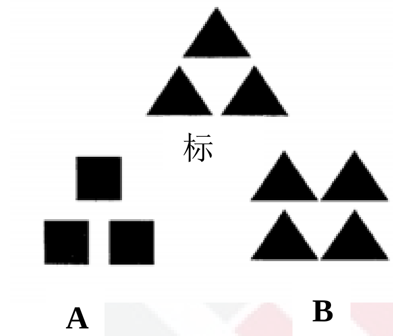

Standard

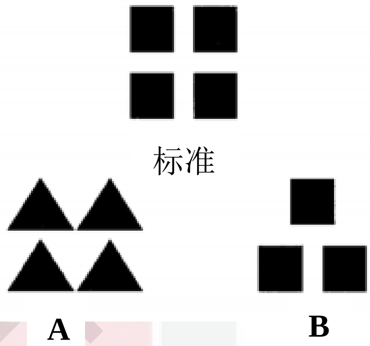

Standard
A
B

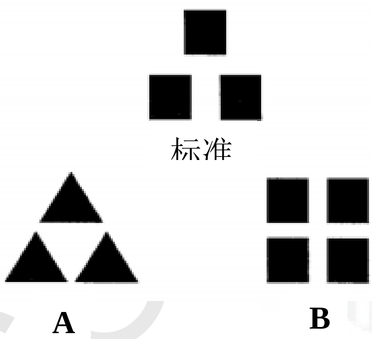

Standard
A
B

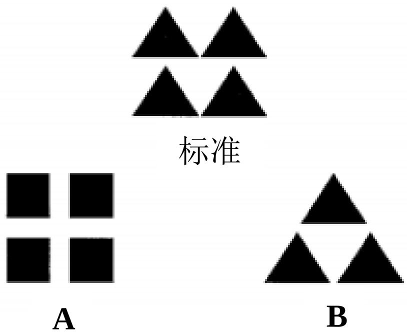
相似度判断任务

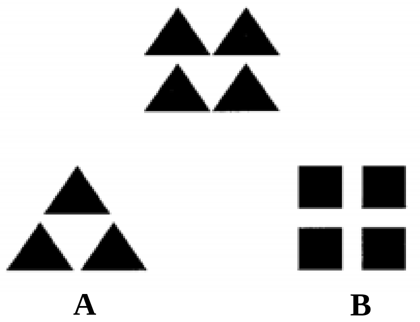
指导语：本任务总共有 8 个判断，每个任务都是以三个图形为一组，上面的图形为标准图形，下面两个 AB 图形为选择图形，**请根据你的第一感觉，选择与标准图形更相似的图形，可以根据整体形状选择，也可以根据内部结构选择，**答案无对错之分，请根据你当下最直观的感受圈出 A 或者 B。本次结果完全保密，请根据自己的实际情况填写。

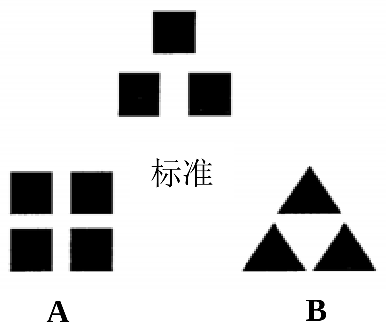


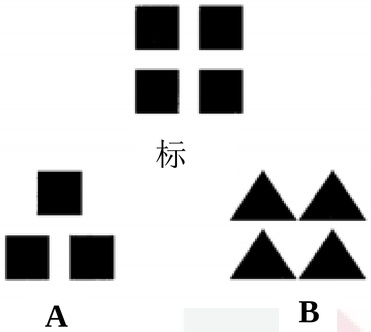


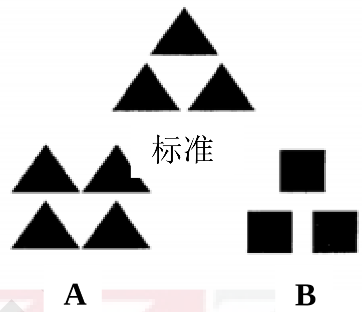





A
B


标准
A
B


标
A
B


标准
A
B

Appendix H

Twenty Statements Test (B. L. Fredrickson & C. Branigan, 2005)

… take a moment to imagine being in a situation yourself in which this particular emotion would arise (the one you wrote on the previous page). Concentrate on all the emotion you would feel and live it as vividly and as deeply as possible. *Given this feeling*, please *list* all the things you would like to do *right now.*

1. I would like to________.
2. I would like to________.
3. I would like to________.
4. I would like to________.
5. I would like to________.
6. I would like to________.
7. I would like to________.
8. I would like to________.
9. I would like to________.
10. I would like to________.
11. I would like to________.
12. I would like to________.
13. I would like to________.
14. I would like to________.
15. I would like to________.
16. I would like to________.
17. I would like to________.
18. I would like to________.
19. I would like to________.
20. I would like to________.

想象力任务

指导语：现在请花一点时间，**专注你当下所有的感受。基于你当下的感受中，**想象一下你此刻你最想做的事，请尽可能生动形象的列出你所有想做的事，（例：我想要踢足球）。答案没有对错之分，可以不填满，请尽可能列出你所有想做的事即可。本次结果完全保密，请根据自己的实际情况填写。

1. 我想要____________________。

2. 我想要____________________。

3. 我想要____________________。

4. 我想要____________________。

5. 我想要____________________。

6. 我想要____________________。

7. 我想要____________________。

8. 我想要____________________。

9. 我想要____________________。

10. 我想要____________________。

11. 我想要____________________。

12. 我想要____________________。

13. 我想要____________________。

14. 我想要____________________。

15. 我想要____________________。

16. 我想要____________________。

17. 我想要____________________。

18. 我想要____________________。

19. 我想要____________________。

20. 我想要____________________。

Appendix I

Borg RPE Scale

Use this scale to tell how strenuous and tiring the work feels to you. The exertion is mainly felt as fatigue in your muscles and as breathlessness or possibly aches. When the exercise is hard it also becomes difficult to talk. It is your own feeling of exertion that is important. Don't underestimate it, but don't overestimate it either. For common exercise, such as cycling, running or walking, 11-15 is a good level. For strength and high-intensity interval training (HIIT), 15-19 is good. If you are sick follow your doctor's advice. Look at the scale and the descriptions and then choose a number. Use whatever numbers you want, even numbers between the descriptions.

6	**No exertion at all**	No muscle fatigue, breathlessness or difficulty in breathing.
7	**Extremely light**	Very, very light.
8		
9	**Very light**	Like walking slowly for a short while. Very easy to talk.
10		
11	**Light**	Like a light exercise at your own pace.
12	**Moderate**	
13	**Somewhat hard**	Fairly strenuous and breathless. Not so easy to talk.
14		
15	**Hard**	Heavy and strenuous. An upper limit for fitness training, as when running or walking fast.
16		
17	**Very hard**	Very strenuous. You are very tired and breathless. Very difficult to talk.
18		
19	**Extremely hard**	The most strenuous effort you have ever experienced.
20	**Maximal exertion**	Maximal heaviness.

Borg RPE Scale®
Ratings (R) of Perceived (P) Exertion (E).

English

博格 RPE 量表®

使用此量表来表示你因体力活动而感受的辛苦和疲劳程度。这种用力的感觉主要是肌肉疲劳、呼吸困难或可能疼痛。当动作强度高时，说话也会变得困难。最重要的是你自己的用力感觉。不要低估它，但也不要高估它。对于骑自行车、跑步或步行等普通运动，11-15 是一个良好水平。对于力量和高强度间歇训练（HIIT）来说，15-19 是良好状态。如果你生病了，请听从医生的建议。请看量表和说明，然后选择一个数字。使用任何你想要的数字，甚至是两个说明之间的数字。

6	**完全不用力**	无肌肉疲劳、喘不上气或呼吸困难。
7	**极轻**	非常非常轻。
8		
9	**很轻**	如同慢慢地走了片刻。非常容易说话。
10		
11	**轻**	就像按自己的节奏而进行的轻量运动。
12	**适度**	
13	**有些困难**	相当吃力，气喘吁吁。没那么好说话
14		
15	**困难**	沉重而费力。健身训练的上限，如快跑或快走。
16		
17	**很困难**	非常吃力。你非常疲惫，上气不接下气。很难开口说话。
18		
19	**极困难**	你所经历过的最费劲的用力。
20	**最大用力**	最为沉重。

博格 RPE 量表®
感知(P)运动量(E)的评级(R)。

中文

Appendix J

Visual Analogue Scale for Motivation

I would like to find out about your evaluation of motivation towards upcoming task, please move the single vertical line to most representative motivation towards subsequent task.

DIRECTIONS: VAS is a 100-mm horizontal line, which “0” present “none at all”, and “100” represent the “maximal” motivation, this is no “good” or “bad” on your marks, just move the line to the most precise and representative position to describe your current motivation toward upcoming task. Thank you.

心理动力感知任务

指导语：心理动力感知任务是指你在对接下来的任务中，心理存在多少内部驱动力来完成接下来的任务，请以一条竖线的形式在横线中画出来，横线的最左边的**”0”**代表对于接下来的任务我**一点动力也没有**，横线最右边**”100”**代表对于接下来的任务我**充满动力**，请用一道竖线画出当下你对于接下来要做任务的心理内部驱动力。结果完全保密，请放心作答！请勿漏答或不答！

Appendix K

Revised Competitive State Anxiety–2 (CSAI-2R)

Directions: A number of statements that athletes have used to describe their feelings before competition are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel right now – at this moment. There are no right or wrong answers. Do not spend too much time on any one statement, but choose the answer which describes your feelings right now.

		Not At All	A Little Bit	Pretty much	Very much
1.	I feel jittery	1	2	3	4
2.	I am concerned that I may not do as well in this competition as I could	1	2	3	4
3.	I feel self-confident	1	2	3	4
4.	My body feels tense	1	2	3	4
5.	I am concerned about losing	1	2	3	4
6.	I feel tense in my stomach	1	2	3	4
7.	I'm confident I can meet the challenge	1	2	3	4
8.	I am concerned about choking under pressure	1	2	3	4
9.	My heart is racing	1	2	3	4
10.	I'm confident about performing well	1	2	3	4
11.	I'm concerned about performing poorly	1	2	3	4
12.	. I feel my stomach sinking	1	2	3	4
13.	I'm confident because I mentally picture myself reaching my goal	1	2	3	4
14.	I'm concerned that others will be disappointed with my performance	1	2	3	4
15.	My hands are clammy	1	2	3	4
16.	I'm confident of coming through under pressure	1	2	3	4
17.	My body feels tight	1	2	3	4

身体心理紧张感受性任务

指导语：下面是运动员在赛前（或赛后）对自己的感受通常描述的内容，仔细阅读每一句话，然后**用"√"划出你此时此刻各种感受的程度**。回答无对错之分。每条不必用大多的时间去考虑，但要回答出最符合你此时所感受到的状况。数字表示的程度为：1=一点也不，2=有点儿，3=适中，4=非常强烈。结果完全保密，请放心作答！请勿漏答或不答。

		一点也没有	有一点	很多	非常多
1.	我感到心神不安	1	2	3	4
2.	我担心这次比赛不能像往常那样比得好	1	2	3	4
3.	我感到自己对这场比赛有信心	1	2	3	4
4.	我身体感到紧张	1	2	3	4
5.	我担心会在比赛中失败	1	2	3	4
6.	我感到胃部紧张	1	2	3	4
7.	我有信心面对这场挑战	1	2	3	4
8.	我担心在这种压力下不能成功	1	2	3	4
9.	我心跳得很厉害	1	2	3	4
10.	我相信我会有出色的表现	1	2	3	4
11.	我担心在比赛中发挥不好	1	2	3	4
12.	我感到胃部下沉	1	2	3	4
13.	我很有信心，因为在我内心已达到自己的目标	1	2	3	4
14.	我担心别人会对我的表现感到失望	1	2	3	4
15.	我的手又湿又凉	1	2	3	4
16.	我有信心在这种压力下完成比赛任务	1	2	3	4
17.	我感到身体发僵	1	2	3	4

Appendix L

Brief Self-Control Scale

Using the scale provided, please indicate how much each of the following statements reflects how you typically are.

		Not at all				Very much
1.	I am good at resisting temptation	1	2	3	4	5
2.	I have a hard time breaking bad habit	1	2	3	4	5
3.	I am lazy	1	2	3	4	5
4.	I say inappropriate things	1	2	3	4	5
5.	I do certain things that are bad for me, if they are fun	1	2	3	4	5
6.	I refuse things that are bad for me	1	2	3	4	5
7.	I wish I had more self-discipline	1	2	3	4	5
8.	People would say that I have iron self- discipline	1	2	3	4	5
9.	Pleasure and fun sometimes keep me from getting work done	1	2	3	4	5
10.	I have trouble concentrating	1	2	3	4	5
11.	I am able to work effectively toward long-term goals	1	2	3	4	5
12.	Sometimes I can't stop myself from doing something, even if I know it is wrong	1	2	3	4	5
13.	I often act without thinking through all the alternatives					

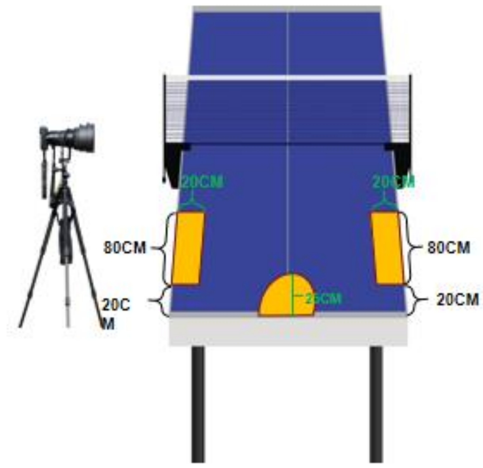
自我控制量表

指导语：请指出下列每条描述在多大程度上反映了您的情况，并尽量按第一反应选出相应选项，并在对应的位置里打"√"。结果完全保密，请放心作答！请勿漏答或不答。

		完全不符合	不符合	不确定	符合	完全符合
1.	我能很好地抵制诱惑。	1	2	3	4	5
2.	对我来说改掉坏习惯是困难的。	1	2	3	4	5
3.	我是懒惰的。	1	2	3	4	5
4.	我会说不恰当的话。	1	2	3	4	5
5.	我会做些能给自己带来快乐但对自己有害的事情。	1	2	3	4	5
6.	我会拒绝对我不利的事情。	1	2	3	4	5
7.	我希望自己能更自律。	1	2	3	4	5
8.	大家说我有钢铁般的自制力。	1	2	3	4	5
9.	有时我会被有趣的事情干扰而不能按时完成任务。	1	2	3	4	5
10.	我难以集中注意力。	1	2	3	4	5
11.	我能为了一个长远目标高效地工作。	1	2	3	4	5
12.	有时我会忍不住去做一些事情，即使我知道那样做是错误的。	1	2	3	4	5
13.	我常常考虑不周就付诸行动。	1	2	3	4	5

Appendix M

Instruments of Measuring Table Tennis Ball Speed and Accuracy



3 target positions for measuring ball accuracy.

The parameters of 3 target places, two rectangular targets (80 cm length, 20 cm width) will be located at 20cm from edges (both left and right sides) of the tables. One semicircle 25 cm in diameter will be located at the center of the edge.

High-speed camera for measuring ball speed.

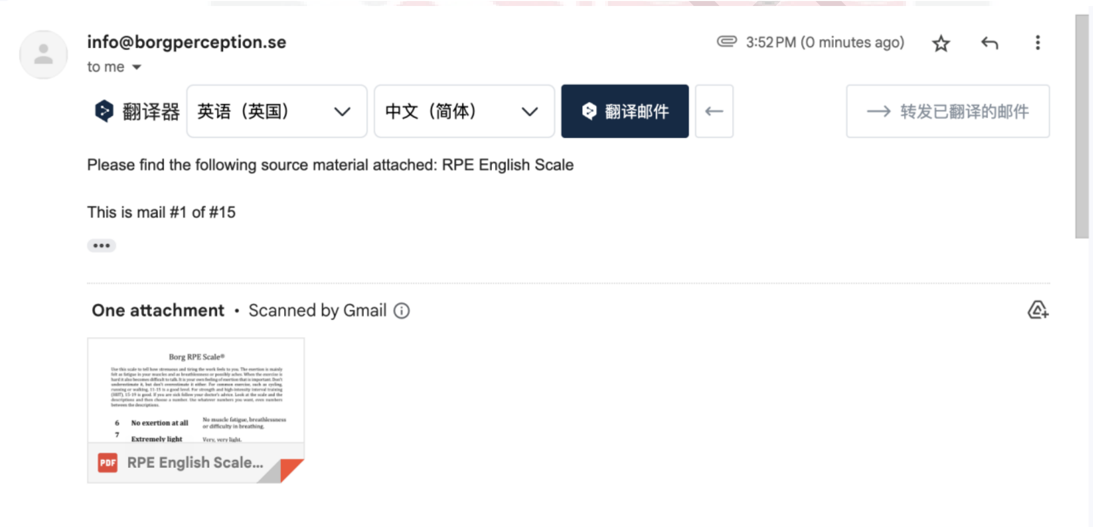
The parameters of ball speed measurement, Ball speed will be measured by a high-speed camera, and the parameters of a high-speed camera will be set as 1080 progressive scanning: 240 frames per second.

Kinovea software

Videos recorded by a high-speed camera will be inputted into Kinovea software to calculate the speed of the ball. Jimenez-Olmedo et al.,2020 Kinovea could be considered as a trustworthy instrument for measuring velocity-based training (Jimenez-Olmedo et al., 2020).

Appendix N

RPE Permission



Appendix P

Validity of the Intervention

Items	Relevance		Clarity	
	CVI	Kappa	CVI	Kappa
1. Mental fatigue intervention	1	1	1	1
2. Mental fatigue inducement duration	1	1	0.833	0.816
3. Music determination	1	1	1	1
4. Music duration	0.833	0.816	0.833	0.816

Appendix Q

Validity of the Measurement

Variables	Measurements	Relevance		Clarity	
		CVI	Kappa	CVI	Kappa
Dependent variables	Mental fatigue	1	1	1	1
	Emotion state	1	1	0.833	0.816
	Attention control	1	1	1	1
	Scope of attention	0.833	0.816	1	1
	Thought-action repertoire	1	1	0.833	0.816
	Stroke accuracy	1	1	1	1
	ball speed	1	1	0.833	0.816
Control variables	Sports anxiety	1	1	1	1
	Self-control	1	1	1	1
Secondary outcomes	Perception of exertion	1	1	1	1
	Motivation	1	1	1	1

Appendix R

Homogeneity Test of Variances at Baseline Test

Items	Variables	Levene Statistic	df1	df2	p value
Demographic characteristic	Age	0.694	3	60	0.559
	Height	0.869	3	60	0.462
	Weight	0.412	3	60	0.745
	Training experience	0.670	3	60	0.574
Confounding variables	Cognitive anxiety	1.191	3	60	0.321
	Self-confidence anxiety	1.026	3	60	0.388
	Total anxiety score	1.692	3	60	0.179
	Self-control score	3.598	3	60	0.019
Dependent variables	Mental fatigue feeling	0.367	3	60	0.777
	Accuracy numbers	1.268	3	60	0.293
	Motivation	2.030	3	60	0.119

Notes: df: degree of freedom.

LIST OF PUBLICATIONS

Publication - Published:

Ding, C. et al. (2024). Does mental fatigue affect performance in racket sports? A systematic review. *BMC Sports Science, Medicine and Rehabilitation*, *16*(1), 179.

Ding, C. et al (2024). Does music counteract mental fatigue? A systematic review. PLoS ONE. Since June 2024

Publication - Under review:

Does mental fatigue affect decision-making performance in athletes? A systematic review and meta-analysis.