The Effects of Neurofeedback Training on Brainwave and Behaviour of the Autistic Disorder Children

Muhamad Sophian

Doctor of Philosophy
2017
The Effects of Neurofeedback Training on Brainwave and Behaviour of the Autistic Disorder Children

Muhamad Sophian

A thesis submitted
In fulfilment of the requirements for the degree of Doctor of Philosophy
(Cognitive Science)

Faculty of Cognitive Sciences and Human Development
UNIVERSITI MALAYSIA SARAWAK
2017
DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. It is original and is the result of my work, unless otherwise indicated of acknowledged as referenced work. The thesis has not been accepted for any degree and is not concurrently submitted in candidature for any other degree.

Name of Student : Muhamad Sophian
Student ID No. : 10011480
Program Degree : PhD
Faculty : Faculty of Cognitive Sciences and Human Development
Thesis Title : The Effects of Neurofeedback Training on Brainwave and Behaviour of the Autistic Disorder Children

Signature of Student : 

Date :
ACKNOWLEDGEMENTS

First and foremost I would like to thank to Allah, the Almighty for giving me the encouragement in completing this study. This study could not been done without the valuable contribution of many individuals. They have contributed their time, advices, efforts and never ending support to finish of this project.

I would like to express my deepest gratitude to my supervisor, Assoc Prof Dr Norsiah Fauzan for all her guidance, support, time, ideas, patience and valuable advices. I would like also to express my appreciation to my colleagues at Counselling, Cognitive Science and Human Resource Development Department, Faculty of Cognitive Sciences and Human Development, UNIMAS.

A special thanks to the Kuching Autistic Association (KAA) and its committee members, parents and teachers who have given me the permission to conduct the study at their association. Their support and cooperation are very much appreciated.

Apart from that, to my wife Dra. Sri Dwirahyati to her patient and support all the time along the completion of this thesis, also my kids; Ridho, Rezky, Rafie and Rasyid. Their support plays a vital role to increase my motivation in dealing hard work and obstacles.

Last but not least, I would like to thank those who are directly or indirectly lend their hands to assist me in the completion of this project. Thank you all.
ABSTRACT

This study explores the application of Neurofeedback Training (NFT) on social and behavioural changes among Autism Spectrum Disorder (ASD) children using pre-test and post-test within subject quasi experimental study. The study involved 34 participants from Kuching Autistic Association (KAA) using Autism Treatment Evaluation Checklist (ATEC) to evaluate the behavioural changes such as speech, language and communication, health and others. Brainwaves were monitored and regulated using Neurofeedback based on the conditions of the ASD children. Protocol were applied based on symptoms identified from ATEC. This study found that 97.06% participants showed improvement in overall score in ATEC, covered the observation for speech/language communication, sociability, sensory/cognitive awareness and health/physical/behaviour. The percentage of improvement for speech, language and communication are 73.5%, and for Sociability improvement are 76.5%. While the improvement for the sensory/cognitive awareness are 82.4% and for health/physical/behavior improvement are 76.5%. Fp1 - Fp2 Beta Training protocol showed a very high level of significance (p<0.0001) changes in the brainwave. These changes indicate that beta protocol inhibit Hi-Beta waves to reduce the autistic symptoms.

Keywords: Neurofeedback Training, Autistic Children, ATEC (Autism Treatment Evaluation Checklist)
**Keberkesanan Latihan Neurofeedback terhadap Gelombang Otak dan Tingkah Laku di kalangan Kanak-Kanak Kecelaruan Autis**

**ABSTRAK**

Kajian ini meneroka Aplikasi Neurofeedback Training (NFT) mengenai perubahan sosial dan tingkah laku di kalangan Autism Spectrum Disorder (ASD) kanak-kanak menggunakan ujian pra dan ujian pasca dalam subjek kajian eksperimen kuasi. Kajian ini melibatkan 34 orang peserta dari Persatuan Autistik Kuching (KAA) menggunakan “Autism Treatment Evaluation Checklist” (ATEC) untuk menilai perubahan tingkah laku seperti pertuturan, bahasa, komunikasi, kesihatan, dan lain-lain. Gelombang otak dipantau dan dikawalselia menggunakan Neurofeedback berdasarkan keadaan kanak-kanak ASD. Protokol telah digunakan berdasarkan simptom yang dikenal pasti daripada ATEC. Kajian ini mendapati bahawa 97.06% peserta menunjukkan peningkatan dalam skor keseluruhan ATEC, meliputi aspek pemerhatian untuk komunikasi pertuturan/bahasa, pergaulan, kesedaran deria/kognitif dan kesihatan/fizikal/tingkah laku. Peratusan peningkatan untuk pertuturan, bahasa dan komunikasi adalah 73.5%, dan peningkatan aspek pergaulan adalah 76.5%. Disamping itu peningkatan kesedaran kognitif/deria adalah 82.4% dan bagi peningkatan aspek tingkah laku fizikal kesihatan adalah 76.5%. Dari aspek perubahan gelombang otak pula, protokol latihan Neurofeedback Fp1-Fp2 Beta menunjukkan tahap signifikans yang sangat tinggi (p<0.0001). Perubahan ini menunjukkan perubahan dalam gelombang otak individu (protokol beta menghalang gelombang Beta Tinggi yang akan mengurangkan gejala autistik).

**Kata kunci:** Latihan Neurofeedback, Kanak-kanak Autistik, ATEC (Autism Treatment Evaluation Checklist)
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Page</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>DECLARATION</td>
</tr>
<tr>
<td>ii</td>
<td>ACKNOWLEDGEMENTS</td>
</tr>
<tr>
<td>iii</td>
<td>ABSTRACT</td>
</tr>
<tr>
<td>iv</td>
<td>ABSTRAK</td>
</tr>
<tr>
<td>v</td>
<td>TABLE OF CONTENTS</td>
</tr>
<tr>
<td>ix</td>
<td>LIST OF TABLES</td>
</tr>
<tr>
<td>x</td>
<td>LIST OF FIGURES</td>
</tr>
</tbody>
</table>

## CHAPTER 1 : INTRODUCTION 1

1.0 Introduction 1

1.1 Background of Study 1

1.2 Problem Statement 5

1.3 Objective of Study 7

1.3.1 Main Objective 7

1.3.2 Specific Objective 7

1.4 Research Hypothesis 8

1.5 Conceptual Framework 9

1.6 Definition of terms 10

1.6.1 Autism 10

1.6.2 Brainwave (EEG) 10

1.6.3 Neurofeedback Training (NFT) 11
1.6.4 ATEC (Autistic Treatment Evaluation Checklist) 11

1.7 Significance of the Study 13

1.8 Limitation of the Study 14

1.9 Summary 15

CHAPTER 2: LITERATURE REVIEW 16

2.0 Introduction 16

2.1 Autism Spectrum Disorder 16

2.2 EEG of Autistic Children 17

2.3 Neurofeedback Training 19

2.4 Theory of Connectivity 21

2.5 Theory of Social Development 24

2.6 Fusiform gyrus in ASD 27

2.7 Functions of Frontal Lobe of Brain 28

2.8 Summary 42

CHAPTER 3: METHODOLOGY 43

3.0 Introduction 43

3.1 Research Design 43

3.2 Research Variables 44

3.2.1 Independent Variables 44

3.2.2 Dependent Variables 44

3.3 Subjects 44

3.4 Setting 44

3.5 Research Informants 45
3.6 Instrument

3.6.1 Autism Treatment Evaluation Checklist (ATEC)

3.6.2 EEG Device / Braintrainer

3.7 Reliability

3.8 Validity

3.9 Procedure of Data Collection

3.9.1 Gantt Chart

3.9.2 Procedure of Experiment

3.10 Procedure of Data Analysis

3.10.1 ATEC Scoring

3.10.2 Descriptive Data Analysis

3.10.3 Inferential Data Analysis

3.10.4 Independent Samples T-test

3.10.5 Paired Samples T-test

3.11 Summary

CHAPTER 4: FINDINGS AND DISCUSSION

4.0 Introduction

4.1 Demographic Characteristic

4.2 Findings

4.2.1 ATEC Total Score for Pre-Training and Post-Training

4.2.2 Percentage of ATEC Improvement for Each Participant

4.2.3 Percentage of Speech, Language and Communication Improvement for Each Participant

4.2.4 Percentage of Sociability Improvement for Each Participant
4.2.5 Percentage of Sensory Integration and Cognitive Awareness Improvement for Each Participant

4.2.6 Percentage of Health, Behavior and Physical Improvement for Each Participant

4.2.7 t-Test for Speech, Language and Communication

4.2.8 t-Test for Sociability

4.2.9 t-Test for Sensory Integration, and Cognitive Awareness

4.2.10 t-Test for Health, Physical and Behaviour

4.2.11 Brainwave Protocol Fp1-Fp2 Beta

4.3 Qualitative Data Observation

4.4 Discussion

4.5 Summary

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

5.1 Summary of study

5.2 Conclusions

5.3 Recommendations

REFERENCES

APPENDICES
LIST OF TABLES

Table 1.1  Some Symptoms of autism  
Table 2.1  EEG Frequency Bands  
Table 2.2  Effect Sizes for Cognitive Functioning  
Table 2.3  Effect Sizes for Social Interaction  
Table 2.4  Effect Sizes for Behavioural Performances  
Table 2.5  Mean Effect Size for 5 Studies  
Table 2.6  Mean Effect for Dependent Variable  
Table 3.1  Gantt chart  
Table 3.2  Range of ATEC scores  
Table 4.1  Participant’s demographics characteristic  
Table 4.2  Paired t-Test for Speech / Language / Communication (Pre and Post)  
Table 4.3  Paired t-Test for Sociability (Pre and Post)  
Table 4.4  Paired t-Test for Sensory / Cognitive Awareness (Pre and Post)  
Table 4.5  Paired t-Test for Health / Physical / Behavior (Pre and Post)  
Table 4.6  Paired sample t-Test for Brainwave Protocol Fp1-Fp2 Beta  
Table 4.7  Summary Some of Qualitative Data pre and post-test  

Page
4
20
36
38
39
40
41
48
50
55
62
63
64
65
66
119


**LIST OF FIGURES**

| Figures 1.1 | Conceptual Framework | Page 9 |
| Figures 2.1 | Rate of hyperconnectivity in ASD person | Page 22 |
| Figures 2.2 | The grand mean ES for the controlled studies compared to the within-subject effect sizes for all 3 core symptoms. Note that the controlled studies are slightly smaller, which could be due to the fact that many controlled studies used a “semi-active” control group. Furthermore, given the evidence intervals the ES for inattention, hyperactivity and impulsivity are significant for both comparisons. | Page 34 |
| Figures 2.3 | General Summary of Data in Terms of Effect Size, using 95% Confidence Interval | Page 42 |
| Figure 3.1 | Range of ATEC scores | Page 53 |
| Figure 4.1 | The differences of ATEC score in pre and post-test | Page 56 |
| Figure 4.2 | Precentage of overall improvement for each participant | Page 57 |
| Figure 4.3 | Speech, Language and Communication improvement for each participant | Page 58 |
| Figure 4.4 | Sociability improvement for each participant | Page 59 |
| Figure 4.5 | Sensory Integration and Cognitive Awareness improvement for each Participant | Page 60 |
| Figure 4.6 | Health, Behavior and Physical improvement for each participant | Page 61 |
| Figure 4.7 | Brainwave Changes First-Training and Last-Training (Subject 1) | Page 67 |
| Figure 4.8 | Brainwave Changes During Training Sessions (Subject 1) | Page 68 |
| Figure 4.9 | Brainwave Changes First-Training and Last-Training (Subject 2) | Page 69 |
| Figure 4.10 | Brainwave Changes During Training Sessions (Subject 2) | Page 69 |
Figure 4.36  Brainwave Changes During Training Sessions (Subject 15)  
Figure 4.37  Brainwave Changes First-Training and Last-Training (Subject 16)  
Figure 4.38  Brainwave Changes During Training Sessions (Subject 16)  
Figure 4.39  Brainwave Changes First-Training and Last-Training (Subject 17)  
Figure 4.40  Brainwave Changes During Training Sessions (Subject 17)  
Figure 4.41  Brainwave Changes First-Training and Last-Training (Subject 18)  
Figure 4.42  Brainwave Changes During Training Sessions (Subject 18)  
Figure 4.43  Brainwave Changes First-Training and Last-Training (Subject 19)  
Figure 4.44  Brainwave Changes During Training Sessions (Subject 19)  
Figure 4.45  Brainwave Changes First-Training and Last-Training (Subject 20)  
Figure 4.46  Brainwave Changes During Training Sessions (Subject 20)  
Figure 4.47  Brainwave Changes First-Training and Last-Training (Subject 21)  
Figure 4.48  Brainwave Changes During Training Sessions (Subject 21)  
Figure 4.49  Brainwave Changes First-Training and Last-Training (Subject 22)  
Figure 4.50  Brainwave Changes During Training Sessions (Subject 22)  
Figure 4.51  Brainwave Changes First-Training and Last-Training (Subject 23)  
Figure 4.52  Brainwave Changes During Training Sessions (Subject 23)  
Figure 4.53  Brainwave Changes First-Training and Last-Training (Subject 24)  
Figure 4.54  Brainwave Changes During Training Sessions (Subject 24)  
Figure 4.55  Brainwave Changes First-Training and Last-Training (Subject 25)  
Figure 4.56  Brainwave Changes During Training Sessions (Subject 25)  
Figure 4.57  Brainwave Changes First-Training and Last-Training (Subject 26)  
Figure 4.58  Brainwave Changes During Training Sessions (Subject 26)  
Figure 4.59  Brainwave Changes First-Training and Last-Training (Subject 27)  
Figure 4.60  Brainwave Changes During Training Sessions (Subject 27)
Figure 4.61  Brainwave Changes First-Training and Last-Training (Subject 28)  108
Figure 4.62  Brainwave Changes During Training Sessions (Subject 28)  108
Figure 4.63  Brainwave Changes First-Training and Last-Training (Subject 29)  109
Figure 4.64  Brainwave Changes During Training Sessions (Subject 29)  110
Figure 4.65  Brainwave Changes First-Training and Last-Training (Subject 30)  111
Figure 4.66  Brainwave Changes During Training Sessions (Subject 30)  111
Figure 4.67  Brainwave Changes First-Training and Last-Training (Subject 31)  112
Figure 4.68  Brainwave Changes During Training Sessions (Subject 31)  113
Figure 4.69  Brainwave Changes First-Training and Last-Training (Subject 32)  114
Figure 4.70  Brainwave Changes During Training Sessions (Subject 32)  114
Figure 4.71  Brainwave Changes First-Training and Last-Training (Subject 33)  115
Figure 4.72  Brainwave Changes During Training Sessions (Subject 33)  116
Figure 4.73  Brainwave Changes First-Training and Last-Training (Subject 34)  117
Figure 4.74  Brainwave Changes During Training Sessions (Subject 34)  117
1.0 Introduction

The aim of this study is to find the efficacy of Neurofeedback Training on Autism Spectrum Disorder children. This chapter serves to gives us further understanding on the research. It discusses about the background of the study, problem statement, objective of the study, the research questions, hypothesis, conceptual framework, definition of term, significance of the study and limitation of the study.

1.1 Background of Study

Neurofeedback Training (NFT) is design to improve poor regulated brainwave patterns by training the brain individually with modern computer technology (Coben, Linden, & Myers, 2009). The history of NFT dates back to 1960s to 1970s where researchers learned that it is possible to train the brainwaves patterns. Some of the initial researches mainly work on the training individual to increase alpha brain waves for the purpose of increasing relaxation. As more information was gathered, researchers started to venture into other human brainwaves such as delta, theta and beta waves. Besides that, researchers also found out that the brainwaves patterns of each individual is different, therefore it is important to have appropriate assessment on the patient before the training to identify which brainwaves is lacking or excessive (Hammond, 2007).
However with lack of consciousness and awareness, subjects of the study will not be able to regulate their brainwave accordingly. During the training, one or more electrodes are placed onto the patient’s scalp with one or two on the earlobes. Then, real-time brainwaves activity will be displayed onto a screen with the assistant of high-tech equipment. The concept of influencing the brainwaves is much like operant conditioning, thus we are considered to reconditioning how the brainwaves work and types of brainwaves to be increased and decreased (Hammond, 2007).

One of the earlier studies of NFT on autistic children done by Jarusiewicz (2002) on the effects of NFT on twelve Autism Spectrum Disorder (ASD) children. The children were trained for more than 20 sessions of training to regulate the brainwaves into the desired state. Rewards reward were presented during the training. After NFT sessions ended, Autism Treatment Evaluation Checklist (ATEC) assessment were given to the twelve children and another twelve ASD children in the control group. Result of the assessment shows that those children with ASD that has gone through NFT resulted in 26 percent reduction in ATEC rating compared to the control group which only shows three percent reduction. The ASD children who underwent NFT also showed improvement on parent ratings, improvement in social interaction, vocalization and school performance. The result of study showed that Neurofeedback training significantly reduced the symptoms of ASD. The crucial factors that lead to the significant improvement of the experimental group are the assessment-guided neurofeedback training that reduced the cerebral hyperconnectivity (Jarusiewicz,
2002) and hypoconnectivity. The efficacy of Neurofeedback depends on the severity of children with autism spectrum disorders (ASD).

The ASD represent a group of developmental conditions characterized by impairment in communication and social interactions, restricted, repetitive and stereotyped behaviour and anxiety and compulsions (Barlow-Stewart & Ross, 2007). The manifested behaviour resulted from the dysregulated brain waves in parts of the brain that further resulted in the connectivity problems at the anterior posterior or left and right hemisphere of the brain.

Signs of ASD in infants and toddlers are limited eye-contact, impaired social interactions, less awareness and responsive to others, becomes attached to unusual objects, does not respond to his or her name by age 1, does not play “pretend” games, does not babble or make meaningful gestures by age 1, loss of language and social skills, does not combine two words by age 2, hearing impaired although no evidence of a hearing problem is present, exhibits unusual repetitive behaviour like hand flapping, humming or rocking and prefer to be alone.

From physical aspect, autistic children look like other normal children. They have no special characteristics on their physical appearance. However, we may clearly distinguish them among the normal child according to their social skills. It is characterized by three main symptoms: impaired language, social and communicative deficits, and repetitive and stereotyped behaviours, such as hand flapping, rocking, and unusual responses to sensory stimuli (Powell, 2004).
From behavioural aspects, autistic child is not like other normal children who like to make friend with their peers. One of the characteristic of autistic child is their dislike to changes in the daily routine and their difficulty to adapt. For example, autistic child do not even like if their parent change their favourite songs, but rather listen to repeated songs over and over again. Furthermore, an individual with autism may show restricted, repetitive, or ritualistic behaviours, interest, and activities, for example (Table 1.1).

**Table 1.1 : Some symptoms of autism**

| - preoccupied with a narrow range of interest | - may be self-injurious |
| - insist on sameness | - easy to anger or show aggression |
| - may line up their toys | - may be resistance to change |
| - like to spin objects | - become angry and upset if their daily routine changes in any way |
| - may rock themselves | - may focus on only a small part of a toy or object |

(Autism Nutritions, 2010)

Besides, one of the most well-known characteristics of ASD is the problem with social interaction. The ASD have a hard time forming relationship and knowing how to interact with and relate to other people (Reed, 1996), inability to build good social interaction with people in their surroundings and not interested in socializing. They have lack of ability to understand the social communication skills such as facial expression, body postures, verbal and non-verbal languages and lack of emotional reciprocity. In the Frequently Needed Autism Answer (2011) the autistic youngster was said to be different from a typically developing being in interpreting thought, moods, feelings and emotions of those around by reading the facial, body language and tone of voice.
Generally, individuals with ASD lack of interpretation skills, an inability that leaves them unable to predict or understand other people’s thoughts, actions and reactions.

1.2 Problem Statement

According to the Norsiah Fauzan (2010), autism is a disorder of neural development characterized by impaired social interaction and communication and by restricted and repetitive behaviour. All the disabilities of autistic children can be treated by the appropriate treatment. Some people just accept their child without putting any afford to treat them. All people especially Malaysian should have awareness on this phenomenon since the development and numbers of autistic children are increasing.

There are lack of research about the treatment using Neurofeedback Training as a new option to improve autism sociability, behaviour and attention. Most of the research in this area had been done in western country. As a result, Malaysians are not aware about this biofeedback treatment instead depend may on medication to treat their child. More support facilities and alternative for the treatment of children with autism and those with hyperactivity and other neurological disorders are needed in Malaysia. The NFT is one of the alternative treatment that can help the children without depending on drugs or medication to treat the children.
Most people are not aware of the existence of the new intervention to treat children with autism such as Neurofeedback Training (NFT). Through this treatment, it is the way for autistic parents for improving their child development especially in their sociability, behavioural and attention. Thus, NFT can be a non-pharmacological approach to treat autism. It is considered as an adjunct therapy to other treatment such as speech therapy, biomedical approach and other Cognitive behavioural therapy required by the ASD children.

Previous researches have published hundreds of studies attempting to evaluate different biomedical and psycho-educational interventions intended to benefit autistic children. Thus, a major obstacle in useful autism research has been the lack of valid means of measuring the effectiveness of various treatments. The Autism Treatment Evaluation Checklist (ATEC) was designed to measure the effectiveness of treatment toward autistic children. It was totally different with the others scales such as The Childhood Autism Rating Scale (CARS), The Gilliam Autism Rating Scale (GARS) and The Autism Behaviour Checklist (ABC) which were designed to diagnose autism.
1.3 Objective of Study

1.3.1 Main Objective

The main objective of this research was to describe the improvement on brainwave and behaviour base on ATEC categories such as Speech, Language, Communication, Sociability, Sensory, Cognitive Awareness, Health, Physical and Behaviour on autistic disorder children individual after undergoing Neurofeedback Training (NFT).

1.3.2 Specific Objective

The followings are specific objectives of this study:

a. To describe the improvement in aspect of Speech, Language and Communication after Neurofeedback Training.

b. To describe the improvement in aspect of Sociability after receive of Neurofeedback Training.

c. To describe the improvement in aspect of Sensory and Cognitive Awareness after receive of Neurofeedback Training.

d. To describe the improvement in aspect of Health, Physical and Behaviour after receive of Neurofeedback Training.

e. To describe the brainwave changes after receiving Neurofeedback Training.
1.4 Research Hypothesis

H₀₁: There is no significant difference of ATEC total score between pre- and post-test after Neurofeedback Training among Autistic Disorder Children.

H₀₂: There is no significant difference of weightage score in Speech, Language and Communication between pre- and post-test after Neurofeedback Training among Autistic Disorder Children.

H₀₃: There is no significant difference of weightage score in Sociability between pre and post-test after Neurofeedback Training among Autistic Disorder Children.

H₀₄: There is no significant difference of weightage score in Sensory and Cognitive Awareness between pre- and post-test after Neurofeedback Training among Autistic Disorder Children.

H₀₅: There is no significant difference of weightage score in Health, Physical and Behaviour between pre- and post-test after Neurofeedback Training among Autistic Disorder Children.

H₀₆: There is no significant difference of beta, high beta and theta brainwave between pre- and post-test Neurofeedback Training among Autistic Disorder Children.
1.5 Conceptual Framework

The conceptual framework of this study is shown in Figure 1.1 below.

Figure 1.1: Flowchart of Research