Anxiety disorders in adolescents with dyslexia: Incidence and Interventions

By:

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Acknowledgments

‘As you set out for Ithaca wish the journey to be a long one, full of adventure, full of discovery. Keep Ithaca always in your mind. Arriving there is what you are destined for. But don’t hurry the journey at all’. (Cavafy, P. C., 1975).

And this PhD journey was full of adventure and discovery indeed, but it would not have been possible without the support and help of some people to whom I will always be grateful.

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Abstract

Internalising problems such as stress and anxiety, low self-esteem, and depression are well established correlates of dyslexia. These symptoms persist well past the early stages of learning to read and yet there has been no systematic attempt to evaluate such symptoms or to develop interventions to reduce them. This thesis examined the incidence of internalising disorders in adolescents with dyslexia and evaluated two interventions. Study 1 investigated the internalising problems of students in higher education. Dyslexic students had higher anxiety and depression, and lower self-esteem than the non-dyslexic students. Study 2 investigated the internalising problems of adolescents at risk of dropping out from school. The dyslexic adolescents had higher anxiety and lower self-esteem than the non-dyslexic adolescents. Study 3 considered the effectiveness of a mindfulness-based intervention on cognitive function and psychological well-being on adolescents. The intervention group improved significantly more than the control group from pre- to post-intervention on the anxiety measures, on self-esteem and on cognitive function measures. Study 4 investigated the performance of adolescents on a number of cognitive tasks, including procedural and declarative memory tasks, and the effects of stress on the performance in these tasks. The dyslexic group had poorer performance in all literacy tests, executive function, and procedural memory tests. Positive correlations were found between anxiety and both declarative and procedural memory tests. Study 5 investigated the effectiveness of a cerebellar challenge intervention on cognitive and motor performance of adolescents. The intervention group improved significantly more than the control group from pre- to post-intervention on most tests, including literacy, executive function, and motor tests. In conclusion, the present research highlights the long-standing incidence of internalising problems in adolescents and students with dyslexia. Furthermore, interventions in terms of mindfulness and cerebellar challenge led to significant improvements of intervention groups both of internalising problems and of executive function issues. The results are interpreted by

the cerebellar/procedural learning framework and highlight the interplay between internalising issues and more intrinsic executive function difficulties of adolescents with learning difficulties.

Table of contents

Acknowledgments....................2

Abstract....................3

Table of contents....................5

List of Tables....................12

List of Figures....................13

Declaration....................15

CHAPTER 1....................16

GENERAL INTRODUCTION....................16

1.1 Introduction....................16

1.2 Organization of the thesis....................21

CHAPTER 2....................24

DYSLEXIA OVERVIEW....................24

2.1 Definitions of developmental dyslexia....................24

2.2 Characteristics of developmental dyslexia....................26

2.2.1 Prevalence of developmental dyslexia....................27

2.2.2 Aetiology of developmental dyslexia....................28

2.2.3 Comorbidity....................31

2.2.4 Assessment and diagnosis....................34

2.3 Theories of developmental dyslexia....................35

2.3.1 Cognitive Level ... 37

2.3.2 Biological Level ... 41

2.3.3 Memory systems of human learning ... 43

2.3.4 Behavioural level ... 50

2.4 Conclusion ... 51

CHAPTER 3 ... 52

ANXIETY AND STRESS ... 52

3.1 Anxiety ... 52

3.1.1 State and Trait anxiety ... 52

3.1.2 Test anxiety ... 53

3.2 Stress ... 55

3.2.1 Stress effects on cognitive function ... 57

3.2.2 Stress effects on declarative and procedural memory ... 58

3.2.3 Stress effects on working memory ... 62

3.2.4 Stress effects on motor function ... 63

3.3 Associated psychological problems of dyslexia ... 65

3.3.1 Characteristics of adolescence and the relation to anxiety ... 66

3.3.2 Adolescents with dyslexia and the relation to anxiety ... 67

3.3.3. Adults with dyslexia and the relation to anxiety ... 71

CHAPTER 4 ... 73

4.1 Overview of the research design ... 73

4.2 Thesis scope and overview ... 77

CHAPTER 5 ... 78

STUDY 1: INTERNALISING PROBLEMS OF DYSLEXIC STUDENTS IN HIGHER EDUCATION....78

5.1 Introduction....78

5.2 Rationale and aim of Study 1....89

5.3 Developing the hypotheses....91

5.3.1 Hypotheses 92

5.4 Methodology 94

5.4.1 Ethical considerations 94

5.4.2 Participants 95

5.4.3 Rationale for the measures used 96

5.4.4 Materials and Apparatus 98

5.4.5 Procedure 102

5.5 Results 102

5.5.1 Descriptive statistics 102

5.5.2 Statistical analyses 107

5.6 Discussion 114

5.7 Limitations....122

5.8 Conclusion 123

CHAPTER 6 124

STUDY 2: INTERNALISING PROBLEMS OF DYSLEXIC ADOLESCENTS AT RISK OF SCHOOL FAILURE....124

6.1 Introduction....124

6.2 Rationale and aim of Study 2....135

6.3 Hypotheses for Study 2....137

6.4 Methodology **138**

6.4.1 Ethical considerations 138

6.4.2 Participants 138

6.4.3 Materials and Apparatus 139

6.4.4 Rationale for the measures used 144

6.4.5 Procedure 146

6.5 Results **147**

6.5.1 Descriptive statistics 147

6.5.2 Statistical analysis 151

6.6 Discussion **157**

6.7 Limitations **163**

6.8 Conclusion **164**

CHAPTER 7 165

STUDY 3: POSITIVE EDUCATION AND POSITIVE PSYCHOLOGY IN SCHOOL – EFFECTS OF A MINDFULNESS-BASED INTERVENTION ON DYSLEXIC AND NON-DYSLEXIC ADOLESCENTS 165

7.1 Introduction **165**

7.2 Rationale and aim of Study 3 .... **176**

7.3 Hypotheses for Study 3 .... **178**

7.4 Methodology **180**

7.4.1 Ethical Considerations 180

7.4.2 Participants 180

7.4.3 Mindfulness Intervention: Experimental Design and Stages of the intervention 180

7.4.4 Materials and Apparatus 184

7.5 Results **187**

7.5.1 Descriptive statistics 187

7.5.2 Statistical analysis 188

7.6 Discussion **208**

7.7 Limitations **218**

7.8 Conclusion **219**

CHAPTER 8 220

STUDY 4: COGNITIVE FUNCTION IN DYSLEXIC AND NON-DYSLEXIC ADOLESCENTS AT RISK OF SCHOOL FAILURE. THE LINKAGE BETWEEN STRESS AND COGNITIVE FUNCTION IN DYSLEXIA. 220

8.1 Introduction **220**

8.1.1 Declarative and procedural memory in Dyslexia and the impact of stress 220

8.1.2 Working Memory in Dyslexia and the impact of stress 224

8.1.3 Motor function in dyslexia and the impact of stress on the cerebellum 227

8.2 Design of the study **229**

8.3 Rationale and aim of Study 4 .... **229**

8.4. Hypotheses for Study 4 .... **230**

8.5 Methodology **232**

8.5.1 Ethical considerations 232

8.5.2 Participants 232

8.5.3 Materials and Apparatus 233

8.5.4 Procedure 247

8.6 Results **248**

8.6.1 Descriptive statistics 248

8.6.2 Statistical analysis 251

8.7 Discussion **263**

8.8 Limitations **275**

8.9 Conclusion **275**

CHAPTER 9 277

STUDY 5: EVALUATION OF A 'CEREBELLAR CHALLENGE' INTERVENTION IN DYSLEXIC AND NON-DYSLEXIC ADOLESCENTS AT RISK OF SCHOOL FAILURE 277

9.1 Introduction **277**

9.2 Rationale and aim of Study 5 .... **282**

9.3 Hypotheses for Study 5 .... **285**

9.4 Methodology **286**

9.4.1 Ethical considerations 286

9.4.2 Participants 286

9.4.3 Zing intervention 287

9.4.4 Experimental design and procedure 288

9.4.5 Intervention training 289

9.4.6 Materials and Apparatus 290

9.5 Results **291**

9.5.1 Descriptive statistics 291

9.5.2 Statistical analysis 293

9.6 Discussion **314**

9.7 Limitations **318**

9.8 Conclusion **318**

CHAPTER 10 320

GENERAL DISCUSSION 320

10.1 Summary of findings **320**

10.2 The relation of the current findings to the overall hypotheses **323**

10.3 Contribution to the existing literature **327**

10.4 Limitations of the present research **334**

10.5 Theoretical implications **334**

10.6 Practical implications **338**

10.7 Directions for future research **340**

10.8 Conclusion **341**

References **343**

List of Tables

Table 4.1 Summary of the self-report measures and cognitive tasks used in the thesis ... 75
Table 5.1 Full breakdown by group, level of study, and gender in Study 1 103
Table 5.2 Means and standard deviations for level of study and for each group 103
Table 5.3 Means and standard deviations of gender and group, together with effect sizes 104
Table 6.1 Mean scores and standard deviations by group and gender, together with effect sizes, for each variable 148
Table 6.2 Means and standard deviations, along with effect sizes, for the self-esteem subscales.. 154
Table 6.3 Mean Rank of the self-esteem subscales.. 156
Table 6.4 Correlations among all study variables for boys (n=25) 156
Table 6.5 Correlations among all study variables for girls (n=20) 156
Table 7.1 Means and standard deviation across three time points (pre-intervention, post-intervention, follow-up) 188
Table 7.2 Means and standard deviations for the dyslexic and non-dyslexic group.......... 204
Table 8.1 Means, standard deviations and median scores by group, along with effect sizes for the DST-S tasks.. 248
Table 8.2 Means and standard deviations by group, for declarative and procedural Memory tests and for the STAI.. 249
Table 8.3 Summary of the Mann-Whitney U test for the DST-S tasks.......................... 255
Table 8.4 Summary of the ANOVA tests for the Declarative and Procedural tasks. and the STAI.. 259
Table 8.5 Correlations between declarative tasks, procedural tasks, literacy tasks, and anxiety measures for the dyslexic group (n = 18) 260
Table 8.6 Correlations between declarative tasks, procedural tasks, literacy tasks, and anxiety measures for the non-dyslexic group (n = 22) 261
Table 8.7 Correlations between motor tasks, literacy tasks, and anxiety measures for the dyslexic group (N= 18) 262
Table 8.8 Correlations between motor function tasks, literacy tasks, and anxiety Measures for the non-dyslexic group (n = 22) 263
Table 9.1 Pre-intervention and post-intervention means and standard deviations for the DST tasks 291
Table 9.2 Pre-intervention and post-intervention means and standard deviations for the declarative and procedural memory tasks and for the STAI 292
Table 9.3 Individual changes from pre- to post-test on tasks with Group (Intervention vs Control) differences 306
Table 9.4 Pre- and post-test means and standard deviations for DST tasks for the intervention group 311
Table 9.5 Pre- and post-test means and standard deviations for non-DST tasks for the intervention group 312

List of Figures

Figure 2.1 Categorization of long-term memory systems and the brain structures involved in each form of memory 44
Figure 5.1 Distribution of Test anxiety categorical scores 105
Figure 5.2 Distribution of Depression categorical scores 106
Figure 5.3 Distribution of Self-esteem categorical scores 107
Figure 5.4 Mean scores of group, gender and level of study for Social anxiety 109
Figure 5.5 Mean scores of group, gender and level of study for Academic anxiety 110
Figure 5.6 Mean scores of group, gender and level of study for Test anxiety 111
Figure 5.7 Interaction effect on Depression between group and gender 112
Figure 5.8 Mean scores of group, gender and level of study for Self-esteem 113
Figure 6.1 Distribution of state anxiety categorical scores 149
Figure 6.2 Distribution of trait anxiety categorical scores 149
Figure 6.3 Distribution of test anxiety categorical scores 150
Figure 6.4 Distribution of Self-esteem categorical scores 151
Figure 6.5 Distribution of Self-esteem subscales categorical scores for the dyslexic group 154
Figure 6.6 Distribution of Self-esteem subscales categorical scores for the non-dyslexic group 155
Figure 7.1 Interaction effect on State anxiety between time and group 191
Figure 7.2 Interaction effect on Trait anxiety between time and group 192
Figure 7.3 Interaction effect on Test anxiety between time and group 194
Figure 7.4 Interaction effect on Self-esteem between time and group 195
Figure 7.5 Interaction effect on Mindfulness between time and group 196
Figure 7.6 Interaction effect on Verbal Fluency task between time and group 197
Figure 7.7 Interaction effect on Backwards Digit Span task between time and group 199
Figure 7.8 Effect sizes upon each variable, by group, across time 202
Figure 7.9 Effect sizes upon each variable, by group, across time 203
Figure 8.1 Balance tester of the postural stability test 236
Figure 8.2 The bead threading test 238
Figure 8.3 Example of the Rapid Automatized Naming test 239
Figure 8.4 Pictures displayed on Visual Declarative Memory test 241
Figure 8.5 Pictures displayed on Picture Memory Recall test 242
Figure 8.6 MST as it appeared on laptop screen 244
Figure 8.7 WIT task as it appeared on the laptop screen 246
Figure 8.8 Distribution of ARQ categorical scores for the dyslexic and non-dyslexic adolescents 250
Figure 8.9 Distribution of State anxiety categorical scores for the dyslexic and non-dyslexic adolescents 250
Figure 8.10 Distribution of Trait anxiety categorical scores for the dyslexic and non-dyslexic adolescents 251
Figure 8.11 Mean scores of performance of dyslexic and non-dyslexic adolescents in the DST subtests 252
Figure 9.1 A screenshot from a session of the Zing programme 290
Figure 9.2 Time effect on the one-minute reading task 294
Figure 9.3 Time effect on the semantic fluency task 295
Figure 9.4 Interaction effect for postural stability between time and group 296

Figure 9.5 Time effect on backwards digit span task 297
Figure 9.6 Interaction effect on declarative memory test between time and group 298
Figure 9.7 Interaction effect on delayed picture memory recall delayed test between time and group 299
Figure 9.8 Interaction effect on MST-Correct sequences in the 1st trial between time and group 300
Figure 9.9 Main effect of time for MST-reaction time in the 1st trial 301
Figure 9.10 Interaction effect on MST-Correct sequences in the 2nd trial between time and group 301
Figure 9.11 Main effect of time on MST reaction time in the 2nd trial 302
Figure 9.12 Interaction effect on WIT real words accuracy between time and group 303
Figure 9.13 Main effect of time for WIT real words speed 303
Figure 9.14 Interaction effect on trait anxiety scores between time and group 305
Figure 9.15 Effect sizes by group for DST subtests of interest and STAI Intervention ... 307
Figure 9.16 Effect sizes by group for Declarative and Procedural Memory tasks 308

Declaration

I, Panagiota Blouchou, confirm that the Thesis is my own work. I am aware of the University's Guidance on the Use of Unfair Means (www.sheffield.ac.uk/ssid/unfair-means). This work has not been previously presented for an award at this, or any other, university.

Part of this thesis has been published in the following scholarly journal:

Blouchou, P. and Nicolson, R.I. (2020). "Cerebellar challenge" for adolescents at risk of school failure: evaluation of a school-based "whole person" intervention. *Frontiers in Education, 5. 88.* doi: 10.3389/feduc.2020.00088

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- European Dyslexia Association Conference (EDU) – The 5th All European Dyslexia Conference. Oral presentation. Modena, Italy (September 2016)
- European Dyslexia Association Conference – 'Bridging the gap between research, policies and practice – Continuing the discussion'. Poster presentation. Munich, Germany (October 2018).
- European Dyslexia Association Conference – 'Bridging the gap between research, policies and practice - opportunities and challenges with accessibility'. Poster presentation. Vaijo, Sweden (September 2019).
- British Dyslexia Association 9th International Conference – Creating Impact Through Innovation. Poster presentation. Guildford, UK (March 2014).
- British Dyslexia Association Conference. Poster presentation. London, UK (October 2016).
- British Dyslexia Association International Conference and EXPO. Poster presentation. Telford, UK (April 2018).
- British Dyslexia Association International Conference 2021 (virtual event) - Advancing dyslexia and dyscalculia. Oral presentation. (May 2021).

Chapter 1

General Introduction

1.1 Introduction

Reading has a central role in everyday life as it offers access to information that surrounds the world. The act of reading is part of human development. Reading is an aspect of comprehending humans' own development as well as the development of the surrounding social world (Freire & Slover, 1983). Reading and writing skills are necessary for communication. Reading skills are based on oral language skills, and language is a valued communication method (NICHD Early Child Care Research Network, 2005). The ability to develop oral language skills is natural and inherent for humans, but the ability to develop reading skills is not innate, and humans need to be taught how to read (Frey & Fisher, 2010).

Reading is a core skill, but it is not a single or simple task; it involves a range of different skills, abilities, and complex processes for humans' educational attainment (Cain, 2010; Vellutino et al., 2007). Not all individuals can read at the expected level; poor readers, and individuals with reading or specific learning difficulties share common underlying problems in learning to read. In considering the possible causes of dyslexia, it is of theoretical importance to understand the theories of learning to read, ranging from the first theoretical approaches to reading acquisition.

Automaticity is an important factor in reading development (Logan, 1997; Samuels & Flor, 1997) and skill learning (Anderson, 1982), and refers to the ability to accomplish complex skills with minimal attentional and cognitive control without using working memory resources (Shiffrin & Schneider, 1977). Automaticity is important for higher order processes, such as reading (LaBerge & Samuels, 1974). Individuals who are capable of automatizing skills, are also able to perform more than one task at a time. Such 'multitasking' is also an important factor in reading, as individuals can decode and comprehend printed text at the same time (Samuels & Flor, 1997).

Automaticity is learned through practice; however, most students often learn skills until accuracy is reached, but not automaticity. Skills learned to automaticity are stored in long-term memory, but skills developed to accuracy level are stored for a shorter time in memory (Shiffrin & Schneider, 1977). Students need to develop reading and skill learning, beyond accuracy, to an automaticity level, as this can free up memory capacity, attention, and cognitive control (Samuels & Flor, 1997). Automaticity is related to fluent reading and reading comprehension, but not quite to speed reading (Frey & Fisher, 2010).

The Phonological Deficit Theory (Snowling, 1987; Stanovich 1988; Stanovich & Siegel, 1994; Vellutino, 1979) claims that phonological impairments in dyslexic children lead to problems in learning to read and phonics acquisition (Stanovich, 1988). In the 1970s, it was considered that visual deficits were the most predominant cause of dyslexia and reading problems. However, Vellutino (1979) claimed that dyslexia difficulties were related to language, rather than visual problems, and that visual problems could also be attributed to language problems. The acquisition of phonological skills in the early years are the foundations for learning to read (Goswami & Bryant, 2016; Hulme et al., 2009; Nation & Snowling, 2004; Vellutino, 1979), as phonological problems in children can predict later reading deficits (Nicolson & Fawcett, 1995).

Phonological skills are also important, in tandem with knowledge of orthography (a method of using letters in the right way to form a word) and syntax (the structure of sentences), for accurate and fluent reading (Vellutino et al., 2004). A number of studies have provided evidence of phonological deficits in children and adults with dyslexia (Snowling, 1995; Wagner & Torgesen, 1987; Ziegler & Goswami, 2005). Ramus and Szenkovits (2008) suggested that the phonological deficit mainly affects three cognitive abilities that are core symptoms of dyslexia, namely, phonological awareness, phonological short-term memory, and slow lexical retrieval ability. Bradley and Bryant (1978) claimed that the most significant predictor of reading and writing skills is phonological awareness.

Children with phonological awareness problems have difficulties with decoding, and children with grammar and vocabulary problems have difficulties with reading comprehension (Nation & Snowling, 1997; Snowling et al., 2020). There are also children who present difficulties at school with both decoding and reading comprehension (Catts et al., 2005). Phonological awareness is a metalinguistic ability to discriminate and manipulate the sounds of words (Melby-Lervag et al., 2012; Nicolson & Fawcett, 2008). Stanovich (1992) argued that children develop phonological awareness in stages; starting with the skill of isolating large elements of sounds, such as words and syllables, then medium elements, such as the onset and rime of a word, and then smaller elements, such as phonemes.

Phonemic awareness and rime awareness have been identified as the most widely used measures of phonological skills in children (Melby-Lervag et al., 2012). The importance of rime awareness in learning to read is emphasized by Goswami and Bryant's (2016) theory, which states that children learn to read by focusing first on the onset and rime units of the word, and that phonemic awareness skills develop later in children, after they have acquired the onset-rime awareness skills. In contrast to Goswami and Bryant, other researchers have found that phonemic awareness is a stronger predictor of reading skills than rime awareness (Hatcher & Hulme, 1999; Muter et al., 2004).

The phonological theory claims that dyslexic individuals in all languages have difficulties with the storage and retrieval of sounds (Goswami et al., 2010; Ramus et al., 2003; Ziegler & Goswami, 2005). Since the learning of grapheme-phoneme correspondence is a core factor in learning to read the alphabet, dyslexic individuals will be particularly affected, as they have difficulties in learning grapheme-phoneme correspondences (Snowling, 1995; Vellutino, 1979). A number of studies have shown that the most supported explanation for reading deficits in dyslexic individuals is the relationship between reading acquisition and phonological deficits (Melby-Lervag et al., 2012; Siegel, 1993; Vellutino et al., 2004). Phonological awareness is the foundation for reading development (Ramus, 2004). Numerous studies have shown that dyslexic individuals present persistent difficulties with phonological awareness (Bradley & Bryant, 1978; Goswami, 2002; Swan & Goswami, 1997).

Although there is a consensus that dyslexia is associated with a deficit within the language system, particularly in phonological processing (Ramus, 2014; Stanovich, 1988; Swan & Goswami, 1997), evidence suggests that phonology is not the only problem in dyslexia (Nicolson & Fawcett, 1995; Stein, 2018; Stoodley et al., 2006). Nicolson and Fawcett (1999) suggested that impaired cerebellar performance can possibly lead to reading difficulties, since research has shown that problems in motor function and automatization can lead to a cerebellar abnormality. Fawcett and Nicolson (1999), and Fawcett et al. (1996) found that children with dyslexia as well as adults with dyslexia (Needle et al., 2006) showed behavioural signs of abnormality in the cerebellum, with problems in balance and muscle tone. More direct evidence of a cerebellar abnormality in dyslexia was found by a PET study (Nicolson et al., 1999), in which adults with dyslexia showed an abnormal pattern of brain activation in a motor sequence learning task, with only 10-20% of the dyslexic adults achieving the expected brain activation level compared to controls.

One of the first developmental tasks that a child has to succeed in is learning to read, and failure to do so may lead to feelings of inferiority and negative self-image (Alexander-Passe, 2015). Individuals with dyslexia often show emotional and social problems such as low-self-esteem and low self-confidence (Novita, 2016). The neurologist Samuel Orton (1937) was the first who found emotional difficulties in some children with dyslexia. It has been reported that between 40% and 60% of young people with dyslexia have mental health problems, including depression and anxiety (Children and Families Policy Research Unit, 2020). Miles (1993) distinguished between primary and secondary effects of dyslexia, referring to literacy difficulties as primary effects, and to difficulties caused by the primary effects, such as psychoemotional problems, as secondary effects. Evidence has shown that anxiety can severely affect cognitive function and brain activity, and therefore anxiety can impair academic performance (McEwen, 1998; Sandi, 2013).

Although there has been extensive and growing research on theories and causes of dyslexia, particularly on phonological deficits, there has been less much emphasis on mental health problems associated to individuals with dyslexia. Research is particularly scarce on emotional and psychological long-time effects and consequences of those with dyslexia, especially of adolescents and young adults. The study of dyslexia and mental health problems is important for a number of reasons. Evidence suggests that 60% of individuals with dyslexia meet the criteria for one psychological disorder (Margari et al., 2013). Research suggests that most adults with dyslexia have perceived the disorder as a hidden and silent 'pain' throughout their life, for which they usually do not discuss with family, friends or in the workplace (Alexander-Passe, 2015; Moody, 2015). Evidence also suggests that students with dyslexia often withdraw from school and attempt self-harm or suicide as a way to cope with and protect themselves from being bullied and humiliated in school, because of their difficulties (Alexander-Passe, 2016; McNulty, 2003). Long-term psychological effects of dyslexia, including anxiety and depression, can affect the way an individual with dyslexia lives, and lead to feelings of low self-esteem and low self-confidence, which in turn can ultimately lead the dyslexic individual to withdraw from the society (Alexander-Passe, 2016).

In addition, there is less research on evidence-based interventions which support the dyslexia-related difficulties and the associated psychological problems. A number of researchers (Nicolson & Fawcett, 2008; Morgan & Klein, 2000; Novita, 2016; Alexander-Passe, 2015; Children and Families Policy Research Unit, 2020) have stressed the necessity of early diagnosis and support for mental health problems in students with dyslexia, so that they do not have to cope and suffer simultaneously with both the educational and psychological effects of dyslexia. Research suggests that it is important to use emotional and psychological criteria as part of the diagnosis, as this would acknowledge that dyslexia is not related to literacy difficulties only, but also to an emotional and psychological aspect of the disorder (Morgan & Klein, 2000).

The present thesis investigated the psychological and emotional difficulties of adolescents and higher education students with dyslexia, along with the effects of stress on cognitive performance. In addition, two experimental studies evaluated the effectiveness of a Mindfulness-based and a Cerebellar-based intervention on cognitive ability, and psychological well-being of adolescents with and without dyslexia.

1.2 Organization of the thesis

The thesis is divided into ten chapters. The literature review comprises Chapters 2 and 3.

Chapter 1 provides a general introduction in the thesis and the organization of the thesis.

Chapter 2 provides a historical overview along with the varying definitions and characteristics of developmental dyslexia, including the prevalence, the aetiology, the comorbidity, and the assessment of developmental dyslexia. Furthermore, the various theories of developmental dyslexia are presented, based on cognitive, biological, and behavioural levels, according to the multilevel framework of Frith (1997).

Chapter 3 reviews the literature in areas of general and specific (test) anxiety and distinguishes the concepts of stress and anxiety. The review also outlines the effects of stress on cognitive function, including different memory systems, and on cerebellar function. The chapter also presents the literature on the effects of stress and anxiety on the psychological well-being and cognitive performance of adolescents and adults with dyslexia.

Chapter 4 presents the overview of the research and the thesis scope.

Chapter 5 includes Study 1. The chapter reviews the internalising problems of students in Higher Education, particularly in students with dyslexia, and describes Study 1.

Chapter 6 includes Study 2 and considers the internalising problems of adolescents at risk of school failure, in particular those with dyslexia, and the associated difficulties in school.

Chapter 7 presents Study 3, which examines the effectiveness of a mindfulness-based intervention on psychological difficulties in adolescents with and without dyslexia, which were tested in Study 2.

Chapter 8 describes Study 4. The chapter presents the results of the link between stress and cognitive development in adolescents at risk of school failure, particularly in adolescents with dyslexia. Results and discussion are further presented.

Chapter 9 describes Study 5. The chapter outlines the results of the evaluation of a cerebellar-based intervention on cognitive and motor performance in adolescents with and without dyslexia, which was tested in Study 4.

Chapter 10 presents the general discussion of the thesis and a summary of the main findings from all five studies and draws the associated conclusions. Practical implications of the findings, and directions for future research are also considered.

Chapter 2

Dyslexia Overview

2.1 Definitions of developmental dyslexia

The definition of dyslexia is one of the most common topics of debate in dyslexia research (Fletcher, 2009; Fisher & DeFries, 2002). Defining dyslexia is not a simple task as there is no consensus among researchers and different disciplines about a unified definition of dyslexia. According to Miles (1995) there cannot be a single definition of dyslexia. This is because different disciplines, such as psychology, education, medicine, and neuroscience, each use a different explanation for dyslexia, and therefore a different definition which serves their own purposes. Educationalists tend to use the term 'specific learning difficulties' or 'at risk' to refer to children with dyslexia, while psychologists and medical professionals use the term 'dyslexia' to refer to the disorder (Miles, 1995). Despite decades of wrangling, there is no universal definition of dyslexia but rather common elements in the definitions. The following two definitions will be illustrated in the present thesis from the World Federation of Neurology and the British Dyslexia Association as the most used definitions by dyslexia and educational researchers.

The classic definition of dyslexia was suggested by the World Federation of Neurology (1968), which defined dyslexia as:

"A disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and sociocultural opportunity. It is dependent upon fundamental cognitive abilities which are frequently of constitutional origin" (World Federation of Neurology, 1968, p.26).

It may be seen that this definition, in common with subsequent definitions, defined dyslexia in term of its symptoms, rather than its causes, and given the multiple potential causes of poor reading, it may be that this lack of clarity has contributed strongly to the subsequent confusion over cause and definition. However, this definition does include an implicit ‘discrepancy criterion’, namely that, children with dyslexia persist in experiencing reading difficulties despite adequate tuition and adequate ability. The definition also identifies the intelligence element as a core attribute of dyslexia (Miciak & Fletcher, 2020).

The British Dyslexia Association has adopted the Rose (2009) definition of dyslexia which is based on the symptoms’ principle, referring to symptoms of dyslexia other than language, including motor functions. The BDA defines dyslexia as:

“Dyslexia is a learning difficulty that primarily affects the skills involved in accurate and fluent word reading and spelling. Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory, and verbal processing speed. Dyslexia occurs across the range of intellectual abilities. It is best thought of as a continuum, not a distinct category, and there are no clear cut-off points. Co-occurring difficulties may be seen in aspects of language, motor co-ordination, mental calculation, concentration, and personal organization, but these are not, by themselves, markers of dyslexia. A good indication of the severity and persistence of dyslexic difficulties can be gained by examining how the individual responds or has responded to well-founded intervention” (Rose, 2009, p.30).

The BDA definition sidesteps the issue of discrepancy, by implicitly suggesting degrees of dyslexia, but for inclusion of participants in studies, discrepancy remains a major cause of contention between theorists (Siegel, 1989; Stanovich, 1996; Cline & Frederickson, 2009), but falls beyond the scope of this thesis. Rather than take an exclusionary approach, in this thesis the criteria for participant inclusion will be stated clearly in each study (see also section 2.2.4).

2.2 Characteristics of developmental dyslexia

The main problem of developmental dyslexia is related to written language (Peterson & Pennington, 2012) along with problems with reading and spelling, but not with reading comprehension (Mather et al., 2011). Dyslexia is a neurobiological and cognitive disorder that affects literacy skills, mainly decoding and encoding ability (Vellutino & Fletcher, 2005). Usually, the impairments of dyslexia become apparent in reading accuracy, reading rate, and reading fluency (Mather et al., 2011).

Most signs of dyslexia are more apparent in children, because academic and school success is an important factor for children, their parents, and teachers, and therefore their weaknesses in reading and spelling are pointed out very often (Boetsch et al., 1996). It should be noted however, that although these characteristics are common signs of dyslexia, every individual has a different experience of dyslexia and different individuals can have completely different indicators of the disorder. Mather et al. (2011) argue that a significant aspect of dyslexia, which is mentioned in most definitions, is that the disorder is considered unexpected in relation to the individual's other abilities. That means that although individuals with dyslexia have weaknesses in their reading and writing abilities, they have strengths in other skills, such as in maths and science, along with oral language and listening comprehension skills.

The term 'specific learning difficulties' is used in the UK to refer to dyslexia, while the term '(specific) learning disability' is used in the USA (Nicolson & Fawcett, 2008). Today, the terms 'dyslexia' and 'specific learning difficulties' are used interchangeably in the UK (Riddick, 2009). The diagnosis of specific learning difficulties is based on the child's performance and the specific learning disorder affected, which needs to be below average for their age, irrespective of any intellectual disability (IQ < average) (Moll et al., 2014). According to the DSM-5 (American Psychiatric Association, 2013), specific learning difficulties can be classified into reading deficits (dyslexia); writing deficits (dysgraphia); and mathematics deficits (dyscalculia). The DSM-5 does not include in this edition the IQ criterion for the diagnosis of learning disorders (American Psychiatric Association, 2013). The terms ‘dyslexia’ and ‘specific reading disability’ are also used interchangeably, even though there are also other types of learning disabilities that can affect reading ability (Mather et al., 2011; Peterson & Pennington, 2012; Riddick, 2009). Evidence suggests that dyslexia is a continuous disorder like all behavioural disorders. Therefore, a cut-off should be established on a continuous variable for the diagnosis of dyslexia (Shaywitz et al., 1992).

2.2.1 Prevalence of developmental dyslexia

The prevalence of dyslexia varies, depending on sample selection criteria, and the definition of dyslexia. Many definitions set the cut-off for reading ability at 1.5 standard deviations below the mean for age and IQ, and estimates suggest that around 7% - 10% of the population have dyslexia (Fletcher et al., 2019; Peterson & Pennington, 2012; Snowling & Melby-Lervag, 2016). Other researchers (Siretanu et al., 2005; Siegel, 2006) suggest that 5% to 10% of school-age students have dyslexia. However, there are also even higher estimates, which suggest that between 5% and 20% of school-age students have dyslexia (Shaywitz & Shaywitz, 2003; 2005). Evidence also suggests that there is a male predominance in dyslexia (from 1.5:1 to 3.1:1) (Rutter et al., 2004), while other researchers suggest an even higher predominance of boys compared to girls (from 3:1 to 6:1) (Stevenson, 1992; Olson, 2002; Dykman & Ackerman, 1991).

Evidence suggests that boys have a high probability, of around 50%, of becoming dyslexic if their father had dyslexia; the probability for girls is lower (Snowling, 1996). However, there are cases of parents who are not aware of having dyslexia; therefore, Uhry and Clark (2005) suggest that the family history of reading difficulties should be investigated prior to a formal assessment and diagnosis of dyslexia. Despite the great body of evidence suggesting a male preponderance of dyslexia, there are also researchers who have not identified gender differences in their studies (Shaywitz et al., 1990; Siegel & Smythe, 2005). The research findings suggested that gender differences have been reported in some studies due to referral bias, methodological factors, or sample selection (Shaywitz et al., 1990; Share & Silva, 2003). For instance, Shaywitz et al. (1990) found no differences between boys and girls according to research identified students with reading difficulties. However, differences were reported between boys and girls according to school identified students with reading difficulties.

Shaywitz and Shaywitz (2003) suggested that another factor related to the gender differences in reading disability is school procedures, in terms of more boys than girls being referred for testing. This happens because boys usually have more externalising behaviour than girls, along with comorbid disorders, such as attention-deficit hyperactivity disorder (Willcutt & Pennington, 2000; Shaywitz & Shaywitz 2003). Another factor contributing to the male preponderance in reading difficulties is that boys show more variability and have more extreme performance in their reading scores compared to girls (Hawke et al., 2009). That means that boys tend to score at the lower tail of the distribution, whereas girls tend to score closer to the mean (Wheldall & Limbrick, 2010). Gender differences in reading disability are also due to biological differences, particularly in cerebral laterality, and to genetic and environmental factors (Shaywitz et al., 1995; Olson, 2002; Clements et al., 2006).

2.2.2 Aetiology of developmental dyslexia

An ongoing debate among developmental psychology researchers is nature (genes) versus nurture (environment), both of which play an important role in children's development, including reading development, and in dyslexia (Hulme & Snowling, 2009). Behavioural genetic studies contribute to the understanding of heritability in dyslexia. Dyslexia can be explained by different factors, such as genetic, cognitive, and environmental factors (Pennington, 2009; Peterson & Pennington, 2012). Dyslexia is moderately heritable and runs in families (Grigorenko, 2004; Pennington & Olson, 2005). According to Pennington & Lefly (2001), 50% of children who have one parent with dyslexia are likely to inherit dyslexia too. Although specific genes that are involved in dyslexia have not yet been identified, however multiple genes that contribute to the disorder have been identified (Grigorenko, 2005; Peterson & Pennington, 2012). All the genes work in collaboration, along with environmental factors, to cause dyslexia. Dyslexia is related to multiple genes on different chromosomes; however, chromosome 6p has been found to be most associated with dyslexia (Hulme & Snowling, 2009; Pennington & Olson, 2007). The genetic factors contributing to dyslexia are usually found in cases of dyslexia related to severe phonological deficits (Bishop & Snowling, 2004).

Most research on the heritability and familial risk factors of dyslexia has been based on studies of twins. Twin studies constitute the most ideal sample to study genetic differences in dyslexia, because research into twins can separate the genetic from the environmental factors that contribute to the disorder (Mather et al., 2011). A USA study (Hensler et al., 2010) investigated genetic influences on dyslexia in 1,024 first grade twin students using measures of reading ability. The findings reported a genetic contribution to dyslexia, as a high heritability was found for both reading ability and dyslexia. A longitudinal study conducted by the Twins Early Development Study investigated genetic influences on reading disability and attention deficits in more than 13,000 twins in England and Wales between 1994 and 1996. The findings indicated significant genetic and environmental influences in regard to both reading and writing abilities (Oliver & Plomin, 2007).

Although there is substantial evidence of genetic influences on the development of dyslexia, environmental factors also contribute to the causality of the disorder. Mather et al. (2011) made a distinction between the genotype of dyslexia, which refers to inherited characteristics, and the phenotype of the disorder, which refers to the behavioural characteristics of the individual, both of which are influenced by the interaction between genes and the environment. Although the school and the home environment cannot cause dyslexia, however they can affect children's reading ability and experience (Samuelsson & Lundberg, 2003). The findings from twin studies suggest that the influence of genetic factors on children's vocabulary and literacy development are more prominent than home environmental influences (Hayiou-Thomas et al., 2012). Research also suggests that there is a shift in the causes of reading development over time; for example, genetic factors influence children's literacy and language development more than environmental factors (Senechal & LeFevre, 2014). However, parents' use of language and commitment, as well as the home environment can also influence their child's reading development. Evidence suggests that home literacy activities and early exposure to reading are important factors for children's vocabulary, reading, and language development (Senechal & LeFevre, 2014; Whitehurst & Lonigan, 1998).

The school environment also plays an important role in supporting students with dyslexia. The student's relationship with the teacher is of utmost importance, particularly for students with learning difficulties, who have additional needs (Mather et al., 2011). Teachers are responsible for creating a supportive, valued, and respected classroom environment for all students (Mather & Goldstein, 2008). However, this is particularly important for students with dyslexia, as they usually suffer from low self-esteem due to reading and language problems. Appropriate instructions and the provision of early literacy interventions are the most significant factors in supporting the needs of students with dyslexia at school (Mather et al., 2011).

2.2.3 Comorbidity

Behavioural disorders, such as dyslexia, often co-occur with other developmental and behavioural disorders (Willcutt et al., 2007). Approximately 60% of children with reading difficulties also have another disorder (Willcutt & Pennington, 2000). Although dyslexia is mainly characterized by phonological deficits, possible comorbidities include language deficits, cognitive deficits, such as executive function and attention, and motor coordination deficits (Pennington, 2006; Reid, 1998; Willcutt & Pennington, 2000). It is important to understand the comorbidity between disorders because this facilitates the understanding of the underlying causes, such as genetic or brain disorders, the diagnostic criteria, as well as the design of appropriate interventions for children who have these disorders (Boada et al., 2012; Willcutt et al., 2007). Kaplan et al. (1998) stated that 'comorbidity is the rule rather than the exception' (p. 484) in developmental disorders.

The most commonly reported co-occurring disorder of dyslexia is Specific Language Impairment (SLI) (Boada et al., 2012; Mc Arthur et al., 2000). SLI is a disorder characterized by difficulties in oral language development (Leonard, 1998; Peterson & Pennington, 2012). One study found that 14% to 20% of children diagnosed with SLI also had dyslexia, and a slightly higher rate of 17% to 35% of children with dyslexia also had SLI (Catts et al., 2005). Speech sound disorder can also be a comorbidity in individuals with dyslexia (Peterson et al., 2009). Speech sound disorder is characterized by difficulties with the accurate production of sounds (Peterson & Pennington, 2012). Dyslexia and Attention Deficit Hyperactivity Disorder (ADHD) are also highly co-occurring disorders (Kaplan et al., 2001; McGrath & Stoodley, 2019). It is estimated that 60% to 80% of children with dyslexia or ADHD also have another comorbid disorder (Germano et al., 2010; Willcutt & Pennington, 2000). In addition, it is reported that between 25% and 50% of children with a diagnosis of dyslexia or ADHD also present a comorbidity with the other disorder (McGrath & Stoodley, 2019).

Evidence also suggests that the comorbidity between SLI and ADHD with specific learning difficulties, including dyslexia, ranges between 10% to 50% (Dykman & Ackerman, 1991; Willcutt & Pennington, 2000). Although these developmental disorders are distinct and have different characteristics, research has identified shared genetic and cognitive risk factors that explain the aetiology for the comorbidity among the disorders (Boada et al., 2012; McGrath & Stoodley, 2019; Peterson & Pennington, 2012). Plomin and Kovas (2005) introduced the generalist genes hypothesis to explain the comorbidity between developmental disorders. According to this hypothesis, a specific gene might affect several brain regions, which can in turn affect several cognitive abilities.

Evidence suggests that dyslexia has a comorbid diagnosis of Developmental Coordination Disorder (DCD), also known as dyspraxia. Developmental Coordination disorder is characterized by difficulties in fine (such as handwriting and drawing), and gross (like running) motor coordination (Barnhart et al., 2003). Studies have reported an estimated overlap between dyslexia and DCD of 16% (Kaplan et al., 2001), and some have found an even higher rate, of between 35% and 50% (Kirby et al., 2008). Previous studies (Hill, 2001; Dewey et al., 2000) have shown a frequent comorbidity between reading disorders, SLI, and DCD. The findings from one study showed that in a sample of 115 children, 53 showed purely signs of DCD, ADHD, and reading difficulties, whereas 62 showed co-occurring signs of all three disorders (Kaplan et al., 1998). Kaplan et al. (1998; 2001) criticised the term ‘comorbidity’, as they argued that distinct developmental disorders do not exist but rather, they reflect the same brain disorder, named ‘atypical brain development’.

Another commonly reported comorbid difficulty that is present alongside dyslexia is difficulties with mathematics, or dyscalculia (Malmer, 2000; Ackerman & Dyckman, 1995). Although there is not much evidence regarding the comorbidity between the two developmental disorders, Gross-Tsur et al. (1996) suggest that the rate of comorbidity is around 17%. Landerl and Moll (2010) have found that difficulties with mathematics were related more to spelling difficulties than reading difficulties. According to Malmer (2000), difficulty with mathematics should not be viewed as a disorder on its own, but rather as a difficulty that co-occurs with dyslexia.

Several studies have identified a high rate of comorbidity between dyslexia and motor difficulties (Nicolson & Fawcett, 2011; Fawcett & Nicolson, 1994; 1999; Krynski et al., 2017). It is estimated that about 60% of children with dyslexia also present motor difficulties (Kaplan et al., 1998). Nicolson et al. (2001) introduced the Cerebellar Deficit Theory of Dyslexia, which suggests that the dyslexia impairments can be attributed to skill automatization deficits, including motor skills, due to cerebellum dysfunction. Based on the Cerebellar Deficit Theory (Nicolson et al., 2001), many studies (Fawcett & Nicolson, 1994; Ramus et al., 2003; Stoodley & Stein, 2013) have reported gross and fine motor deficits in dyslexic children, particularly in balance, postural stability, peg moving, and sequencing. Motor deficits have been found in dyslexic children (Brookes et al., 2010; Kaplan et al., 1998; Stoodley et al., 2005) as well as in dyslexic adults (Stoodley et al., 2006). However, the research into motor deficits and reading difficulties is inconsistent, as some studies have not found motor deficits in children with reading difficulties (Savage, 2004; Savage & Frederickson, 2005; Kelly et al., 2002). It is argued that these inconsistencies are due to comorbidity with other developmental disorders, such as ADHD (Wimmer et al., 1999), Developmental Coordination Disorder (Ramus et al., 2003), or Specific Language Impairment (Irannejad & Savage, 2012). However, according to Kaplan et al. (2001), there are no discrete categories of developmental disorders but rather only a high rate of overlapping disorders. According to Brookes et al. (2010), the controversial results may be due to different measurement techniques or the design of each study, such as differences in age groups, experimental conditions, or the place and duration of the experiment.

2.2.4 Assessment and diagnosis

It is important to identify the underlying causes of children's specific learning difficulties before the first symptoms arise, so that the appropriate support, either educational or psychological, can be provided to the child at the right time (Mather et al., 2011; Nicolson & Fawcett, 2008). The diagnosis of dyslexia is not an easy task for practitioners, psychologists, or researchers, due to the plethora of definitions that mainly describe the symptoms, relating to reading difficulties, rather than the causes of dyslexia (Nicolson & Fawcett, 2008). According to Kirk and Johnson (1951), the diagnosis of a disorder is significant not for the categorization of the disorder, but rather for the provision of remediation and intervention planning.

The diagnosis of dyslexia is usually made by a qualified psychologist, or a specialist teacher administering a battery of accredited standardised cognitive and achievement tests and generate a full report (Fawcett, 2016; Sadusky, Reupert, Freeman, & Berger, 2021). The accredited tests evaluate, among others, areas such as reading speed, accuracy, and comprehension (Shaywitz, 1998; Schulte-Korne, 2010). In addition, school and family history are important for a comprehensive diagnosis of dyslexia (Schulte-Korne, 2010). Additional tests of cognitive ability, including IQ tests, language tests, or memory tests are administered for a more comprehensive diagnosis (Siegel, 2006; Shaywitz, 1998). A diagnostic test with a broader scope is usually preferred by clinicians, practitioners, and researchers, as it provides more information about a child (Schulte-Korne, 2010). For instance, Nicolson and Fawcett (1997), and Fawcett and Nicolson (2004) have designed screening tests for different school years and adults, which include tests not only of phonological ability but also of a broader range of skills, such as motor skills, cerebellar function, auditory processing, and memory, which can be administered by educators or health professionals. The diagnosis of dyslexia should also include the child's school history, such as their academic achievements or difficulties, clinical or educational observations, and clinical data (Shaywitz, 1998; Schulte-Korne, 2010).

Researchers often follow some criteria for diagnosis, such as an IQ score of greater than 90 (Ellis, 1984), or a reading age of between 1.5 and 2 years behind the individual's chronological age (Ellis, 1984; Nicolson & Fawcett, 2008).

In addition to screening tests, the administration of questionnaires, either self-report or by other informants such as by teachers and parents, is also used to assess specific learning difficulties (Willcutt et al., 2011; Barry et al., 2015) and dyslexia in children (Adlof et al., 2017; Helland et al., 2011) as well as in adults (Lefly & Pennington, 2000; Snowling et al., 2012). Self-report questionnaires are considered to be valid measures for identifying and categorizing individuals with specific learning difficulties (Nicolson & Fawcett, 1997; Snowling et al., 2012). According to Pennington and Bishop (2009), the administered questionnaires should include several aspects of deficits to be considered a valid method of dyslexia evaluation. For instance, the Colorado Learning Difficulties Questionnaire (Willcutt et al., 2011) is administered by parents, and evaluates different areas of academic achievement, including reading, math and spatial difficulties, social cognition, and social anxiety. The adult self-report questionnaires, such as the one designed by Snowling et al. (2012) (Adult self-report questionnaire), and the Adult Reading History Questionnaire (Lefly & Pennington, 2000) assess symptoms of reading difficulties experienced by individuals in the past.

2.3 Theories of developmental dyslexia

Researchers from different disciplines have studied the concept of dyslexia from different perspectives. Although a number of theories have been developed about developmental dyslexia, there is still no consensus about a unified theory. Knight and Hynd (2002) suggest that the number of different theories of dyslexia is because reading development is a complex process that involves the processing of sensory, phonological, and semantic information. Nicolson and Fawcett (2008) suggest that it is important to explain the underlying causes of dyslexia in ‘ontogenic levels’, which describe the main symptoms of dyslexia that are influenced by history, by the brain, by genes, and by development. Reid and Fawcett (2004) also suggest that an interdisciplinary approach is necessary to understand the underlying causes of dyslexia.

Frith (1999) has suggested a causal modelling framework for clearly understanding the underlying causes of dyslexia, based on different levels, or categories, namely cognitive, biological, and behavioural. According to Frith’s (1999) multilevel framework, dyslexia is not only explained by difficulties in reading, writing, and spelling, but also by biological and behavioural manifestations. According to this framework, it is easy to classify the different deficits of dyslexia into each level. For instance, speed deficits of processing, working memory problems, phonological processing, and automatization deficits are included in the cognitive level, while genetic factors, brain function, and magnocellular deficits are included in the biological level, and reading and spelling difficulties are included in the behavioural level (Frith, 1999).

There are different theories of dyslexia in the literature, which relate to different manifestations of dyslexia including the phonological deficit theory (Vellutino, 1979, Snowling, 1987; Stanovich 1988), the rapid auditory processing deficit theory (Tallal, 1980), the automatization deficit theory (Nicolson & Fawcett, 1990), and the double deficit theory (Wolf & Bowers, 1999) at the cognitive level; the magnocellular deficit theory (Stein & Walsh, 1997), and the cerebellar deficit theory (Nicolson et al., 2001) at the biological level, as well as the procedural learning deficit theory (Nicolson & Fawcett, 2007) at the neural systems level. Although the phonological problems in children with dyslexia are well documented, there are also secondary problems, which are important to be explained. It was of particular interest, in the present thesis, to look at non-phonological aspects of dyslexia as the participants of the present thesis are adolescents and students in higher education. The significant contributions of the phonological theory (see p. 17-18) are well established for early stages of learning to read, but once a child is no longer having reading instruction, the explanatory power of the framework is limited.

The focus of the present thesis was on the enduring aspects of dyslexia, those that persist beyond the primary school years, including cognitive components such as procedural learning and executive function deficits together with affective components such as internalising problems. In this section, the relevant cognitive theories will be presented and discussed in detail. Namely, the automatization deficit theory (Nicolson & Fawcett, 1990) at the cognitive level, the cerebellar deficit theory (Nicolson et al., 2001) at the biological level, and the procedural learning deficit theory (Nicolson & Fawcett, 2007) at the neural systems level.

2.3.1 Cognitive Level

2.3.1.1 The Automatization Deficit Hypothesis.

There are three stages when learning a skill; at the first stage, the declarative stage, learning is conscious; at the second stage, the procedural stage, knowledge becomes a habit; and at the final stage, the autonomous stage, the habitual skill becomes fluent and automatic, and can be completed unconsciously (Anderson, 1982). It is well established that dyslexic children face difficulties in acquiring and mastering some skills, but the underlying causes remain unexplored (Nicolson & Fawcett, 2007). Research into dyslexia has mostly focused on language-related difficulties, especially reading. However, Nicolson and Fawcett (1990) aimed to provide a wider framework of dyslexia and the associated difficulties and explore the hypothesis that dyslexia is not limited to reading but extends to a further deficit in the automatization of skills.

A cognitive-level hypothesis was proposed by Nicolson and Fawcett (1990), the Automatization Deficit Hypothesis (ADH), which suggests that dyslexic children struggle to learn skills at the point that they become automatic and fluent and, therefore, when attention and conscious effort are no longer necessary. Nicolson and Fawcett predicted that children with dyslexia will face difficulties in any task that needs to be automatized, such as reading or spelling. This framework provides an explanation of a range of dyslexia symptoms outside of the literacy domain, such as in motor skills and balance, in addition to phonological, working memory, and processing speed difficulties. Evidence also reveals that motor skills, such as riding a bike and swimming, are delayed in dyslexic children and, even when learnt after extensive practice, they are still less automatic than non-motor tasks (Miles, 1993). These deficits have been attributed to an impairment in skill automatization.

The Automatization Deficit theory (Nicolson & Fawcett, 1990) states that although individuals with dyslexia might appear to perform within the normal range in some skills, in fact this is achieved by trying harder, by ‘conscious compensation’, to achieve normal levels of performance. This means that although dyslexic individuals lack the automaticity of skills, they can perform at normal levels by consciously concentrating using the controlled processing, in a task that is supposed to be automatic, at the cost of trying harder, or even by masking the deficit (Nicolson & Fawcett, 1990). As dyslexic individuals appear not to be able to automatize skills sufficiently, it is difficult for them to become experts at a task. It is therefore believed (Nicolson & Fawcett, 2008) that the harder the task is to learn, the more impaired dyslexic individuals will appear to be. Nicolson and Fawcett observed that dyslexic children with average literacy skills were still slow and needed more effort to complete a reading task, as the ADH theory suggests (Nicolson & Fawcett, 1990). Augur (1985) noted that when dyslexic children constantly attempted to maintain their effortful performance, they fatigued quickly and lost concentration on the tasks.

Support for the Dyslexia Automatization Deficit was found by Fawcett and Nicolson (1992) using a dual task paradigm of balancing and counting backwards. The dual task is a critical test for automaticity, where the child performs the primary task (balance) concurrently with a secondary task (counting backwards), which distracts conscious attention from the primary task. If the child performs the primary task automatically, then the second task can be performed with little interference but if the primary task requires conscious attention, then there will be a decrease. The results of Fawcett and Nicolson’s study (1992) showed that the dyslexic’s group performance on the single balancing task was at the same level as the performance of the control group. However, when they performed a dual task of balancing and counting backwards, the dyslexic adolescents had incomplete skills in terms of automaticity for balance. The performance of the dyslexic group on the counting backwards task, in the dual task condition, was also lower than that of the control group. Nicolson and Fawcett (1990) suggested that the dyslexic children showed a poorer performance on the dual task because they needed to use more conscious resources for the task, as it was difficult for them to perform the skills unconsciously, and therefore they had limited available resources to carry out the two tasks simultaneously. As the dyslexic and control participants showed the same performance in the single task, the theory of ‘Conscious Compensation’ was put forward to explain this finding (Nicolson & Fawcett, 1990). Therefore, trying to perform two tasks at the same time may be overwhelming for the dyslexic brain.

The dual task study (Nicolson & Fawcett, 1990) was followed up by comparing the performance of the dyslexic and control students in a balance task under two conditions: when blindfolded and not blindfolded. It was found that the dyslexic group showed significantly poorer performance in the blindfolded condition, eliminating the possibility that the results from the previous dual task experiment were due to a general attention deficit.

The concept behind the Automatization Deficit Hypothesis was described by Shiffrin and Schneider (1977, p .127): ‘Automatic processing is well learnt in long-term memory, is demanding of attention only when a target is presented, is parallel in nature, is difficult to alter, to ignore or to suppress once learned, and is virtually unaffected by load’. Anderson’s theory (1982; 1983) of the acquisition of expertise offered an explanation of skill acquisition; first, the declarative knowledge of what should be done needs to be acquired, and then it gradually shifts to the ‘proceduralization’ of the knowledge, before resulting in the procedural knowledge of how to do a task. Anderson’s (1982; 1983) theory is not only applicable to motor tasks, but also to a series of other tasks, such as cognitive tasks, letter recognition tasks, and language development tasks (Nicolson & Fawcett, 1990).

Regardless of the empirical research on automatization deficits in dyslexia, the automatization theory has not accumulated much support due to the inconsistent results. Wimmer et al. (1998), and Wimmer et al. (1999) replicated the results of Nicolson and Fawcett (1990) with dyslexic children and age-matched control children. The researchers used the same blindfold balancing task used in Nicolson and Fawcett’s study, in which the children had to stand on one or two feet for some time before some force was applied to their back, as well as a dual task. In addition, a rapid naming speed task and a phonological task were included by Wimmer et al. (1998) in their study. The results of Wimmer et al. (1998), and Wimmer et al. (1999) revealed that in both studies there were no differences between the groups in the dual or the balance task, and therefore no evidence of an automatization deficit was found. There was only evidence supporting the differences between the dyslexic and control children in terms of the phonological and naming tasks.

2.3.2 Biological Level

2.3.2.1 The Cerebellar Deficit Hypothesis.

The Cerebellar Deficit Hypothesis (Nicolson et al., 2001) provides a biological and neurological explanation of dyslexia and is an elaboration of the cognitive explanation of dyslexia provided by the Automatization Deficit Hypothesis (Nicolson & Fawcett, 1990), as the latter hypothesis does not specify which brain structure is involved in reading and phonological skills. The Cerebellar Deficit Hypothesis states that dyslexic individuals show a range of symptoms due to cerebellar deficit in skill automatization and motor skills. The cerebellum is considered to be the motor area of the brain. Nicolson et al. (2001) showed that the cerebellum is involved in the process of skill automatization, as well as in the execution of cognitive skills, particularly those involved in language development (Fawcett & Nicolson, 2004). Frank and Levison (1973) were the first to study the cerebellum and developmental dyslexia, and they found evidence of a cerebellar/vestibular abnormality in the majority of the dyslexic children that they tested. The dyslexic children showed a range of different deficits such as in balance, muscle tone, and dysmetric-visual perception. A number of studies have found an association between learning, atypical cerebellum function and reading difficulties (Fawcett & Nicolson, 1994; Nicolson & Fawcett, 2000; Nicolson et al, 2002; Mariën et al., 2014). Furthermore, there is clear evidence of balance impairment in dyslexic children (Fawcett and Nicolson, 1994; Chaix et al., 2007; Stoodley et al., 2005).

Further support for cerebellar impairment in dyslexia has been found in neuroimaging and neuroanatomical studies, providing neurobiological evidence of cerebellar dysfunction in the dyslexic population (Finch et al., 2002; Laycock et al., 2008; Leonard et al., 2001; Nicolson et al., 2001). Several studies have shown a link between dyslexia and cognitive and balance deficits, supporting the theory of the involvement of the cerebellum in dyslexia (Brookes et al., 2010; Stoodley et al., 2006; Wimmer et al., 1999). Neuroscientific studies have also confirmed the involvement of the cerebellum in working memory tasks (Desmond & Fiez, 1998; Hayter et al., 2007; Stoodley, 2015), in language (Ackerman et al., 2007), and in reading tasks (Fulbright et al., 1999; Turkeltaub, et al., 2002; Feng et al., 2017). fMRI studies have shown weak cerebellar activation in motor tasks (Nicolson et al., 1999; McCrory et al., 2000), as well as differences in the activation of the brain between dyslexic and non-dyslexic individuals (Berry et al., 1998; Nicolson et al., 1999). There is also evidence of functional and anatomical impairments in the cerebellar activation in dyslexic individuals (Leonard, et al., 2002; Rae, et al., 2002; Vicari, et al., 2003)

However, critics (van Daal & van der Leij, 1999; White et al., 2006) of the cerebellar deficit theory have argued that impaired cerebellar function is not strongly correlated with literacy symptoms in dyslexia due to inconsistent results in speed processing and motor tasks. Ramus et al. (2003) assessed three theories of dyslexia (phonological, magnocellular, and cerebellar theories) with a sample of university students and found inconsistent results for the cerebellar theory of dyslexia. Ramus et al. claimed that a motor deficit was only very weakly supported by the cerebellar deficit theory or by the automatization deficit theory. Ramus et al. (2003) did not find a link between dyslexia and time estimation deficit in children, nor an association between motor deficit and reading skills, but they found a strong correlation between phonological processing and reading skills. Another study (Raberger & Wimmer, 2003) with children with reading difficulties and/or ADHD, who participated in a balancing task, found that only the ADHD group showed impaired balancing, while the group with reading difficulties showed an impairment in the rapid naming task. Raberger and Wimmer (2003) attributed the balance impairment found in other studies to the comorbidity factor within the sample, rather than to dyslexia per se. A meta-analysis of 17 studies, comparing the balancing skills of dyslexic and control individuals, revealed that although a balance impairment was found in the dyslexic group, this was attributed to comorbidity with other developmental disorders, and not solely to dyslexia (Rochelle & Talcott, 2006). Other researchers (Barth et al., 2010) found no differences in cerebellar function between reading disabled children and typically achieving children on a bead threading and postural stability test (taken from the DST-J, Nicolson & Fawcett, 2004). The authors concluded that the cerebellar tasks used in the study fail to identify a link between cerebellar function and academic performance.

Criticism of the cerebellar deficit theory also arises from whether cerebellar deficit should be accounted for as the core cause of dyslexia (Bishop, 2002; Ivry & Justus, 2001). A possible explanation has been offered by Zeffiro and Eden (2001) who argued that the cerebellum may be acting as the 'innocent bystander' such that the cerebellum may work well in dyslexic individuals, but the information that is given to it by other sources, such as the magnocellular system, might be impaired.

2.3.3 Memory systems of human learning

Before outlining the Procedural Learning Deficit Hypothesis (see section 2.3.3.1), it is necessary to describe the different memory systems involved in human learning.

Memory is the mental function that is responsible for encoding, storing, and retrieving information and thoughts from the environment (Sherwood, 2015). The human memory can be divided into different types: sensory memory, which is the first stage of information processing; short-term memory (working memory), which is the second stage, where the information moves to; and long-term memory, the last stage where the information ends up (McLeod, 2007). The sensory memory is the most primitive type of memory; it is very brief and can hold sensory information for less than a second. The sensory memory is divided into the visual, auditory, and tactile sensory memory (Byrne, 2017). The short-term memory can hold information for a few seconds up to a minute; it has limited capacity, and encodes the information retrieved acoustically (McLeod, 2007). Miller (1956) showed that the short-term memory can store seven items, plus or minus two. But the short-term memory capacity can be increased with the 'chunk' process, in which information goes together such that more can be remembered (Miller, 1956).

Unlike the short-term memory, the long-term memory has unlimited capacity, and can store information for an unlimited time, sometimes even for a whole lifetime. The long-term memory encodes the information semantically (Baddeley, 1966) and is divided into declarative (also known as explicit) memory, which is considered as conscious thought (Cohen & Squire, 1980), and non-declarative or procedural (also known as implicit) memory (how to perform a task), which is not involved in conscious processes. Figure 2.1 presents the long-term memory systems and brain structures involved in each memory system.

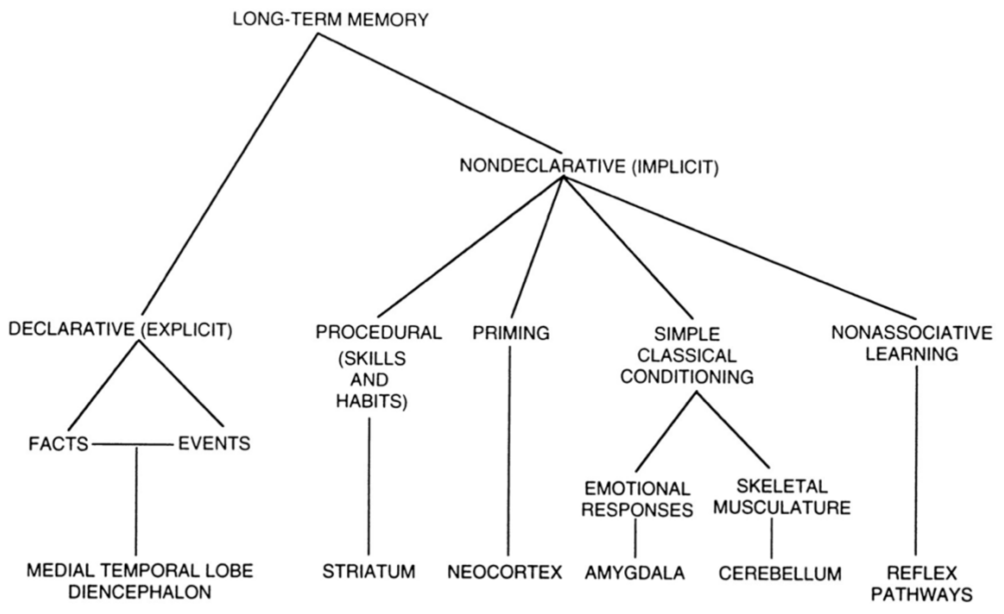


Figure 2.1 Categorization of long-term memory systems and the brain structures involved in each form of memory. The figure was reproduced from Neurobiology of Learning and Memory, 82, Squire, L. 2004, 171-177. Memory systems of the brain: A brief history and current perspective. Permission was given by Elsevier, Copyright (2004).

There is a major distinction between the declarative and procedural memory, which refers to different brain circuits. The declarative memory is scaffolded by the hippocampus (McClelland et al., 1995) and is responsible for general knowledge and the learning of events and facts (Squire, 1987). The declarative memory is quite rapid and requires little exposure to the stimulus in order to occur (Squire, 2004). It is divided into two forms: the semantic memory (common knowledge, and memory for facts and events), and the episodic memory (specific memory for personal experiences and personal events) (Cohen & Squire, 1980; Tulving, 1972). The semantic memory refers to common and world knowledge obtained throughout one's life (McRae & Jones, 2013). Tulving (2002) described the semantic memory as 'knowing'. Tulving (2002) described the episodic memory as 'self-knowing or remembering', as the episodic memory is the memory of personal experiences that happened at specific times and places. According to Tulving (1972) episodic memory can be characterized by mental time travel, a connection to oneself, and autonoetic consciousness (self-awareness).

The procedural memory is scaffolded by the cerebellum and basal ganglia (Squire, 1987), and is part of the several brain systems that are responsible for the acquisition, consolidation and retrieval of implicit knowledge (Willingham et al., 2002). The procedural memory is important for motor, cognitive and linguistic skills (Ullman, 2004). This system is involved in cognitive functions, such as the learning of rules and sequences (Poldrack et al., 1999), retrieval from the declarative memory (Ullman, 2004) and working memory (McNab & Klingberg, 2008), as well as grammar learning (Ullman, 2001). In addition, the procedural memory and learning system include three subtypes, statistical learning, reward – based learning, and trial and error learning, and is responsible for learning skills and habits to the extent that they become automatic (Squire, 1987). The knowledge and skills that rely on the procedural system are considered implicit and are thus available to unconscious thought (Lum et al., 2013).

The model of cognitive learning distinguishes between Controlled Processing, which is considered to require attention and control, uses working memory capacity and is mostly serial, and Automatic Processing, in regard to which it is believed that once information is learned in the long – term memory capacity, it does not require attention and control, and does not use up working memory capacity (Anderson, 1983). The model of cognitive learning is divided into three stages of skill acquisition: the declarative stage, where it is worked out what needs to be done; the procedural stage, where it is worked out how it needs to be done; and the tuning stage, where skills become automatic (Nicolson & Fawcett, 2018). The study of the amnesic patient, HM, who was described by Squire (1987), helped establish the fundamental differences in memory functions, as well as the existence of different memory systems in the brain. HM did not have problems with their long-term memory, and therefore with learning procedural memory tasks (such as a mirror-drawing task), but had problems with their short-term memory, and therefore the declarative memory, and was incapable of remembering any information or facts minutes after they were said.

Controlled processing works though declarative processing, using conscious, attentional control while doing the task; however, it is comparatively slow, and a person cannot concentrate on more than one task at a time. By contrast, automatic processing works through procedural processing; it is fast and does not require many attentional and conscious resources (Nicolson & Fawcett, 2018). Shiffrin and Schneider (1977) argued that declarative processing is considered to be easy to set up, although the processing can be quickly forgotten, whereas procedural processing is more demanding and requires extensive practice. Anderson (1982) proposed that 'proceduralization', which refers to the change from the declarative to the procedural stage, is a difficult process. Proceduralization is a key component of learning motor skills and developing the muscle commands necessary for carrying out a skill. Proceduralization is necessary for implicit skills, i.e., those that happen unconsciously and habitually, and thus automatically. As mentioned above, the cerebellum is responsible for the execution of these fluent and coordinated skills.

The declarative, procedural and neural circuit learning systems were developed at different times in the human brain. The three types of the procedural learning system were the first to develop and are considered as the 'primitive' types. The declarative learning system is considered to be more recent; it was specialised by humans and depends more on thought and consciousness. The neural circuit building system is the least investigated system in human development, as well as in reading. The three learning systems combine to work in the brain and may sometimes compete (Kim & Baxter, 2001).

Recent developments in learning have detected different phases of learning acquisition: fast learning (that happens within minutes), slow learning (that happens within hours), consolidation (that happens overnight), automatization (that happens over hundreds of trials), and retention (that happens within weeks) (Doyon & Benali, 2005; Robertson et al., 2004). Neuroimaging studies have proved the involvement of cortical regions of the brain in learning, including the premotor area and primary motor area, as well as the involvement of subcortical regions, including the cerebellum and the striatal regions (Doyon et al., 2003). According to Doyon et al. (2003), two motor-learning systems have been distinguished: the cortico-striatal system, involving structures from the motor cortex to the basal ganglia; and the cortico-cerebellar system, involving structures from the motor cortex to the cerebellum. The motor cortex, basal ganglia and cerebellum are involved in the fast and slow phases of learning, which makes it difficult to detect the unique contribution of each system to the learning process. The cortico-striatal system is fundamental for the acquisition of motor-sequence, whereas the cortico-cerebellar system is fundamental for motor adaptation.

2.3.3.1 The Procedural Learning Deficit Hypothesis.

The Procedural Learning Deficit (Nicolson & Fawcett, 2007) theory is an approach to developmental dyslexia at the neural systems level. The theory attributes dyslexia problems to atypical function of the Procedural Memory system, while the Declarative Memory system remains somewhat intact. Doyon et al. (2003) proposed that the cortico-striatal and cortico-cerebellar brain system corresponded to the declarative and procedural memory systems, respectively. Nicolson and Fawcett (2007) based the neural systems theory on Doyon and Benali's (2005) theory that more than one region of the brain was involved, and that several regions were responsible for the acquisition and execution of cognitive and motor tasks, and thus the neural system should be approached as a whole, and not through its different parts. Nicolson and Fawcett's (2007) neural system theory was inspired by Ullman's (2001; 2004) theory which states that the declarative and procedural memory systems not only refer to language skills but also to motor skills. Ullman (2001) proposed that the declarative memory system underpins the 'mental lexicon', which involves the hippocampus, whereas, the procedural memory system underpins the 'mental grammar', which involves the cerebellum, basal ganglia, and frontal cortex (particularly Broca's area). According to Ullman's (2001) theory, the procedural learning system comprises the cortico-striatal and cortico-cerebellar structures not only for language but also for motor-related cortical regions of the brain. Individuals with dyslexia have difficulties with the procedural memory system as it is mediated by the cerebellum (Nicolson & Fawcett, 1999), whereas the declarative memory system remains intact as it is mediated by the hippocampus and frontal lobes (McClelland et al., 1995).

Nicolson and Fawcett (2000) explored long-term learning in dyslexic adolescents, using a motor sequence learning task named PACMAN. The participants first had to learn four letters on the keyboard, and later they had to learn another set of letters. A dual task was used in the study, in which the participants had to press a button with their foot after hearing a tone while carrying out the computer task at the same time. The results revealed that both groups learned the set of letter keys quite quickly. However, during the first phase of the learning sequence task, the dyslexic group started much more slowly than the control group and did not perform at the same level as the controls even after extensive practice. During the second phase of the study, the dyslexic group was more affected by the key shift than the control group. Although the speed of the dyslexic group gradually increased throughout the task, they still made more errors than the controls. This result suggests that even though the dyslexic participants could automatize to some extent, they still had limitations in terms of speed processing and accuracy. Also, this observation reveals that it is difficult for dyslexic individuals to unlearn already learned skills. Automatized performance has different aspects, such as the 'quality of automatization' (with regard to speed and accuracy), and the 'strength of automatization' (with regard to resistance to unlearning) (Nicolson & Fawcett, 2000). In Nicolson and Fawcett's study (2000), the quality of automatization in the dyslexic group was less good, as it was slower and less accurate compared to the non-dyslexic group. The strength of automatization, however, was similar to the non-dyslexic group. Nicolson and Fawcett's theory was supported by Frith (1986), who found that dyslexic individuals not only struggle during the initial stages of learning, but also between the different learning stages.

Nicolson and Fawcett (2007) presented five paradigms to support the procedural learning deficit theory. In a motor sequence learning task study, Nicolson et al. (1999) found that the dyslexic group did not show evidence of cerebellum activation either at the first stage of learning or after the task had become automatic. In a response blending task, Nicolson and Fawcett (2000) found that dyslexic participants were impaired during all stages of learning, that is through the fast stage, the automatic stage, as well as the in-between stages, suggesting potential impairments in both the cortico-striatal and cortico-cerebellar systems. In an eye-blink conditioning task (Maschke et al., 2003; Nicolson et al., 2002), evidence showed impairment in the dyslexic participants. In a prism adaptation cerebellar task (Brookes et al., 2007) a dyslexic group was compared to a Developmental Coordination Disorder group, and a control group. The results indicated that the dyslexic and the DCD group had weak adaptation skills. Another study showed that dyslexic individuals performed at the same level as controls on a declarative learning task, but they showed impaired performance on a procedural learning task (Vicari et al, 2003).

Considering all the evidence from neuroscientific, cognitive, brain, and behavioural studies, it is suggested that mild cerebellar dysfunction is an underlying cause of dyslexia, which in turn explains the phonological problems associated with the disorder. Since reading depends on good phonological processing and automatization skills, which one can master through practice, the Procedural Learning Deficit hypothesis, at the neural systems level, seems to provide an integrated explanation of dyslexia.

2.3.4 Behavioural level

According to Frith (1999) the behavioural characteristics of dyslexia are manifested because of the underlying biological and cognitive factors along with environmental factors that affect the behavioural manifestations. There as some common behavioural manifestations of dyslexia, resulting from cognitive and biological factors; however, not all individuals with dyslexia show the same behavioural characteristics and symptoms. A common characteristic of dyslexia is reading difficulties, particularly with rhyming words, learning letter names and letter sounds, reversal of letters, slowness, and spelling (Shaywitz et al., 1990; Vellutino et al., 2004). Behavioural characteristics also include difficulties with handwriting (Fawcett & Nicolson, 1999), automatization skills deficits (Nicolson et al., 2010; Nicolson & Fawcett, 1990), working memory problems (Vellutino et al., 2004), auditory processing difficulties (Stein, 2001; Nicolson & Fawcett, 1990), and difficulties with motor tasks, such as with balance or sequencing (Nicolson & Fawcett, 1994; Ramus et al., 2003; Stoodley et al., 2006). Some characteristics are more common in children (for instance, difficulty with rhyming words) while others are more common among secondary school students and adults (for instance, a slow reading rate) (Mather et al., 2011).

2.4 Conclusion

The theories discussed in this chapter contribute to an understanding of the underlying causes of developmental dyslexia from different viewpoints, particularly from a cognitive, biological, and neural systems approach. In summary, the principal explanatory framework has been in terms of phonological deficit, with other symptoms being attributed to secondary factors such as motor skill. The broader automatization deficit framework (Nicolson & Fawcett, 1990) provides a principled explanation not only of phonological deficits but also the ‘secondary’ deficits. The hypothesis states that children with dyslexia have difficulties with undertaking fast and fluent skills that involve performing two actions simultaneously. Thus, they lack automaticity not only in literacy-related skills, such as in reading (Stanovich, 1988) but also in motor-related skills (Fawcett & Nicolson, 1995). A brain level explanation of dyslexia, consistent with the automatization deficit framework is provided by the cerebellar deficit hypothesis which states that children with dyslexia have problems with automatizing language and motor skills due to a cerebellar deficit, as was evidenced by the link between the cerebellum and automaticity. Finally, an intermediate level framework in terms of neural systems is provided by the procedural learning deficit hypothesis which states that children with dyslexia have problems with the procedural memory system and consequently with the procedural learning system (Nicolson et al., 2010). This procedural learning framework provides one leg of the theoretical aspects of dyslexia, and the second leg derives from the internalising problems of dyslexia, as discussed in the following chapter.

Chapter 3

Anxiety and Stress

3.1 Anxiety

Anxiety disorders are common mental health disorders (Kessler et al., 2005; Michael et al., 2007) with different aetiological factors such as genetic, psychological, and social factors (Somers et al., 2006). Anxiety, depression, stress, and anger are all emotions which indicate lack of indicators of psychological well-being that motivate a person's behaviour (Spielberger & Reheiser, 2009). Anxiety is an emotional state of uneasiness, such as worry or fear (Spielberger, 2010), which is experienced by everyone at some point in their life. Anxiety is defined as a psychological and physiological state with cognitive, physiological, and behavioural characteristics (Seligman et al., 2001). According to the DSM-5 (APA, 2013), anxiety disorders include, amongst others, generalised anxiety disorder (GAD), panic disorder, separation anxiety disorder, and agoraphobia. Individuals with high levels of trait anxiety often also have high levels of state anxiety (Stake et al., 1995; Wilken et al., 2000).

3.1.1 State and Trait anxiety

Anxiety is distinguished into two categories: state anxiety and trait anxiety. Spielberger (1966) was among the first psychology researchers to distinguish anxiety into two types. There is disagreement in the literature as to whether state and trait anxiety should be perceived as unidimensional or multidimensional measures. On the one hand, Endler et al. (1989), and Endler and Parker (1990) demonstrated that state and trait anxiety are multidimensional constructs. On the other hand, Taylor (1953), and Vagg et al. (1980) conceptualised anxiety as a unidimensional construct, which is differentiated into two aspects: in state and trait anxiety (Spielberger et al., 1983). Endler and Parker (1990) have distinguished state anxiety into two dimensions: cognitive-worry and autonomic-emotional, and trait anxiety into four dimensions related to specific situations: social evaluation threat, physical danger threat, ambiguous threat, and daily routines threat.

State anxiety is described as a temporary reaction to a situation that is perceived as dangerous or threatening and is associated with heightened sympathetic nervous system activity (Spielberger et al., 1983). Spielberger et al. (1983) defined state anxiety as an emotional state occurring at a particular time and at a particular intensity. Individuals often experience state anxiety in specific situations. For instance, individuals might feel anxious in a physical danger condition, but not in a social event condition (Endler & Parker, 1990). Trait anxiety, on the other hand, is described as a generally stable personality characteristic, associated with high arousal. Individuals who present with trait anxiety experience negative emotions (such as worry and fear) and respond to threatening and dangerous situations with state anxiety (Gidron, 2013; Spielberger et al., 1983; Vagg et al., 1980).

3.1.2 Test anxiety

Test anxiety is prevalent among students and interferes with cognitive performance. Test anxiety is referred to as a type of state anxiety (Lufi et al., 2004) that is triggered by testing. There are several theories and models of test anxiety. Mandler and Sarason (1952) were the first researchers to study test anxiety, and they proposed the cognitive interference model which states that test anxiety is provoked by the evaluation situation and subsequently by test performance. According to Cassady and Johnson (2002), this model suggests that students who suffer with high levels of test anxiety do not perform well in exams because of constant negative thoughts during the testing process. Wine (1971) proposed the cognitive attentional theory, which added the attentional dimension to Mandler and Sarason's (1952) cognitive interference model. Wine's theory proposes that students with severe test anxiety are unable to focus on the exam material due to task-irrelevant thoughts, worries, or negative feelings about prior preparation for the exam, which hinders the retrieval of information relative to the task.

Liebert and Morris (1967) proposed the 'two-factor conceptualization' test anxiety model, which is composed of two dimensions: the cognitive dimension is referred to as 'worry', and the physiological dimension as 'emotionality'. During exam-taking situations, physiological reactions can happen (such as increased heart rate, and body tension) in the autonomic nervous system, which refer to the emotional component, whereas cognitive aspects (such as thoughts about failure) refer to the worry component (Liebert & Morris, 1967; Morris et al., 1981). Worry refers to cognitive concern about an individual's performance. Worry is elicited by cues or thoughts about the consequences of failing. Emotionality refers to autonomic arousal which occurs under stressful examination conditions and is mainly elicited by testing cues (Liebert & Morris, 1967; Morris et al., 1981). According to Hembree (1988), performance is more negatively affected by the worry component than the emotionality component. Irving et al., (2009) found that cognitive measures had a stronger correlation with the worry component than the emotionality component of test anxiety.

Test anxiety is considered to be a significant source of academic anxiety (Putwain, 2007), which has negative effects on students' academic performance and academic testing, particularly for those students with low levels of academic self-concept (Nelson et al., 2015). According to Cassady (2010), between 25% and 40% of students present with test anxiety symptoms. A small amount of anxiety can facilitate performance and motivate a student to try harder; but a large amount of anxiety can disrupt the cognitive and mental processes that are necessary for optimal performance (Wachelka & Katz, 1999). Hancock (2001) found that students' test anxiety levels increased while their performance decreased because of high levels of evaluative threat, such as in a testing environment. Students with test anxiety find it hard to concentrate on the testing material, as well as to understand and follow simple instructions (Zeidner, 1998). Studies have also shown that test anxiety is associated with academic performance (Aysan et al., 2001; Cohen et al., 2008). In addition, working memory and attention are affected by test anxiety, which in turn has a negative impact on academic performance (Irving et al., 2009). Researchers have found that test anxiety is self-perpetuating and develops into a vicious cycle. Students who experience test anxiety in one testing situation often become more anxious and distressed about it happening again, and therefore the vicious cycle continues (Putwain, 2019).

3.2 Stress

The psychological literature makes a distinction between the constructs of stress and anxiety. According to Spielberger et al. (1976), stress refers to a negative situation that triggers an anxiety reaction, and to the stress reaction itself. Spielberger also suggests that the emotion of stress is generally triggered in a situation that is perceived as threatening or dangerous. Several factors determine if a situation is perceived as threatening and how an individual responds to stress, such as individual differences, personal traits, similar past experiences of an individual, vulnerability, and coping mechanisms (Endler & Parker, 1990; Lazarus, 1990; McEwen, 1998; Sandi & Richter-Levin, 2009). The concept of stress dates back to Aristotle and Socrates, who were aware of the effects of stress in daily life (Fink, 2009). Stress is defined as ‘a state of disharmony or threatened homeostasis. The adaptive responses can be specific to the stressor or can be generalised and non-specific (p.1245)’ (Chrousos & Gold, 1992). As a response to a stressful or dangerous situation, stress hormones, such as cortisol, adrenaline, and glucocorticoids, are released from the adrenal cortex (Sapolsky et al., 2000) and increased activity occurs in the hypothalamic-pituitary-adrenal axis (de Kloet et al., 2005).

Stress occurs within specific brain regions related to cognition and emotion, such as the prefrontal cortex, the limbic systems, the hippocampus, and the amygdala (a brain region involved in emotional processing) (Lupien & McEwen, 1997). After confronting a stressful situation, the amygdala is activated and sends the information to the hypothalamus (a brain part which links the nervous system to the endocrine system) which then connects to the body via the autonomic nervous system (McEwen et al., 2015; Joels & Baram, 2009). The autonomic nervous system is comprised of the sympathetic and parasympathetic nervous system. The sympathetic nervous system causes a fight-or-flight response (or acute stress), which triggers the body to respond to the stressful situation. In contrast, the parasympathetic nervous system is responsible for controlling the homeostasis and the normal function of the body organs, which can be disturbed during intense stress, for example, the heart rate and blood pressure can increase. After the amygdala sends the signal, the hypothalamus in turn activates the sympathetic nervous system through the adrenal glands. As a result, stress hormones are released and physiological responses are triggered in the body, such as an increase in heart rate and blood pressure (Diamond & Cribbet, 2012).

Stress can be divided into acute stress, which refers to a psychological response to a traumatic experience or to a single stressor (Reynaud et al., 2015; Sheilds, Sasma, & Yonelinas, 2016), and into chronic stress, which refers to difficulty experienced by an individual for a prolonged period that may or may not be an ongoing threat in their life (Sheilds et al., 2016). It is well established that stress has impairing effects on executive functioning but enhancing and improving effects of stress have also been reported, particularly on memory (Schwabe, Joels, Roozendaal, Wolf, & Oitzl, 2012; Sheilds et al., 2016). Chronic stress can have detrimental impact throughout the brain, as it ultimately leads to psychiatric disorders, such as anxiety and depression, neurological disorders, and metabolic problems (Sousa, 2016). Common stress symptoms are physiological, such as increased pulse rate, shortness of breath and sweating, and psychological, such as irritability, anger, and mood changes (Alexander-Passe, 2015). The adverse consequences of longer-term exposure to chronic stress were described as the ‘General Adaptation Syndrome’ (Selye, 1950) in which chronic stress leads to a general ‘burnout’ in which the individual loses their capacity to resist the stressors. A more recent framework, the ‘toxic stress model’ (Shonkoff & Garner, 2012), highlights the lifelong adverse consequences of early childhood stress, and a recent study has shown that corresponding effects can occur for adolescents who are subject to chronic environmental stressors (Joos et al., 2019). Previous studies have ascribed upper respiratory and immune system infections (Pedersen et al., 2010) to chronic stress.

3.2.1 Stress effects on cognitive function

Cognitive function is a term that refers to mental processes involved in knowledge acquisition, information manipulation, and reasoning. Cognitive functions include skills such as memory, attention, decision making, perception, language, and visuospatial processing (Kiely, 2014). Executive functions are a set of cognitive functions that need control and direction to work, and include cognitive processes such as working memory, planning, and inhibition (Stuss & Alexander, 2009). Inhibitory control, cognitive flexibility, and working memory are the most common executive function processes (Davidson et al., 2006).

Stress is thought to impair cognitive and executive function (Sandi, 2013; McEwen, 1998), as well as brain activity, and the neural circuits underpinning cognitive functions (Bremne & Vermetten, 2001; Bierzynska et al., 2016). In addition, stress has a negative impact on the prefrontal cortex, the hippocampus, and the amygdala, all of which are connected via the hypothalamus (Joels & Baram, 2009). There is an empirical U-shaped relationship between an individual’s ability to complete a cognitive task and their levels of stress or arousal (Mendl, 1999), which is called the Yerkes-Dodson Law (Yerkes & Dodson, 1908 as cited in Reber, 1995). According to the law, a certain level of stress can increase performance up to a point; however, when levels of stress exceed that point, then performance decreases. Not all tasks need the same level of stress for an optimal performance. For instance, difficult tasks require lower levels of stress, whereas tasks that need stamina and persistence to be performed require higher levels of stress. The Yerkes-Dodson Law emphasizes that in intellectually demanding tasks, stress can diminish performance as it causes difficulties with concentrating on the task.

For the purposes of the present thesis, which considers specific cognitive and executive functions, particularly memory function (Study 3, Study 4, and Study 5), the effects of stress will be discussed in the following sections with regard to declarative, procedural, and working memory.

3.2.2 Stress effects on declarative and procedural memory

Neuroimaging evidence indicates that multiple memory systems are involved in task performance, such as working memory, and declarative and procedural memory. Some researchers argue that none of the memory systems work on their own but, rather, each of them contributes to some extent and they collaborate with each other for better performance (Kim & Baxter, 2001; McGaugh, 2000). In contrast, other researchers argue that the memory systems do not collaborate, but rather they compete (Matthews & Best, 1995; Poldrack et al., 2001). Researchers have shown that a rigid, habitual, procedural memory system is used more in task learning over a cognitive, declarative system (Iaria et al., 2003). It has been established that the hippocampus is involved in learning and memorizing spatial and contextual information (Jarrard, 1993) as well as in mood regulation (Duman et al., 2001).

Schwabe et al. (2010) suggested that memory is shaped through stressful conditions. Researchers have found effects of stress on the hippocampus (de Kloet et al., 1999; Schwabe et al., 2012), and therefore it has been hypothesized that stress affects the way that each of the memory systems contributes, and thus can affect the learning process (Schwabe et al., 2010). The impairing effects of stress on the hippocampus are particularly important as the role of the hippocampus is necessary in learning and memory (Conrad, Wright, & McLaughlin, 2009). Therefore, the declarative memory, which is scaffolded by the hippocampus is thought to be affected by psychological stress (Kirschbaum et al., 1996; Lupien et al., 1997; Schwabe & Wolf, 2009) but the procedural memory system is not thought to be affected by stress (Kirschbaum et al, 1996; Lupien et al., 1997; Luethi et al., 2009).

A study with rats, which investigated their performance on a dual navigation task under a stressful condition, found that their performance promoted a shift from the hippocampal, declarative memory system to the dorsal-striatal procedural learning system (Kim et al., 2001). Likewise, humans may be affected by the involvement of the hippocampus and the dorsal-striatum dependent memory as well. In Schwabe and Wolf's study (2012), in which participants were put under stress before participating in a probabilistic classification learning task, there was no difference in participants' classification performance; however, the participants were affected by stress in a way that their task knowledge was minimised, and they shifted their learning from a conscious, declarative system to a more rigid, habitual procedural system. The evidence provided by Schwabe and Wolf sheds light on the effects of acute stress on the engagement of, and the shift between memory systems in cognitive processing.

The switch between memory and learning systems is considered by Schwabe et al. (2010) to be an adaptive behaviour to stress. This is supported by Schwabe's and Wolf's (2012) study, in which participants were tested on cognitive tasks after completing a 'socially evaluated cold pressor test' (SECPT), as described in Schwabe et al. (2008). The results showed that the learning performance of those exposed to the stressful condition was negatively associated with the hippocampus activity, and therefore with the declarative system, and that they shifted their learning strategy to the procedural system to optimise their performance. This behaviour can be related to the 'flight or fight' response. According to Vogel & Schwabe (2016) the shift between the declarative and procedural memory systems can also be repressing for students, as it can create strong, negative memories, and lead to habitual actions, which in turn can affect their ability to obtain new knowledge and use new information.

Adverse experiences and chronic stress can lead to anxiety and 'learned helplessness' (Nicolson, 2015). The concept of learned helplessness was suggested by Maier and Seligman (1967). In order to study this behaviour, Maier and Seligman (1967) conducted an experiment with dogs, in which a shuttle box was used to test the dogs' behaviour under stress. The dogs were given electrical shocks, after hearing a tone for 20 seconds, which the dogs could avoid by jumping to a lower part of the box. The results showed that most of the dogs learned the task and escaped the shock; however, some dogs passively laid down and did not escape the shock. Maier and Seligman (1976) concluded that, for those dogs that laid down, the shock was inescapable, and the dogs did not try to escape because they did not expect anything to stop the shock, and just became helpless. This behaviour can be associated with a 'flight or fight' response to stress or threat (Nicolson, 2015). Likewise, humans have minimised cognitive function when affected by severe and chronic stress (Maier & Seligman, 1976) which can lead to learned helplessness. High levels of stress and anxiety experienced by students in school may lead to learned helplessness, and can have detrimental effects on their self-esteem, as they accept the failure with passive behaviour and feel helpless (Maier & Seligman, 1976).

There is conflicting evidence about whether stress impairs or enhances learning and performance. On the one hand, evidence suggests that exposure to mild stress can enhance performance in executive function and working memory tests (Duncko et al., 2007). On the other hand, evidence suggests that stress impedes performance in working memory tasks and learning (Henderson et al., 2012; Schoofs et al., 2008; Vogel & Schwabe, 2016). Therefore, it is unclear under which circumstances stress can improve or hinder performance. Research suggests that controllability plays the main role in stress response (Arnsten, 2009). In other words, the stress response depends on how individuals handle stress and respond to stressors. It has been suggested that moderate stress is beneficial in working memory tasks, but extreme and uncontrollable stress leads to poor performance (Henderson et al., 2012; LeBlanc, 2009; Vogel & Schwabe, 2016). Evidence also suggests that stress responses depend on the type of stressor (Lepine et al., 2005). If an individual perceives the stressor as challenging, then their performance will be enhanced, but if they perceive the stressor as threatening, then their performance will be poorer.

In contrast to studies that found that stress impairs memory performance, other studies found that individuals who were exposed to stress before training in declarative and procedural memory tasks showed improved performance in the tasks. Shorts (2006) found that males who were exposed to stress before training showed facilitated performance in procedural conditioning tasks. Similarly, exposure to stress before training in fear conditioning tasks showed improved performance among humans (Jackson et al., 2006) and rats (Cordero et al., 2003). Similar improved performance, after one-minute exposure to a cold stressor test before training, was identified in men who completed declarative tasks, specifically two hippocampus-dependent tasks (Duncko et al., 2007). Individuals who were exposed to psychosocial stress before a verbal learning task, and who showed high cortisol responses, had improved performance in the verbal learning task (Nater et al., 2007).

3.2.3 Stress effects on working memory

Working memory is a cognitive system that stores and manages information temporarily and has limited capacity. Working memory is often used interchangeably with short-term memory; however, there are differences between the two memory systems. The working memory simultaneously stores and processes information, whereas the short-term memory only stores information temporarily (Cowan, 2008). Working memory is a multicomponent system that includes two stores, the phonological loop where verbal memory is held, and the visuospatial sketchpad where visuospatial memory is held. Working memory is also comprised of a third store, the central executive system, which has a small capacity, and is where all the executive processes occur (Baddeley & Hitch, 1974). Baddeley (2000) proposed a fourth store in the model of working memory, the episodic buffer, which has limited capacity and stores information temporarily; it is also capable of integrating and processing information from the long-term memory and the subsystems of working memory.

Previous researchers (Kuhlmann et al., 2005; Schoofs et al., 2008) have suggested that the effectiveness of working memory may be diminished under stressful conditions. Oei et al. (2006) found that when young healthy men were tested on working memory and memory retrieval under stress, their working memory performance was impaired at high loads, but unimpaired at low loads. Slow working memory was related to high levels of cortisol at high loads, but not at low loads. Klein and Boals (2001) investigated the association between life stress and working memory performance in college students and found that those students who reported higher levels of life stress had poorer working memory function on an arithmetic operation-word span task, supporting the idea that negative thoughts about stressful events impair working memory performance.

de Veld et al. (2014) explored working memory performance with a forward and backward task, delayed retrieval performance in school children under stressful conditions, as well as the relationship between physiological stress and performance. Stress was induced by exposing the children to a public speaking task, as well as to a mental arithmetic task. de Veld et al. (2014) found that the children's performance was poorer under the stressful condition, on the working memory backward task, but no differences were found between the stressful and control conditions on the forward memory task, or on the delayed retrieval task. An association between cortisol levels and performance in the stressful condition was found for the working memory forward task and the delayed retrieval task. Higher cortisol levels indicated better performance in the working memory forward task. Vogel and Schwabe (2016) have suggested that stress has detrimental effects on memory in school examinations. Although learning and performance may be enhanced by moderate stress, memory retrieval will be impaired, which can lead to uncontrollable and extreme anxiety in students before school exams.

3.2.4 Stress effects on motor function

The role of the cerebellum in motor and cognitive function is well established and accepted (Fawcett & Nicolson, 1999; Stoodley, 2012). There is converging evidence suggesting the role of the cerebellum in emotional regulation and psychiatric disorders, such as stress and anxiety disorders (Caulfield & Servatious, 2013; Moreno Rius, 2019; Philips et al., 2015). The cerebellum is associated with anxiety-related brain areas, such as the hypothalamus (Bains et al., 2015), the hippocampus (McEwen et al., 2016), the amygdala (McEwen, 2007), the prefrontal cortex, and the midbrain structures (McEwen et al., 2016).

There is evidence of changes in the cerebellar function under stressful conditions from studies of both animals and humans (Babenko et al., 2012). Seo et al. (2011) exposed healthy participants to a stressful imagery script session and found a cerebellar activity in the medial brain regions. Hommer et al. (2013) replicated Seo et al.'s study (2011) with adolescents and observed the same enhanced cerebellar activity in the medial brain regions under a stressful condition. A Positron Emission Tomography study (Tillfors et al., 2002) which was conducted with patients with social anxiety disorder, who were exposed to public speaking, one of the most anxiety-provoking situations for individuals with social anxiety, showed enhanced cerebellar activity, as well as alterations and changes within the cerebellum during the public speaking activity. In addition, further data from studies with adolescents who were exposed to maltreatment (Edmiston et al., 2011) and negative experiences and events from childhood (Walsh et al., 2014) revealed cerebellar functional changes in their grey matter volumes.

Schmahmann (2001) suggested that some symptoms and characteristics of psychiatric disorders are due to dysfunction in the cerebellum. The Cerebellar Cognitive Affective Syndrome (CCAS) (Schmahmann, & Shermann, 1998) is a condition that results from cerebellar damage and refers to cognitive impairments in executive function, spatial cognition, language and affect due to cerebellar damage (Schmahmann, 2010; Wolf et al., 2009). Schmahmann (2001) suggested the role of the cerebellum in emotion and affect, as well as in a number of psychiatric and neurodevelopmental disorders related to a deficit in the cerebellum, such as depression, schizophrenia, ADHD, autism, and dyslexia. Schmahmann and Sherman (1998) observed changes in the emotions and behaviour of clinical patients with impairments in the cerebellum posterial lobe and vermis. A PET study (Sakai et al., 2005) with patients who suffered with panic disorders showed that the participants had high state anxiety before scanning and exhibited higher levels of glucose uptake in the amygdala, hippocampus, cerebellum, mid brain and in thalamus compared to the control group.

In conclusion, the literature suggests that moderate levels of stress can facilitate cognitive performance through improved working memory and memory retrieval before or after an examination, which can be particularly beneficial for students' academic performance, but that these benefits are limited to stronger focus at the expense of flexible thinking. Unfortunately, the major effects of acute stress are in terms of a negative impact on cognitive function such as attention, inhibition, working memory, and cognitive processing as well as on brain activity. The implications of stress are particularly important for students as stress leads to poor academic progress and decreased cognitive performance, decreased attention and concentration, and ultimately to decreased self-esteem; skills that are necessary for optimal academic performance. The impact of stress on learning and cognitive performance is particularly important for students with dyslexia. Considering that students with dyslexia have relatively weak attention and working memory in non-stressful situations, elevated levels of stress can have a further impact on their performance and lead to learned helplessness. Furthermore, Schwabe's et al. (2008) theory about the shift from the declarative to the procedural learning system under stress is also relevant to dyslexia because if stress causes a shift from the declarative to the procedural learning system, then dyslexic individuals may be more affected due to an impaired procedural memory system, as suggested by the PLD hypothesis (see section 2.3.3.1). This shift can have adverse effects on dyslexic individuals' learning and performance, as under stressful conditions, dyslexic individuals may be forced to switch from the stronger, cognitive declarative learning system to the impaired, automatic procedural learning system.

3.3 Associated psychological problems of dyslexia

Dyslexia is often described in terms of language and phonological deficits. However, the secondary symptoms of dyslexia, which are also described as psychological problems, such as stress and anxiety, low self-esteem, and depression, and their effects on adolescents with dyslexia, are less often discussed. Similarly, there is less emphasis on psychological difficulties of adults with dyslexia, including adult students in higher education. Therefore, the current literature review presents the relation between dyslexia and psychological problems, particularly stress and anxiety, as potential confounding factors of dyslexia.

3.3.1 Characteristics of adolescence and the relation to anxiety

Adolescence is an important developmental period characterized by neurobiological, psychological, and hormonal changes (Krapic et al., 2015). Adolescents have to deal with different stressful situations during this period, such as puberty, physical changes, school and academic tasks, social and peer relationships, and the need for independence (Byrne & Mazanov, 2002; Krapic et al., 2015). Adolescence has been characterized as a period of 'storm and stress' (Kessler et al., 2005; Krapic et al., 2015) as it is considered a risky time for the onset of psychopathology and anxiety related disorders, and depression (Kessler et al., 2005; Krohne & Hock, 2011; Van Ameringen et al., 2014), due to high levels of academic and social pressures (Sanger et al., 2016). Stressful experiences in adolescence can also lead to chronic stress, antisocial behaviour, and physical problems in adulthood (Krapic et al., 2015). Brain maturation and plasticity of the nervous system occur during adolescence, when characteristics of the brain start differing between childhood and adulthood (Spear, 2000; Casey et al., 2008).

Anxiety disorders are the most common psychopathological disorders, along with behavioural disorders, in adolescence (Beesdo et al., 2009). The World Health Organization (WHO, 2015) has reported that depression is the major cause of adolescents losing years at school. Estimates of the number of adolescents with anxiety range between 2% to 32% (Coughlan, et al., 2014; Merikangas et al., 2010). Epidemiological studies have shown that common symptoms of anxiety, experienced by children and adolescents, include phobias, stress, physical and behavioural symptoms (Tassin et al., 2014), lack of concentration and lack of attention, distraction, emotional distress, and somatic complaints (Arnold et al., 2005;

Willcutt & Pennington, 2000). Biological changes, and temperamental and cognitive factors may account for anxiety development in adolescence (Zavos et al., 2011), as well as environmental factors, such as overprotective parents (McLeod et al., 2007). Higher rates of girls present with anxiety disorders compared to boys (Beesdo et al., 2009; Leikanger & Larsson, 2012). Levine (2005) found that early negative experiences in one's life affect behaviour and stress management later in life. That means that individuals who experience stress at a young age become more sensitive to stress responses, such that physiological responses are caused even by a small stressor.

3.3.2 Adolescents with dyslexia and the relation to anxiety

Developmental dyslexia is characterized as a risk factor for developing psychological disorders in childhood and adolescence (Arnold et al., 2005; Carroll et al, 2005; McNulty, 2003; Mugnaini et al., 2009). There is increased comorbidity between dyslexia and mental health problems, particularly with anxiety (Boyes et. al., 2019; Livingston et al., 2018; Willcut & Pennington, 2000), and depression (Arnold et al., 2005; Alesi et al., 2015). There is also comorbidity between dyslexia and low self-esteem (Casey et al., 1992; Humphrey & Mullins, 2004; McNulty, 2003; Terras et al., 2009), as well as with behavioural and emotional problems (Eissa, 2010; Knivsberg & Andreassen, 2008). According to Willcutt and Pennington (2000), children are more likely to develop anxiety and depression and withdraw from school because of academic underachievement or academic failure.

The literature suggests an explanatory framework for the association between reading difficulties, including dyslexia, and psychological problems (Children and Families Policy Research Unit, 2020; Grills-Taquechel et al., 2012). According to the framework, first, there are common risk factors for the development of reading difficulties and psychological problems, such as genetic and environmental factors, which lead to common neurological and functional deficits. Second, psychological problems can be caused by reading difficulties, through low self-esteem and feelings of inferiority that are frequently reported in students with reading difficulties, which in turn lead to anxiety disorders. Third, reading difficulties can be aggravated by psychological problems, as chronic anxiety and mental health problems have a negative impact on the coping mechanisms of students with reading difficulties. Adolescents with specific learning difficulties experience higher levels of anxiety compared to their non-dyslexic peers (Fisher et al., 1996).

Similar to the previous framework (Grills-Taquechel et al., 2012), the literature also suggests three theoretical models for the relationship between learning difficulties and emotional disorders. The first model is the secondary reaction theory (Crinchley, 1970) according to which children with difficulties in learning to read develop some emotional and neurotic reactions. The second model is the primary disorder theories (Spreen, 1989) according to which learning difficulties are a result of emotional disorders such as anxiety, phobia, depression, and compulsive disorders, as these disorders block the child’s ability to achieve. The third model is the cerebral dysfunction theory according to which anxiety and learning difficulties share a common aetiology which is either genetic or biological, such as a brain dysfunction, and so these two often co-occur (Spreen, 1989). According to Spreen, there is no clear evidence as to whether these three theories interact with each other, therefore they could be viewed either as independent of each other or interdependent.

Child and adolescent psychopathology is divided into internalising disorders (with symptoms of anxiety, phobias, sadness, or social withdrawal), and externalising disorders (with symptoms of aggression, impulsivity, and hyperactivity) (Sourander & Helstela, 2005). Internalising disorders occur more often and at higher rates in adolescents (32%), compared to externalising disorders (19%) (Merikangas et al., 2010). Dyslexic individuals present with considerably high levels of internalising problems, not only in childhood and adolescence, but also in adulthood (Mugnaini et al., 2009). Dyslexia can have detrimental consequences on a child's academic experiences, and in later life in the workplace (Hales, 1994). Students with specific learning difficulties often experience negative academic situations, due to reading and literacy problems, which can consequently cause them to suffer from stress and anxiety (McNulty, 2003; Lindeblad et al., 2019). Cohen and Wills (1985) suggested that anxiety can often hinder learning more so than learning difficulties per se. Students with dyslexia are more likely to develop psychological problems because of mainstream class teaching and the lack of provision for dyslexia, which may put dyslexic students at a disadvantage in the classroom (McNulty, 2003). Dyslexia is related to externalising and behavioural disorders (Mugnaini et al., 2009; Terras et al., 2009), and individuals with dyslexia are three times more likely to experience behavioural difficulties than those without dyslexia (Margari et al., 2013).

Reading and writing are stressful tasks for dyslexic students and therefore, adolescents with dyslexia find academic tasks demanding and frustrating because reading plays a key role in school coursework (Eissa, 2010). In addition, students with dyslexia have lower self-esteem and less motivation regarding reading or writing tasks, and they are more likely to drop out of school than non-dyslexic students due to reading and academic difficulties (Goldston et al., 2007). Stanovich (1986) referred to the Matthew Effect and observed that *'Initial and specific difficulties in learning to read may result in generalized deficits in learning because of the behavioral-cognitive-motivational spinoffs from failure at such crucial tasks as learning to read'* (p. 389).

Other studies (Willcutt & Pennington, 2000; Maughan et al., 2003) have reported that adolescents with reading difficulties show more depressive symptoms compared to their non-dyslexic peers. Eissa (2010) found that adolescents with dyslexia were more often bullied, and they had lower self-esteem and felt inferior compared to their non-dyslexic peers, and they blamed their dyslexia for these attitudes. Adolescents with learning and reading difficulties are twice as likely to develop violent and suicidal behaviour (Svetaz et al., 2001).

A number of studies have reported the detrimental impact of anxiety on school performance and academic achievement (Pascoe et al., 2019; Van Ameringen et al., 2003). Anxiety also has a negative impact on cognitive performance which disrupts attention, working memory and information processing (Lukasik et al., 2019).

Habib and Naz (2015) found that emotional difficulties are a predictor of cognitive disorders in dyslexic children, measured by errors and mistakes made in everyday life. Habib and Naz argue that emotional problems along with cognitive difficulties exacerbate the existing specific learning difficulties experienced by children with dyslexia. In addition, Nelson et al. (2015) reported that working memory and non-verbal ability are predictors of test anxiety in college students with dyslexia. It is evident that the emotional and psychological problems experienced by dyslexic students can have a negative impact on academic success (Heiman & Precel, 2003).

Early evaluation and diagnosis of dyslexia, as well as early interventions are important, so that potential difficulties can be prevented earlier (Schulte-Korne, 2010). Most researchers (Bowyer-Crane et al., 2008; Duff et al., 2014; Galuschka et al., 2014) suggest intervening in phonological awareness and processing deficits associated with dyslexia by delivering phonological and reading interventions. However, there is less research (Pradhan et al., 2017) into positive psychology interventions on improving the psychological difficulties associated with dyslexia (the interventions are discussed in detail in Chapter 7 and Chapter 9).

3.3.3. Adults with dyslexia and the relation to anxiety

There is increasing concern over the levels of stress and the prevalence of mental health problems among university students. A WHO survey (Auerbach et al., 2018) found that one in three first year students had at least one psychological problem such as anxiety, or a mood or substance disorder. Similar estimates have been found by other researchers (Brufaerts et al., 2018; Ibrahim et al., 2013). Dyslexia and the associated psychological problems do not only occur in childhood and adolescence, but also affect adulthood (Carroll & Iles, 2006; Lufi & Darliuk, 2005; Undheim, 2003). Students with dyslexia report high anxiety levels from early education through to university (Maughan & Carroll, 2006; Nelson & Harwood, 2011).

Adults with dyslexia have higher social and general anxiety (Carroll & Iles, 2006; Riddick et al., 1999) and significantly lower self-esteem (Baker & Ireland, 2007; Riddick et al., 1999) than non-dyslexic adults. Adults with dyslexia have claimed that their negative childhood and school experiences have long-lasting effects through until adulthood (Alexander-Passe, 2015; Nalavany et al., 2011). Adults may recall these negative feelings when disclosing dyslexia to their workplace (Denhart, 2008). Hughes and Dawson (1995) found that adults with dyslexia experienced feelings of humiliation, failure, and a lack of understanding through adulthood, which caused severe emotional difficulties.

Whitacker-Sena et al. (2007) suggested that symptoms of anxiety are experienced differently by individuals with specific learning difficulties in childhood and adulthood. Children had more physical symptoms of anxiety, whereas adults showed more cognitive difficulties, particularly attention deficits. Evidence suggests that cognitive and emotional problems related to dyslexia can lead to cognitive impairment with aging (Harada et al., 2013). Boetsch et al. (1996) found that adults with dyslexia reported loss of job satisfaction and were more prone to antisocial behaviour compared to adults without dyslexia, and adults with dyslexia often experienced negative emotions about their work life due to persistent literacy difficulties (de Beer et al., 2014). Alexander-Passe (2015) found that adults with dyslexia often avoided specific jobs or career paths that demanded good literacy and numeracy skills, due to their anxiety that they might be seen as incompetent by their bosses or colleagues.

The emotional impact of growing up with specific learning difficulties can lead adults with specific learning difficulties to drop out of post-secondary education (Hoy et al., 1997). College and university students with specific learning difficulties show higher anxiety levels than their peers without specific learning difficulties, and this can lead to long term effects (Hoy et al., 1997; Gregg et al., 1992). Riddick et al. (1999) reported that college students with dyslexia showed higher levels of anxiety regarding academic and written performance compared to their non-dyslexic peers, but there were no differences in their state or trait anxiety. This finding suggests that anxiety may be limited to academic, rather than general situations for dyslexic university students. Pollak (2005) suggested that the psychological difficulties experienced by dyslexic students may be because they felt different to their non-dyslexic peers, as they experienced academic difficulties, for instance they needed more time to read or to understand text, or to write reports and essays. Nelson and Gregg (2012) found that undergraduate students had higher anxiety and depression levels than those students transitioning from high school, suggesting that the emotional difficulties accompanying dyslexia are still significant at this point of life. It is evident that adults with dyslexia, whether university students or not, present anxiety symptoms. McNulty (2003) stressed the need to focus on the emotional difficulties of dyslexia, while most researchers place more emphasis on the language difficulties that are at the heart of dyslexia.

Chapter 4

4.1 Overview of the research design

The present thesis investigated the psycho-emotional difficulties associated with dyslexia in adolescence and young adulthood. As discussed in Chapter 2, most research has focused on the language-based difficulties associated with dyslexia and little evidence exists on the impact of psychological disorders on dyslexic individuals. Two research questions guided the present thesis. First, what is the impact of stress and anxiety on dyslexic adolescents and dyslexic university students? Three empirical studies were designed to answer this question (see chapters 5, 6, and 8). Second, what is the effectiveness of a positive psychology and a cerebellar based intervention in alleviating anxiety symptoms and enhancing cognitive performance in adolescents including those with dyslexia? Two empirical studies were designed to answer the second research question (see chapters 7 and 9).

As discussed in Chapter 2, there is extensive research on the language and phonological deficits associated with dyslexia (Mathering et al., 2011; Shaywitz et al., 1990; Pennington & Bishop, 2009; Vellutino & Fletcher, 2005), but as pointed out in Chapter 4 there is less evidence on the secondary emotional difficulties associated with dyslexia, particularly in regard to specific domains of anxiety, such as academic anxiety, test anxiety and social anxiety. In addition, psychological and emotional difficulties are less well documented for adolescents and young adults with dyslexia, particularly those pursuing higher education. As discussed in Section 4.3, the number of students at university with mental health problems is increasing, and the number of students with dyslexia and mental health problems is also a concern. However, the University provision for the mental health issues accompanying students with dyslexia may not be sufficient. Research on psychological disorders related to adolescents

(Boyes et al., 2019; Humphrey, 2002; Livingston et al., 2018; Terras et al., 2009) and adults with dyslexia (Baker & Ireland, 2007; Carroll & Iles, 2006; Riddick et al., 1999) has shown that these groups have higher levels of anxiety and lower self-esteem compared to their non-dyslexic peers. Therefore, it was predicted that anxiety would have a negative impact on the psychological well-being of adolescents and young adults in the present research, and it was expected that they would score higher on measures of anxiety (general and specific domains of anxiety) and lower on measures of self-esteem compared to the non-dyslexic participants (Hypothesis 1).

Previous studies (Habib & Naz, 2015; Kempe et al., 2011; Lukasik et al., 2019;) have shown that the cognitive ability of adolescents with dyslexia was severely affected by stress and anxiety, which led to impaired cognitive performance, compared to the performance of adolescents without dyslexia. Thus, it was predicted that anxiety would be associated with cognitive function in adolescents, and have a negative impact on their cognitive performance, particularly for those students with dyslexia (Hypothesis 2).

As noted in Chapter 2, most of the research has focused on exploring interventions related to the language-based difficulties associated with dyslexia, such as phonological deficits and reading and writing difficulties (Galuschka et al., 2014; Snowling et al., 2008; Snowling et al., 2014). However, other psychological interventions, such as mindfulness, may alleviate stress and anxiety (see Chapter 7). As discussed in Section 3.2.1 and Section 3.2.4 stress has a negative impact on cognitive and cerebellar function. Scmahmann (2001) suggested a role of the cerebellum in emotion and affect and stated that some symptoms and characteristics of psychiatric disorders are due to dysfunction in the cerebellum. There is no previous research on cerebellar computer-based training effects on anxiety disorders, but such an intervention could indirectly enhance emotional well-being if the cerebellum could be sufficiently trained.

Two experimental studies (studies 3 and 5) were designed to evaluate the effectiveness of two different psycho-educational interventions in regard to cognitive ability, affected by stress, as well as the psychological well-being of adolescents with and without dyslexia. The first intervention was a mindfulness-based practice (see chapter 7), and the second was a cerebellar-based practice, called Zing (see chapter 9). It was predicted that the mindfulness intervention would decrease the levels of anxiety in highly anxious adolescents, including those with dyslexia, and that the cerebellar-based practice would enhance the psychological well-being along with the cognitive performance of highly anxious students, including those with dyslexia, by training the cerebellum, which is involved in anxiety-related disorders (Hypothesis 3). Table 4.1 presents a summary of the measures used in each empirical study to answer the hypotheses of the thesis.

Table 4.1 Summary of the self-report measures and cognitive tasks used in the thesis

Measures	Number of items	Completed by	Description of measures used
Study 1. Internalising problems of students with dyslexia in Higher Education.			
Social anxiety Scale. Carroll and Iles (2006).	30	Adults	Assesses levels of anxiety in social situations.
Academic anxiety Scale. Carroll and Iles (2006).	30	Adults	Assesses levels of anxiety in academic situations.
Westside Test anxiety Scale. Driscoll (2004).	10	Adults	Assesses levels of anxiety in testing and examination situations.
Rosenberg Self-esteem Scale. Rosenberg (1965).	10	Adults	Assesses mood within the most recent two-week period.
Beck Depression Inventory – II. Beck et al. (1996).	20	Adults	Assesses one’s own feelings of worthiness, and the relation between self-esteem and life outcomes.
Study 2. Internalising problems in dyslexic and non-dyslexic adolescents at risk of school failure.			
State Anxiety Inventory. Spielberger et al. (1970)	20	Adolescents	Assesses a current state of anxiety.
Trait Anxiety Inventory. Spielberger et al. (1970)	20	Adolescents	Assesses general and chronic anxiety symptoms
Westside Test anxiety Scale. Driscoll (2004).	10	Adolescents	Same as in Study 2.

Culture Free Self-esteem Inventory – 3rd edition (CFSEI-3). Battle (2002).	67	Adolescents	Assesses personal traits and characteristics in adolescents. The measure is separated in five subscales.

Study 3. Positive Psychology in School: Effects of a Mindfulness-based intervention on internalising problems and cognitive performance on dyslexic and non-dyslexic adolescents at risk of school failure.

State Anxiety Inventory. Spielberger et al. (1970).	20	Adolescents	Same as in Study 2.
Trait anxiety Inventory. Spielberger et al. (1970).	20	Adolescents	Same as in Study 2.
Westside Test anxiety scale. Driscoll (2004).	10	Adolescents	Same as in Study 2.
Culture Free Self-esteem Inventory – 3rd edition (CFSEI-3). Battle (2002).	67	Adolescents	Same as in Study 2.
Mindfulness Attention Awareness Scale-Adolescents. (Brown et al. (2011)	15	Adolescents	Assesses mindfulness in children and adolescents.
Backwards Digit Span test. Fawcett and Nicolson, 2004.	1	Adolescents	Assesses verbal working memory.
Verbal Fluency. Fawcett and Nicolson, 2004.	1	Adolescents	Assesses memory retrieval fluency.

Study 4. The link between stress and cognitive performance in dyslexic and non-dyslexic adolescents at risk of school failure.

DST-S. Fawcett and Nicolson, 2004.	12	Adolescents	Assesses literacy skills, phonological awareness, memory ability, motor skills and balance.
Declarative tests. Nicolson, 2010.	2	Adolescents	Assess declarative memory and declarative learning.
Procedural tests. Nicolson, 2010.	2	Adolescents	Assess procedural memory and procedural learning.
State Anxiety Inventory. Spielberger et al. (1970)	20	Adolescents	Same as in Study 2.
Trait Anxiety Inventory. Spielberger et al. (1970)	20	Adolescents	Same as in Study 2.

Study 5. Evaluation of a 'cerebellar challenge' intervention in dyslexic and non-dyslexic adolescents at risk of school failure

DST-S. Fawcett and Nicolson, 2004.	12	Adolescents	Same as in Study 4.
Declarative tests. Nicolson, 2010.	2	Adolescents	Same as in Study 4.
Procedural tests. Nicolson, 2010.	2	Adolescents	Same as in Study 4.
State Anxiety Inventory. Spielberger et al. (1970)	20	Adolescents	Same as in Study 2.
Trait Anxiety Inventory. Spielberger et al. (1970)	20	Adolescents	Same as in Study 2.

4.2 Thesis scope and overview

The present thesis aimed to investigate, first, the effects of psychological disorders, particularly stress and anxiety, on adolescents and university students with dyslexia, and second, the effectiveness of psycho-educational interventions for adolescents with anxiety, including those with dyslexia. The core objective of the present thesis was to investigate the impact of different domains of anxiety (general, academic and test anxiety) on dyslexic adolescents and young adults who attend university, and the effectiveness of two psycho-educational interventions in regard to reducing anxiety and enhancing academic performance. Self-report psychological measures and cognitive tasks were used in the empirical studies to test the two main hypotheses of the present thesis. The following Chapters 5 - 9 describe the design, methodology and results of the empirical studies. Chapter 10 presents the general discussion of the thesis, based on the research findings, along with the conclusions and directions for future research.

Chapter 5

Study 1: Internalising problems of dyslexic students in Higher Education

5.1 Introduction

This chapter presents the first empirical study that aimed to explore the internalising problems of university students, particularly those with dyslexia, as there is growing evidence that students with dyslexia may still be at greater risk of internalising problems compared to non-dyslexic students.

Mental health problems in the university population have been increasing in recent years, with depression and anxiety being the most prevalent mental disorders in university students. It has been estimated that 15.6% of undergraduate students report anxiety and depressive symptoms, and for graduate students the figure is 13% (Eisenberg et al., 2007). Depression and anxiety have been shown to be risk factors for poor test and examination performance in university students (Andrews & Wilding, 2004), and mental health problems are negatively associated with academic performance and academic self-efficacy (Brachney & Karabenick, 1995; Haines et al., 1996). A UK mental health student survey by Macaskill (2012) found that the levels of anxiety and depression increased in second year students, and although they reduced in the third year, they remained quite high.

A WHO study (Auerbach et al., 2018) explored the linkage between mental health probability and several demographic variables, with female gender, older age, and secondary school being amongst the risk factors, but found only weak differences in outcome, concluding that mental health risks occurred throughout student populations. It is therefore concerning that one specific group of students (i.e., dyslexic students) have been found to suffer from heightened stress and low self-esteem compared to other students (Burden, 2008; Ghisi et al., 2016; Jordan et al., 2014; Riddick et al., 1999;). Hales (2001) also reported that adults with specific learning difficulties show heightened anxiety, low self-confidence, and low emotional stability.

Boetsch et al. (1996) suggested that socioemotional difficulties in dyslexic students are quite common, including depressive symptoms, behavioural problems, attention difficulties, low self-esteem and low self-confidence, and feelings of hopelessness with regard to academic difficulties. Nelson and Harwood (2011) supported the view that stress and anxiety are psychological difficulties experienced by all students at some point during their education, and that these difficulties have negative effects on them; even gifted students have been found to suffer with anxiety (Zeidner & Schleyer, 1998). Although it is common for all students to experience some anxiety in academic situations, levels of anxiety are often higher for students with specific learning difficulties compared to their non-dyslexic peers (Carroll & Iles, 2006).

Research into anxiety and depressive symptoms in adults with dyslexia is limited in the literature. Carroll & Iles (2006) conducted a study with 32 university students with dyslexia and without dyslexia who completed a number of questionnaires including state anxiety, social, academic and appearance anxiety. The results indicated that the dyslexic students showed higher levels in regard to state anxiety, as well as to academic and social anxiety. Academic anxiety is defined as ‘a state of distress induced by a student’s appraisal of excessive academic demands’ (Lee & Larson, 2000, p. 249). Jordan et al. (2014) found that university undergraduate dyslexic students showed higher levels of mathematics anxiety relative to non-dyslexic students, but they did not find any differences in the levels of general anxiety. Heiman and Precel (2003) indicated higher levels of anxiety in post-secondary students with specific learning difficulties compared to typically achieving students. Adults with specific learning difficulties are also twice as likely to experience high levels of depression, anxiety, and distress relative to adults without specific learning difficulties (Wilson et al., 2009).

Social anxiety has been found to affect students' performance in social as well as academic situations (Topham & Russell, 2012). According to Schlenker and Leary (1982, p.642), social anxiety is caused by 'the prospect or presence of interpersonal evaluation in real or imagined social settings'. It is a common characteristic among individuals to feel worried about what other individuals think of them (Leary & Kovalski, 1995). Previous research suggests that dyslexic students experience higher levels of social and general anxiety relative to their non-dyslexic peers (Jensen et al., 1999; Riddick et al., 1999; Carroll & Iles, 2006), possibly because the academic situations are also part of the university students' general social interactions. Therefore, academic anxiety generalises to aspects of anxiety in social settings too. For individuals with dyslexia, participation in social situations might be challenging and stressful due to a lack of confidence and self-esteem in group situations, which can result in social withdrawal (Terras et al., 2009).

Previous research has shown that test anxiety is more prevalent among students with specific learning difficulties than typically achieving students (Nelson et al., 2015). Nelson and Harwood (2011) found that test anxiety was higher in college students with specific learning difficulties compared to typically achieving students. Students with specific learning difficulties had less test-taking skills than typically achieving students (Kirby et al., 2008). Ackerman and Heggestad (1997) reported that the cognitive skills of students with reading difficulties had a negative correlation with test anxiety. Naveh-Benjamin et al. (1981) also supported the view that test anxiety is caused by a lack of cognitive skills. Due to low cognitive functional skills such as working memory and short-term memory, which are necessary skills for optimal performance in exams, Nelson et al. (2015) reported that tests and examinations are more stressful situations for learning-disabled students compared to non-learning-disabled students.

Gaudry and Spielberger (1971) found that high levels of test anxiety are a risk factor for poor academic performance for university students. Previous studies (Nunez-Pena et al., 2016; Putwain & Daly, 2014) on gender differences in regard to test anxiety have reported higher test anxiety in females compared to males, possibly because males perceive the testing situation as a challenge, and therefore they are less anxious, whereas females are more likely to perceive the testing situation as a threat, and therefore they are more anxious (Liebert & Morris, 1967). Female students showed higher levels of test anxiety compared to males in both undergraduate and postgraduate levels of study (Chapel et al., 2005).

Previous research suggests that there is a link between dyslexia, anxiety, and low self-esteem (Riddick et al., 1999). Self-esteem refers to one’s evaluation of their personal worth (Rosenberg, 1965; Orth & Robins, 2014). Low self-esteem is a potential risk factor in the development of psychological problems, such as anxiety and depression (Beck et al., 2001; Millings et al., 2012). High levels of self-esteem are associated with better psychological well-being and positive life consequences, whereas low levels of self-esteem are associated with psychological problems, particularly anxiety and low motivation (Harter, 1990; Morley & Moran, 2011; O’Brien et al., 2006).

Ghisi et al. (2016) investigated the psychological and psychopathological problems of 28 university students with dyslexia, compared to non-dyslexic students, on a range of measures including self-esteem, resilience, depression, and behavioural problems. The results indicated that the dyslexic students reported lower self-esteem, higher depression, and higher levels of social problems compared to the non-dyslexic students; however, no differences were found with regard to resilience skills between the two groups.

Previous research has reported that undergraduate students with dyslexia have lower levels of self-esteem and higher levels of anxiety compared to their non-dyslexic peers (Carroll & Iles, 2006; Riddick et al., 1999). One recent Italian study (Scorza et al., 2018) found heightened socioemotional problems for male dyslexic students (compared with male non-dyslexic students) but no difference among female students. In contrast, Bruck (1985) found that adjustment problems were more evident in women than men. Adults with dyslexia have also shown more social and behavioural problems than non-dyslexic adults (Rutter, 2000; Wiener & Scneider, 2002), along with low levels of self-esteem and negative emotions toward themselves (Carroll & Iles, 2006; Riddick et al., 1999). Hales (2001) reported that adults with specific learning difficulties showed higher levels of anxiety and lower levels of self-confidence and self-esteem compared to non-learning-disabled adults. Carawan et al. (2015) reported that individuals with dyslexia, who had negative emotional experiences, tended to show low self-esteem. The authors suggested that negative social and emotional experiences contribute to low self-esteem.

The literature suggests that academic achievement is influenced by self-esteem (Aryana, 2010; Lawrence, 2000). Strong associations have been reported between self-esteem and academic success in university students (Arshad et al., 2015). Riddick et al. (1999) investigated self-esteem and anxiety in 16 adults with dyslexia and 16 without dyslexia and found that the dyslexic adults showed significantly lower self-esteem; however, no differences were found in their anxiety levels. Carawan et al. (2015) compared the emotional experiences of dyslexic and non-dyslexic adults and found that dyslexic adults reported significantly lower self-esteem relative to non-dyslexic adults. The dyslexic adults also reported that family support had a positive impact on increasing their self-esteem and reducing the effects of negative experiences.

McNulty (2003) reported that in an interview study with 12 dyslexic adults, it was found that all of them presented self-esteem difficulties by school age, as they experienced frequent school failures, and their school years were described as traumatic. In another interview study in the Netherlands with 27 dyslexic adults, Hellendoor and Ruijssenaars (2000) found that participants mostly had negative experiences in school and thus negative school memories. However, they described their family as being supportive and positive towards them, which shows that individuals with dyslexia may possibly have lower self-esteem with regard to academic and school performance rather than in their general and social life. Other research also supports the view that positive relationships with family can have a positive impact on self-esteem of dyslexic adults (Hellendoorn & Ruijssenaars, 2000; McNulty, 2003).

Previous research has reported significant associations between academic failures, self-esteem, and anxiety, particularly in individuals with dyslexia (Humphrey & Mullins, 2004; Riddick et al., 1999). Alexander-Passe (2015) found that low self-esteem in adults with dyslexia is not only associated with academic or emotional difficulties, but also with interpersonal and communicational difficulties. Butkowsky and Willows (1980) found differences in attribution styles between poor and good readers. Poor readers more frequently attributed failure to themselves, and success to luck. The authors also reported that the poor readers had negative emotions about themselves in relation to both reading and more general tasks, such as drawing. McNulty (2003) reported that adults with specific learning difficulties had long-lasting low self-esteem problems from childhood to adulthood. Likewise, Hellendoorn and Ruijssenaars (2000) found that adults with specific learning difficulties had had self-esteem and emotional problems since their childhood, which made them feel insecure in their adult life.

On the other hand, Lewandowski and Arcangelo (1994) reported no differences on the Tennessee Self-concept Scale between groups with and without learning difficulties. However, not all the participants with specific learning difficulties were in college. Therefore, the authors suggested that self-esteem might decrease in individuals with specific learning difficulties once they leave behind the demands of academic life. The authors also added that some participants with specific learning difficulties scored within the clinical range on the Tennessee scale, suggesting that there were individuals with specific learning difficulties who scored low on self-esteem, but they were fewer than expected.

Depression has also been found to positively correlate with specific learning difficulties in children, even from the young age of 8-years-old, as well as in adolescents, and high school students (Dalley et al., 1992). Depression has been found to lead to task-specific impairments in information processing (Hubbard et al., 2016; Lau & Waters, 2017; Schweizer et al., 2019), with a proposal that common mechanisms may be involved in the 'internalising disorders' of depression and anxiety (Hankin et al., 2016). Although there is research that has investigated depressive symptoms in children and adolescents with specific learning difficulties, the literature is limited in regard to adults with specific learning difficulties, particularly in students in higher education. A qualitative study, by Shesell and Reiff (1999), found that 11 out of 14 adults, aged between 26 and 60 years of age, related depression to their specific learning difficulties. Gender can be an important factor in psychological problems, especially in depression, as females with specific learning difficulties have reported higher levels of depression compared to females without specific learning difficulties (Alexander-Passe, 2009; Heath & Ross, 2000; Hoy et al., 1997). Knivsberg and Andreassen (2008) reported a high rate of anxiety and depression in severely dyslexic individuals.

Moreover, an interview study with dyslexic adults by Alexander-Passe (2015) showed that all the participants had suffered with depression throughout their lives, since its onset in either childhood or adolescence. The most important theme that emerged from the qualitative data was that stress, with regard to academic or school performance, led to severe symptoms of depression and even to self-harm and suicidal ideation. In contrast, there is a number of studies that have reported no differences in depression levels between dyslexic and non-dyslexic students, or between students with and without specific learning difficulties (Boetsch et al., 1996; Ghisi et al., 2016; Maughan et al., 2003; Nelson & Liebel, 2018). The different results of these studies (Boetsch et al., 1996; Ghisi et al., 2016; Maughan, et al., 2003; Nelson & Liebel, 2018) have been attributed to different factors, such as the family environment, social and peer support, the severity of dyslexia, as well as resilience skills. One US study (Nelson & Liebel, 2018) did not report any differences between students with and without dyslexia in regard to depression and anxiety and attributed this result to socially desirable responding in the dyslexic group.

There is less emphasis on mental health problems, low self-esteem, and the different domains of anxiety in dyslexic students (Boetsch et al., 1996); or on differences between undergraduate and postgraduate students with dyslexia in relation to mental health problems. Previous studies have focused on the cognitive aspects of dyslexia (Snowling, 2005; Snowling, 2013; Van Daal & Van Der Leij, 1999) rather than on its psychological effects. Although the relationship between specific learning difficulties and psychological problems has been investigated, it is difficult to interpret the results in terms of dyslexia alone, due to the heterogeneity of large samples with general learning difficulties (Boetsch et al., 1996). Furthermore, research on emotional and psychological problems associated with dyslexia has been centred more on school-aged children and adolescents than on university students (Carroll & Iles, 2006).

Evidence suggests that different factors cause anxiety in undergraduate and graduate students. For instance, among the factors that cause stress and anxiety in undergraduate students is the transition from school to university, and therefore to young adulthood (Hicks & Heastie, 2008). Some of the stressors are also associated with independent living away from family, new peer relationships, as well as more academic demands and academic expectations (Pierceall & Keim, 2007; Stallman, 2008). Furthermore, financial issues, such as fees and university loans, may cause anxiety, as well as the large number of students in university classes, which makes it difficult to get to know the tutor or the other students, may also be a stressor (Hicks & Heastie, 2008; Scanlon et al., 2010). One study found that undergraduate students who experienced depression could not make decisions easily about their future career options (Saunders et al., 2000). The factors that cause anxiety in graduate students include financial issues, future career worries, and a lack of family or academic support (Hudd et al., 2000; Mazzola et al., 2011), as well as an imbalance between work, personal and social life (Kausar, 2010).

The American College Health Association (2014) reported that graduate students did not perceive academic achievements or academic success as a major cause of stress compared to undergraduate students (American College Health Association, 2014). The differences in stress levels between undergraduate and graduate students have been attributed to the different coping strategies used by the two groups. On the one hand, undergraduate students tend to use more avoidant coping, for instance risky behaviours, such as drinking or smoking, which can have a negative impact on anxiety disorders (Labrie et al., 2012; Pettit & DeBarr, 2011). On the other hand, graduate students tend to use more active behaviour, such as physical exercise or peer and social support, to deal with stress and anxiety (Hoalahan & Moos, 1987).

Previous research (Carroll & Iles, 2006; Jordan et al., 2014; Riddick et al., 1999) has found that students with specific learning difficulties in higher education showed higher levels of anxiety and depression compared to students without specific learning difficulties. Students with specific learning difficulties also showed lower self-esteem due to lack of self-confidence both in academic and social situations (Riddick et al., 1999). Likewise, dyslexic university students reported higher levels of academic anxiety than typically achieving students (Carroll & Iles, 2006). This can probably be explained by reading and writing problems, difficulties with organization and time management skills (Mortimore & Crozier, 2006), or difficulties with working memory and concentration (Riddick et al., 1999). A meta-analysis by Nelson and Hartwood (2011) investigated the association between specific learning difficulties and anxiety and found a positive relationship between them in most studies (95%). Owens et al. (2012) found that anxiety, worry and depression have been positively linked to poor working memory and poor academic performance in typically achieving students. Owens et al. found that the higher the anxiety and depression levels, the higher the worry about academic tasks.

Females are at greater risk of psychological and mental health problems compared to males, even from childhood (Hankin et al., 1998; Lewinsohn et al., 1998; Nolen-Hoeksema, 1990). Research suggests that anxiety remains stable in adolescence until early adulthood for females, while it changes for males throughout this time (Craske, 2003). Different psychosocial factors have been associated with anxiety disorders and with being a female, such as environmental stress, low self-esteem, coping skills, and social functioning (Benjamin et al., 1990; Lewinsohn et al., 1998). Lewinsohn et al. (1998) suggested that controlling for psychosocial factors could possibly reduce the relationship between anxiety disorders and females. Research suggests that gender differences in internalising problems might stem from biological, physical, or environmental factors (Lewinsohn et al., 1998; Rutter, 2007; Zahn-Waxler et al., 2008;).

Gender differences in anxiety disorders might also be attributed to different experiences and social roles between males and females (Lewinsohn et al., 1998).

Depression has been found to have a greater preponderance in women compared to men; studies have shown that females are twice as likely as males to present with depressive symptoms from adolescence onwards, and these symptoms often increase sharply until adulthood, whereas men show fewer depressive symptoms, which even decrease with age (Nolen-Hoeksema, 2001; Weissman et al., 1996). Coping strategies is a factor that could account for the gender differences in anxiety and depression. Coping refers to cognitive and behavioural strategies used by individuals to respond to stress or to manage negative feelings and pressures (Lazarus & Folkman, 1984). There are two categories of coping strategies: problem focused, and emotion focused coping strategies (Compas et al., 1993; Lazarus & Folkman 1984). Problem focused coping refers to cognitive and behavioural strategies that are used to respond to stressors, while emotion focused coping refers to emotional responses to stressors, which are less effective (Kelly et al., 2008). Previous researchers have found that women use emotion focused coping strategies as a response to stressful situations, whereas men use more problem focused coping strategies to respond to stress, which seems to be more effective (Endler & Parker, 1990; Kelly et al., 2008). Cohen (2002) reported that women who use emotion-based coping strategies to manage stressful situations show more anxiety and depressive symptoms compared to women who use these strategies less often.

There are gender differences in regard to self-esteem, with males reporting higher levels compared to females (Bleidorn et al., 2016; Costa et al., 2001; Shaw et al., 2010). Previous studies have suggested that higher levels of self-esteem in males have their onset in adolescence, and last until middle adulthood, after which time the gender gap in self-esteem starts to decrease until late adulthood (Orth & Robins, 2014; Zeigler-Hill & Myers, 2012).

Gender differences in relation to self-esteem can be due to biological factors or cultural gender roles (Costa et al., 2001; Kling et al., 1999). Another explanation of the gender gap is that masculinity is related to self-confidence, which is a traditional stereotypical trait of males (Kling et al., 1999). Another explanation is that females place more emphasis on appearance and physical attractiveness because the society displays this norm for females, which has a negative impact on their self-esteem (Bleidorn et al., 2016).

Although there is extensive research on gender differences in regard to psychological problems in the general population, research is scarce concerning gender differences in the dyslexic population. A few studies have examined gender differences in regard to psychological problems in individuals with dyslexia alone, mostly among children and adolescents, but not among adults. Heath and Ross (2000) found that girls with specific learning difficulties were at greater risk of presenting with psychological and mental health problems than boys, and girls reported higher levels of depression relative to boys. Nelson and Gregg (2012) assessed anxiety and depression in adolescents and college students with either a diagnosis of dyslexia or ADHD and found that there were no differences either in anxiety or in depression levels between the two groups; however, there was a significant difference in terms of gender, with the dyslexic females presenting higher levels of depression and anxiety compared to the dyslexic males. Other research also supports the view that females with dyslexia show higher rates of anxiety disorders relative to males (Carroll et al., 2005).

5.2 Rationale and aim of Study 1

The onset of anxiety disorders usually occurs in childhood and adolescence (Van Ameringen et al., 2014) with the implications often persisting into adulthood (Clark et al., 2007). Students with specific learning difficulties in Higher Education show higher levels of anxiety and depression, as well as lower levels of self-esteem than typically achieving students

(Carroll & Iles, 2006; Riddick et al., 1999). However, there is limited research investigating dyslexia alone. Previous studies (Carroll & Iles, 2006; Ghisi et al., 2016; Jordan et al., 2014; Riddick et al., 1999) limited their focus on exploring the relationship between specific learning difficulties or dyslexia and anxiety disorders in undergraduate students only. There is also limited research on postgraduate students with dyslexia and the relationship with mental health problems (Richardson & Wydell, 2003). The literature is also scarce on mental health problems of typically achieving postgraduate students compared to undergraduates (Chapel et al., 2005; Eisenberg et al., 2007). The results of these studies revealed that the undergraduate students scored higher on anxiety, depression and stress measures compared to postgraduate students.

Therefore, there is a lack of recent information in UK universities, mixed findings in other countries, and absence of any evidence regarding possible differences between undergraduate and postgraduate students. Study 1 contributes to the body of research by including and examining mental health problems in postgraduate students with dyslexia, in tandem with undergraduates, and comparing the results to non-dyslexic students.

The aim of study 1 was to investigate the internalising problems of students with dyslexia at university compared to students without dyslexia, and to identify the most prevalent domains of anxiety. The focus of this study lies in three different domains of anxiety: namely, academic anxiety, social anxiety, and test anxiety. Previous research on test anxiety has mainly focused on children and adolescents with specific learning difficulties (Lufi et al., 2004; Peleg, 2009; Swanson & Howell, 1996) but not on students in Higher Education.

Study 1 focused on anxiety, depression, and self-esteem in dyslexic students in Higher Education, based on the results of a meta-analysis study (Klassen et al., 2011) for two reasons; first, because anxiety and depression were previously studied together and were found to have a high correlation with each other in childhood as well as in adulthood, in dyslexic and typically achieving individuals (Klassen et al., 2011; Miller et al., 2005; Mugnaini et al., 2009; van Lang et al., 2006;) anxiety, depression, and self-esteem have also been studied together (Alexander-Passe, 2006), however there are small number of studies; second, because there is a relatively limited research on exploring different areas of anxiety, along with depression and self-esteem, in Higher Education students with dyslexia.

5.3 Developing the hypotheses

One of the aims of this study was to examine whether anxiety and depressive symptoms are prevalent in adult dyslexic students. Based on the previous literature discussed in the Introduction (Chapter 4), the evidence suggests that adult students with dyslexia experience more anxiety and depressive symptoms compared to students without dyslexia. Study 1 explored whether anxiety stems from academic difficulties only, whether it extends to other areas and settings, such as in social situations or interactions with peers; or whether it mostly occurs during anxiety-provoking situations, such as during exams.

Considering the depressive symptoms of dyslexic adult students, there is research suggesting that, in most cases, anxiety is experienced in tandem with depression in dyslexic students, during childhood and adulthood. Some researchers (Alexander-Passe, 2008; Undheim, 2003) suggest that depression stems from hopelessness feelings, due to severe academic difficulties that many dyslexic students face either at school or at university, as well as due to the luck of support they receive regarding their academic difficulties and mental health issues. Therefore, a significant question is whether students with dyslexia in Higher Education have higher levels of anxiety (particularly in which domain of anxiety) and depression compared to typically achieving students. Based on previous research (Alexander-Passe, 2008; Carroll & Iles, 2006; Ghisi, 2016; Humphrey & Mullins, 2004), the hypotheses for the present study were developed to compare psychological problems, including anxiety, depression, and self-esteem, between dyslexic and non-dyslexic university students.

Considering the self-esteem symptoms of dyslexic university students, there is evidence suggesting that dyslexic students have low self-esteem because they find it harder to keep up with academic work, and thus they feel inferior to their non-dyslexic peers (Alexander-Passe, 2008). Based on previous research (Humphrey & Mullins, 2004; Riddick et al., 1999), the hypothesis developed for this study was that adult students with dyslexia would report lower levels of self-esteem than students without dyslexia.

5.3.1 Hypotheses

The following hypotheses were reported in Study 1:

Based on Carroll and Ile's (2006) finding (see section 5.1), it was expected that students with dyslexia in Study 1 would score higher on academic anxiety compared to non-dyslexic students.

- Hypothesis 1: Dyslexic students will show higher levels of academic anxiety, on the Carroll & Ile Academic Anxiety Scale, compared to non-dyslexic students.

Based on previous literature (Carroll and Iles, 2006; Jensen et al., 1999; Riddick et al., 1999) (see Section 5.1), which has demonstrated that students with dyslexia showed higher levels of social anxiety compared to non-dyslexic students, hypothesis 2 was:

- Hypothesis 2: Dyslexic students will show higher levels of social anxiety, on the Carroll & Ile Social Anxiety Scale, compared to non-dyslexic students.

Based on previous literature (Ackerman and Heggestad, 1997; Nelson and Harwood, 2011; Nelson et al., 2015) (see section 5.1), which has demonstrated that students with dyslexia showed higher levels of test anxiety compared to non-dyslexic students, hypothesis 3 was:

- Hypothesis 3: Dyslexic students will show higher levels of test anxiety, on the Westside Test Anxiety Scale, compared to non-dyslexic students.

Based on previous literature (Alexander-Passe, 2015; Ghisi et al., 2016; Knivsberg & Andreassen, 2008) (see Section 5.1), which has demonstrated that students with dyslexia showed higher levels of depression compared to non-dyslexic students, hypothesis 4 was:

- Hypothesis 4: Dyslexic students will show higher levels of depression, on the Beck Depression Inventory-II, compared to non-dyslexic students.

Based on previous literature (Ghisi et al., 2016; Hales, 2001; McNulty, 2003; Riddick et al., 1999) (see section 5.1), which has demonstrated that students with dyslexia showed lower levels of self-esteem compared to non-dyslexic students, hypothesis 5 was:

- Hypothesis 5: Dyslexic students will show lower levels of self-esteem, on the Rosenberg Self-Esteem Scale, compared to non-dyslexic students.

It was not expected that any differences would be found between undergraduate and postgraduate students, as there was no literature available suggesting that there are differences between the two groups. However, it was of interest in Study 1 to test for potential differences in psychological disorders between typically achieving undergraduate and postgraduate students, as well as in dyslexic students.

Due to the lack of research into gender differences in the dyslexic population, no hypotheses were made about gender effects in the dyslexic population. Evidence suggests that females with specific learning difficulties are more prone to anxiety disorders compared to males with specific learning difficulties (Carroll et al., 2005; Hales, 1994; Lewinsohn et al., 1998; Nelson & Gregg, 2012) however, that evidence has been related to general learning difficulties and not to dyslexia alone.

However, there is evidence suggesting that there are gender differences in psychological disorders in the general population, with females sometimes reporting twice as much anxiety and depression as males (Lewinsohn et al., 1998; Shear et al., 2000; Weinstock, 1999). The same result has also been found for test anxiety. Gender differences have been found on self-report test anxiety measures, when female students have reported higher levels of anxiety compared to male students (McDonald, 2001; Putwain & Daly, 2014; Zeidner & Schleyer, 1999). Therefore, the following hypotheses were proposed about gender differences:

- Hypothesis 6: Females will show higher levels in all the anxiety measures compared to males.
- Hypothesis 7: Females will show higher levels in the depression measure compared to males.

5.4 Methodology

5.4.1 Ethical considerations

Study 1 received ethical approval from the Department of Psychology Research Ethics committee in accordance with the University of Sheffield's Research Ethics Approval Procedure. Informed consent was obtained from all the participants. Since the study was an online one, the consent form was at the beginning, where participants had to declare that they were willing to take part in the study, and then they continued to the self-report questionnaires if they wanted so. It was made clear from the beginning that the participants could withdraw from the study at any stage without giving any reason for doing so. The principles of consent, withdrawal, debriefing, confidentiality, anonymity, integrity, impartiality, and respect were always adhered to in Study 1 (Code of Ethics and Conduct, BPS, August 2009). Participants were assigned a unique code, so that the data were anonymous.

5.4.2 Participants

Two hundred and eighty-two undergraduate and postgraduate students, from the University of Sheffield, participated in Study 1. The initial total number of students who consented to take part in the study was 376 but 85 students did not complete the study to the end, and therefore they were excluded from the study. In addition, nine participants were removed from the study because they were over 35 years old. As most of the students who participated in Study 1 were below 35 years of age and based on previous research with adult students (Riddick et al., 1999), only those participants who were below 35 years were included in the study, so that an age factor would not affect the data distribution and analysis of the study. Although it is not possible to identify why the students did not complete the study to the end, it is likely that the length of the study demotivated the students to complete all the measures, and because the study was significantly text heavy, which is particularly aversive for dyslexic students.

The sample consisted of 282 university students; 57% of the participants (N=161) were undergraduate students (mean age 20.87 years), and 43 % (N=121) were postgraduate students (mean age 26.77 years) (Masters and PhD).

For the dyslexic group, the inclusion criterion was a diagnosis of dyslexia. For the non-dyslexic group, the inclusion criterion was that the students had not previously been diagnosed with dyslexia or other learning difficulties.

Participants were unpaid volunteers, contacted via e-mail from the University of Sheffield volunteers list for students. The dyslexic participants were also recruited via e-mail sent from the University of Sheffield Disability and Dyslexia Support Service. Of the participants, 122 were dyslexic students who had a previous diagnosis of dyslexia and were all registered with the University Disability and Dyslexia Support Service (DDSS). Of those students, 80 (86%) declared that they were receiving support for dyslexia from the DDSS. Seventy students with dyslexia (64%) had a diagnosis of an anxiety disorder, and 63 (52%) of those students were receiving support for anxiety. The dyslexic students ranged from 18 to 35 years (mean age 23.23 years). There were 68 males and 54 females in the dyslexia group. The non-dyslexic group included 160 students who had never been diagnosed with any learning difficulties, including dyslexia. Of those students, 52 (33%) had a diagnosis of an anxiety disorder, and 47 (83%) were receiving support for anxiety. The non-dyslexic students ranged from 18 to 35 years (mean age 23.51 years). There were 62 males and 98 female students in the non-dyslexic group.

5.4.3 Rationale for the measures used

To assess different areas of anxiety, depressive symptoms, and self-esteem for students in Higher Education, several self-report measures were administered in Study 1. Established measures that have previously been used in research and were indicated to be reliable were used. It was important that these measures had previously been used either with a dyslexic population or with students in higher education, so that the results of this study could be compared to results of previous similar studies.

To explore potential differences in social and academic anxiety between dyslexic and non-dyslexic students, the Social Anxiety Scale, and the Academic Anxiety Scale constructed by Iles (2006) were included. These measures were previously used by Carroll and Iles (2006) to investigate social and academic anxiety between dyslexic and non-dyslexic students in higher education. The results of Carroll and Iles showed that students with dyslexia scored higher on social and academic anxiety compared to non-dyslexic students. The scale was considered suitable for Study 1 as there are not many measures that explore only academic anxiety symptoms. Most available measures assess general anxiety, with only some aspects of the measure referring to academic difficulties or achievements.

The Westside Test Anxiety Scale (WTAS) has been used in previous studies with students in Higher Education (Driscoll et al., 2009) as well as with students with dyslexia. Uwakwe and Akanbi (2017) used the scale to examine differences between secondary school students with and without learning disabilities, and to study the effectiveness of Dialectical Behavior Therapy in reducing test anxiety. Although there were no differences in Uwake and Akanbi (2017) study between students with and without learning disabilities, they found that students who participated in the DBT had reduced anxiety levels after the intervention. The Westside Test Anxiety Scale was chosen for Study 1, because it is a measure of test anxiety focussing on the impairment and behavioural aspects of anxiety, rather than on physiological over-arousal symptoms, and because it assesses cognitions, such as worry, and performance impairments during examinations.

The Beck Depression Inventory (BDI-II) was chosen for Study 1 because it is a well-established measure for assessing depression (Beck et al., 1996). The BDI-II assesses a number of different symptoms of depression such as agitation, concentration difficulty and loss of energy. The BDI-II has previously been used to assess the severity of depression in diagnosed patients, and in normal populations (Archer et al., 1991; Piotrowski & Keller, 1992). The BDI-II has previously been used both with a university sample (Makhubela, 2016) as well as with dyslexic samples (Alexander-Passe, 2015; Ghisi et al., 2006) and samples with specific learning difficulties (Hoy et al., 1997; Nelson & Gregg, 2012). Ghisi et al. (2006) used the BDI-II to explore differences between dyslexic and control students in higher education.

The Rosenberg Self-esteem Scale (Rosenberg, 1965*)* was used in Study 1 because it measured global feelings of self-esteem as well as one's feelings of self-worth and self-acceptance. The scale has also been used in previous research with university students (Ghisi et al., 2016) and it is mainly used for research and academic purposes only, and not as a diagnostic measure for psychological states (Rosenberg, 1965). Ghisi et al. (2016) used the scale in a study to examine potential differences in self-esteem between dyslexic and control students in higher education.

5.4.4 Materials and Apparatus

The measures in the present study were not used as diagnostic tools for clinical anxiety disorders or clinical depression, but rather they were used to identify and describe the symptoms of anxiety and depression. The following self-report measures were administered in Study 1.

Social and academic anxiety scale

Social and academic anxiety was measured using two separate questionnaires devised by Carroll and Iles (2006), who developed a questionnaire with three subscales to investigate different areas of anxiety in a dyslexic population- namely social, academic and appearance anxiety. Carroll and Ile's questions were partly based on two established questionnaires: the IPAT self-analysis form (Cattell, 1957) and the Screen for Child Anxiety-Related Emotional Disorders (SCARED; Birmaher et al., 1997). The questionnaires were valid and reliable in previous research studies (Carroll & Iles, 2006; Muris et al., 1998; Jastrowski Mano et al., 2012).

Carroll and Ile's (2006) measure comprised 90 items: 30 items on each of the three separate areas of anxiety; social, academic, and appearance anxiety. For the purposes of the current study, which was investigating the differences between dyslexic and non-dyslexic students in social and academic anxiety, two of the three questionnaires were used – the social anxiety and the academic anxiety questionnaire. Therefore, the students in this study answered a total of 60 items, with 30 items in each measure.

Anxiety was measured in two areas to determine whether dyslexic students were particularly anxious in regard to academic challenges, or whether the anxiety symptoms expand to other areas of their lives, such as in social situations. For each question of the social and academic anxiety scale, the participants had three options which were scored on a scale of 1-3, with 3 representing the highest level of anxiety. The total score is calculated by summing the scores.

According to Carroll and Iles (2006), both the social and academic anxiety scales have good internal consistency with a Cronbach alpha coefficient reported of .870 for social anxiety, and .903 for academic anxiety. Analysis for internal consistency was also carried out for both Social and Academic anxiety scales for the sample in Study 1. Cronbach's α was .919 for social anxiety, and .922 for academic anxiety, both of which show good reliability.

Westside Test Anxiety Scale

The Westside Test Anxiety Scale comprised 10-items, was designed by Driscoll (2004) to identify students with a test anxiety impairment. Items cover self-assessed anxiety levels and cognitions that can hinder performance during an exam. Items assessing physiological stress were not included in the scale, as they were considered as weak indicators of performance deficits (Driscoll, 2007). The scale includes six items, similar to those in the Alpert-Haber Debilitative Anxiety Scale (1960), assessing incapacity (such as performance impairment, low memory skills and poor cognitive processing), and four items assessing worry and dread (such as fear of failure and catastrophizing) which interfere with concentration during an examination (Driscoll, 2007; Cassady & Johnson, 2002). Items assessing incapacity include: 'I lose focus on important exams, and I cannot remember material that I knew before the exam'. Items assessing worry include: ‘During important exams I feel that I am doing awful, or that I may fail’.

Scores are on a five-point Likert scale ranging from 1 (never true) indicating no anxiety to 5 (always true) indicating panic. According to Driscoll (2007), a score of 3.5 – 3.9 indicates high anxiety, while a score of 4.0 – 5.0 indicates extreme anxiety. Lower scores than 3.5 indicate: 3.0 – 3.4 moderately high anxiety, 2.6 – 2.9 high normal test anxiety, 2.0 – 2.5 normal or average test anxiety, and 1.0 – 1.9 comfortably low-test anxiety. A score is calculated of the sum of 10 questions divided by 10. The Westside Scale has been used to measure test anxiety among diverse student populations (Driscoll, 2007), and is a reliable and valid measure of assessing test – anxiety levels. According to Onyeizugbo (2010) the Westside Test Anxiety scale has good internal consistency with a Cronbach alpha coefficient reported of .78. In the current study, Cronbach’s α was .911, which indicates good internal consistency for the sample in Study 1.

Beck Depression Inventory – II

The Beck Depression Inventory-II (BDI-II; Beck et al., 1996) was derived from the original BDI, first published in 1961 (Beck et al., 1961). The BDI-II is a 21 self-report inventory which requires 5 – 10 minutes to complete. Although the first edition of the inventory (BDI) was originally designed to assess the severity of depression in psychiatrically diagnosed population, the BDI-II has been widely used with adolescents and adults without psychiatric diagnosis (Steer et al., 1987). According to Beck et al. (1996) the BDI-II was designed to assess mood changes within the most recent two weeks. There is a four-point scale for each item ranging from 0 to 3, and ratings from each item are summed to calculate the total score ranging from 0 to 63. Item 16 (sleep pattern changes), and item 18 (appetite changes) are rated on a seven-point Likert scale for diagnostic purposes, in order to assess increased or decreased behavioural changes. Cut-off scores for individuals who demonstrate depression were recommended in the BDI-II manual (Beck et al., 1996): Scores between 0 and 13 indicate minimal depression, 14 to 19 indicate mild depression, 20 to 29 indicate moderate depression, and 30-63 indicate severe depression. According to Oliver and Simmons (1984) when assessing non-depressed individuals, scores higher than 15 are indicators of possible depression.

The BDI – II has very good internal consistency: Cronbach alpha was .92 among outpatients, and .93 among college students (Beck et al., 1996). Test – retest reliability within one week was high (.93). According to Beck et al. (1996) construct validity of the BDI – II Inventory was found to be high (.93) when compared to the first edition of the instrument (BDI, Beck et al., 1996). In the current study, the Cronbach alpha coefficient was .932.

Rosenberg Self-esteem Scale

The Rosenberg Self – Esteem Scale (RSES; Rosenberg, 1965) is a self-esteem measure used in social science research. The RSES was originally developed to assess self-esteem among adolescents and high school students, but it has also been used with adults. The scale measures one's own feelings of worthiness, as well as the relationship between self-esteem and life outcomes. The scale has been used for research and public education purposes, but not as a diagnostic tool for psychological-related problems (Rosenberg, 1965). The scale comprised 10 items related to feelings of self-acceptance and self-worth. Half items are positively stated, and half are negatively stated. Items are rated on a four-point Likert scale (0= 'Strongly Disagree', 3= 'Strongly Agree'). The total score is calculated by summing the scores for the 10 items after reverse scoring the negatively stated items. The scale ranges from 0 – 30, with 30 representing the highest score possible, indicating higher self-esteem. According to Rosenberg (1965), a score of less than 15 suggests low self-esteem, scores between 15 – 25 are within normal range, and scores between 25 – 30 suggest high self-esteem. The RSES has good internal consistency, with a Cronbach alpha coefficient reported of between .77 and .88 (Rosenberg, 1986; Blascovich & Tomaka, 1993). Internal consistency has also been supported with an analysis of studies using the scale in 53 countries with a Cronbach alpha of .83 (Schmitt & Allik, 2005). The scale has shown good test-retest reliability over a period of 2 weeks with correlations of .82 and .88. In the current study, the Cronbach's alpha coefficient was .75.

5.4.5 Procedure

Participants were invited to complete an online study using the Qualtrics Survey tool. Participants were first presented with the information sheet including information relevant to the purpose of the study. If they wished to take party in the study, they had to complete the consent form. Following that, participants had to answer some demographic questions including age, gender, level of study, diagnosis of dyslexia or anxiety. Participants completed all the measures in a fixed order; Social and Academic anxiety were presented first, followed by the Westside Test Anxiety Scale, Beck Depression Inventory, and Rosenberg Self-Esteem Scale.

Participants were requested to answer all the questions and they were informed that they could not skip any question or go back to change a response after they had finished answering a measure. They were also informed that the study would take around 20 minutes to complete.

5.5 Results

5.5.1 Descriptive statistics

Descriptive statistics across the whole sample are reported in the following tables. Table 5.1 reports the full breakdown by group, level of study and gender. Mean scores and standard deviations across Higher Education level, for each group, and for each variable are presented in Table 5.2.

Table 5.1 Full breakdown by group, level of study, and gender in Study 1

	Dyslexia (122)		Non-dyslexia (160)	
Level of study	Frequency	Percentage	Frequency	Percentage
1st year undergraduate	29	10.3%	34	12.0%
2nd year undergraduate	26	9.2%	29	10.3%
3rd year undergraduate	22	7.8%	21	7.4%
Total undergraduates	77	27.3%	84	29.8%
Postgraduate taught	31	11.0%	46	16.3%
Postgraduate research	14	0.5%	30	10.6%
Total postgraduates	45	16.0%	76	26.9%
Total sample	122	43.3%	160	56.7%
Undergraduate females	29	10.3 %	51	18.0 %
Postgraduate females	25	8.9 %	47	16.7 %
Females total	54	19.1%	98	34.7 %
Undergraduate males	48	17.0 %	33	11.7 %
Postgraduate males	20	7.0%	29	10.3 %
Males total	68	24.1 %	62	22.0%

Table 5.2 Means and standard deviations for level of study and for each group

Measures	Higher Education level	Dyslexics Mean (SD)	Non-dyslexics Mean (SD)	Total Mean (SD)
Social anxiety	Undergraduates	50.90 (10.29)	46.85 (8.78)	48.79 (9.71)
	Postgraduates	50.29 (8.31)	47.69 (7.09)	48.66 (7.63)
Academic anxiety	Undergraduates	51.70 (10.96)	47.67 (7.44)	49.60 (9.47)
	Postgraduates	43.62 (6.00)	40.73 (4.88)	41.81 (5.48)
Test anxiety	Undergraduates	2.56 (.58)	2.36 (.64)	2.46 (.62)
	Postgraduates	2.86 (.68)	2.62 (.72)	2.71 (.71)
Depression	Undergraduates	17.77 (4.43)	16.08 (4.60)	16.89 (4.59)
	Postgraduates	17.84 (4.38)	16.70 (4.05)	17.12 (4.19)
Self-esteem	Undergraduates	18.07 (3.77)	19.25 (3.70)	18.69 (3.77)
	Postgraduates	18.66 (3.59)	20.02 (4.00)	19.52 (3.89)

Table 5.3 reports the mean scores and standard deviations for gender and group, along with the effect sizes for each variable.

Table 5.3 Means and standard deviations for gender and group, together with effect sizes

	Gender	Dyslexics Mean (SD)	Non-dyslexics Mean (SD)	Total Mean (SD)	Effect size
Social anxiety	Male	47.80 (7.84)	45.63 (7.00)	46.77 (7.50)	
	Female	54.27 (10.39)	48.28 (8.45)	50.41 (9.60)	
	Total (group)	50.67 (9.58)	47.26 (8.00)	-	0.43
Academic anxiety	Male	46.44 (7.83)	42.50 (5.91)	44.56 (7.23)	
	Female	51.59 (12.02)	45.57 (7.74)	47.71 (9.88)	
	Total (group)	48.72 (10.19)	44.38 (7.22)	-	0.60
Test anxiety	Male	2.53 (.60)	2.40 (.74)	2.47 (.68)	
	Female	2.84 (.62)	2.54 (.66)	2.65 (.66)	
	Total (group)	2.67 (.63)	2.48 (.69)	-	0.27
Depression	Male	15.97 (3.43)	15.66 (4.32)	15.82 (3.87)	
	Female	20.09 (4.43)	16.82 (4.32)	17.99 (4.62)	
	Total (group)	17.79 (4.40)	16.37 (4.35)	-	0.33
Self-esteem	Male	19.00 (3.87)	20.60 (4.18)	19.76 (4.08)	
	Female	17.40 (3.29)	19.00 (3.52)	18.43 (3.51)	
	Total (group)	18.30 (3.70)	19.61 (3.86)	-	-0.34

5.5.1.1 Distribution of categorical scores.

Figures 5.1 and 5.2 present the percentage distribution of categorical scores, converted to each measures’ category ratings (based on cut-off scores) for each group separately (dyslexic and non-dyslexic). The distribution of scores was checked with frequencies.

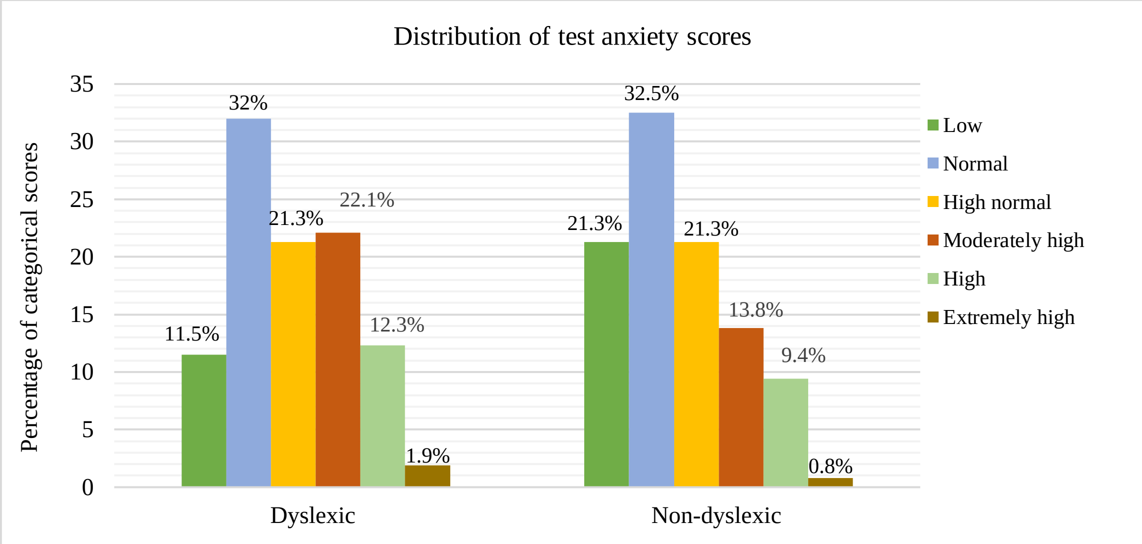


Figure 5.1 Distribution of Test anxiety categorical scores

As shown in Figure 5.1, the dyslexic group had a distribution with a high percentage of test anxiety scores (32%) in the 'normal anxiety' category, and lower percentage of scores (22.1%) in the 'moderately high anxiety', and the 'high normal anxiety' category (21.3%). Fewer scores were in the 'high anxiety' (12.3%), and 'low anxiety' category (11.5%), and there was only a low percentage of scores (1.9%) in the 'extremely high anxiety' category.

For the non-dyslexic group, the percentage of scores (32.5%) in the 'normal anxiety' category was similar to the dyslexic group. The same percentage of scores (21.3%) was in the 'high normal anxiety' and 'low anxiety' category for the non-dyslexic group. Lower percentage of scores (13.8%) was in the 'moderately high anxiety', 'high anxiety' (9.4%), and 'extremely high anxiety' (0.8%) categories.

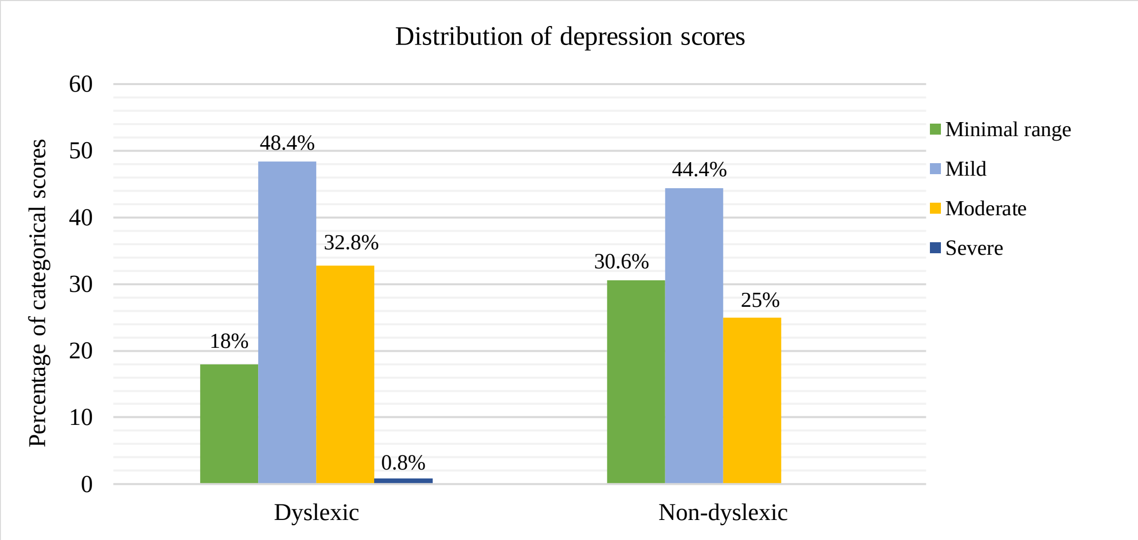


Figure 5.2 Distribution of Depression categorical scores

As presented in Figure 5.2, the dyslexic group revealed a distribution with the highest percentage of scores (48.4%) in the 'mild depression' category, and lower percentage of scores (32.8%) in the 'moderate depression' category, in the 'minimal range' category (18%), and a very low percentage (0.8%) in the 'severe depression' category.

The non-dyslexic group showed a high percentage of scores (44.4%), similar to the dyslexic group, in the 'mild depression' category. The group had lower percentage scores (30.6%) in the 'minimal range' category, and in the 'moderate depression' category (25%). Students in this group had no scores into the upper end, which is the 'severe depression' category.

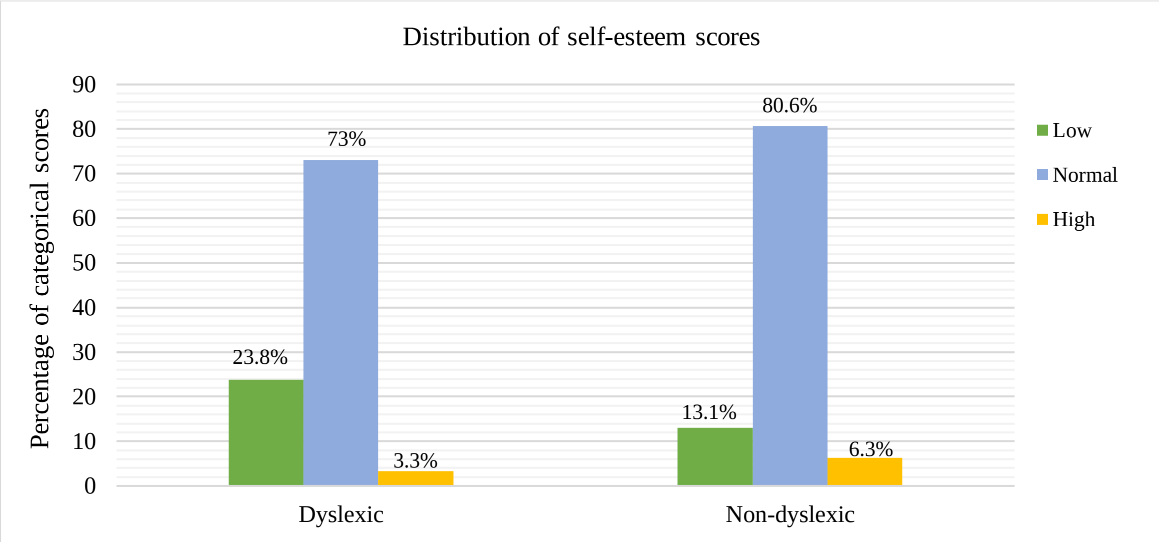


Figure 5.3 Distribution of Self-esteem categorical scores

As shown in Figure 5.3, the dyslexic group showed a distribution with a very high percentage of scores (73%) in the 'normal self-esteem' category, a lower percentage (23.8%) in the 'low' category, and the lowest percentage (3.3%) in the 'high self-esteem' category. The non-dyslexic group showed a very high percentage of scores (80.6%) in the 'normal' category, as did the dyslexic group, a lower percentage (13.1%) in the 'low' category, and a very low percentage (6.3%) in the 'high' category.

5.5.2 Statistical analyses

After collecting the data, the dataset was screened to examine for distributions and outliers to ensure that the data was appropriate for the statistical analysis planned for Study 1. A Shapiro-Wilk test, along with inspection of histograms showed that the data were normally distributed, except for the social and academic anxiety measures (Shapiro Wilk test < .05). The examination of boxplots indicated that there were a few outliers in the data, however they were not extreme scores, and therefore, no cases were excluded from the statistical analysis.

An alpha level of 0.01 with correction for five comparisons (0.05 divided by 5) was chosen as the threshold for statistical significance after applying Bonferroni adjustment to control for Type 1 Error. A three-way between groups analysis of variance (ANOVA) was conducted to explore the effect of group (dyslexic vs non-dyslexic), gender, and higher education level (undergraduate vs postgraduate) on each variable, and to identify any interaction effects. Levene's test showed that the assumption of equality of error variances was met ($p > .05$) for most of the dependent variables, except for social and academic anxiety. A log-transformation was applied to those two measures that were not normally distributed and did not pass the Levene's test, however, the results were similar to that of the ANOVA analysis. Based on that, the results that were finally reported for the above two measures were the ANOVA results, in order to facilitate better interpretation among the results. The results are presented separately for each variable.

5.5.2.1 Between group statistical tests.

For all the anxiety measures, higher scores indicated higher levels of anxiety. On the depression measure, higher scores indicated higher levels of depression. On the self-esteem measure, higher scores indicated higher levels of self-esteem.

Social anxiety

The results showed that there was a significant main effect for group on social anxiety, $F(1, 274) = 12.48$, $p < .001$. The dyslexic group scored higher compared to the non-dyslexic group. There was also a significant main effect for gender, $F(1, 274) = 22.33$, $p < .001$. The females scored higher than males. Pairwise comparisons showed that significant gender differences were in the dyslexic group only, with the females scoring higher than males ($p < .001$) (see Table 5.3). No gender differences were reported in the non-dyslexic group ($p = .05$). There was no difference in level of study, $F(1, 274) = .46$, $p = .49$, and no interaction effects were reported in the combinations among group, gender, and level of study in social anxiety, F (1, 274) = .01, p > .01. The mean scores of social anxiety are shown in Figure 5.4.

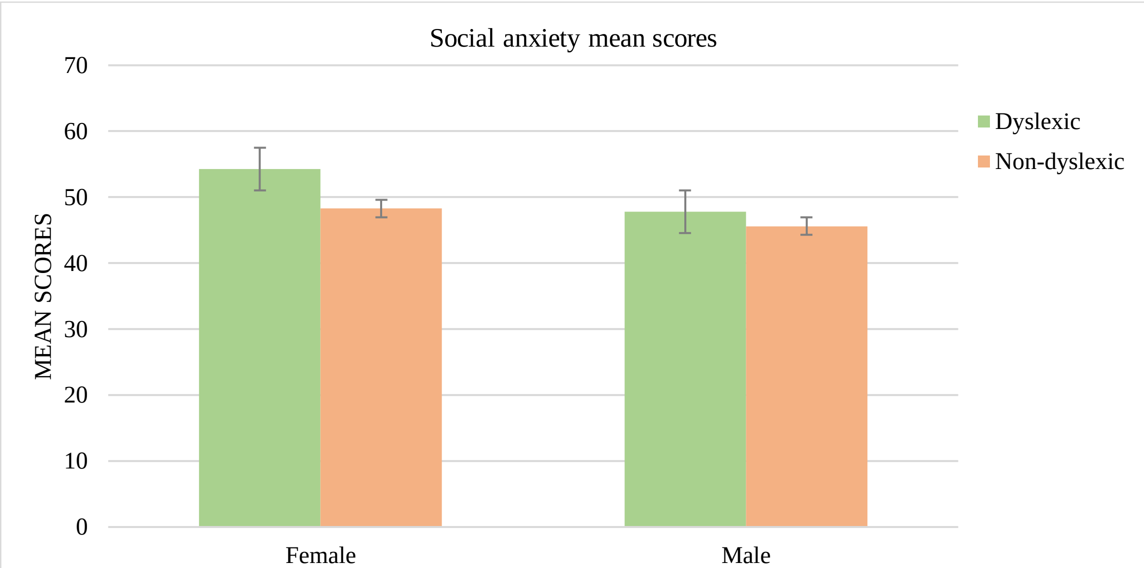


Figure 5.4 Mean scores of group, gender and level of study for Social anxiety.
Note. Error bars indicate standard error.

Academic anxiety

The results showed a significant main effect for group on academic anxiety, F (1, 274) = 20.56, p < .001. The dyslexic group scored significantly higher than the non-dyslexic group. There was also a main effect for gender, F (1, 274) = 24.49, p < .001, with the females scoring higher than males. Pairwise comparisons showed significant gender differences only in the dyslexic group (p < .001) (see Table 5.3). No gender differences were reported in the non-dyslexic group (p = .02). A significant difference was also found between the undergraduate and postgraduate group, F (1, 274) = 74.73, p < .001, with the undergraduate group scoring higher compared to the postgraduate group. There was no interaction effect in the combinations between group, gender and level of study, F (1, 274) = .76, p > .01. The mean scores of academic anxiety are shown in Figure 5.5.

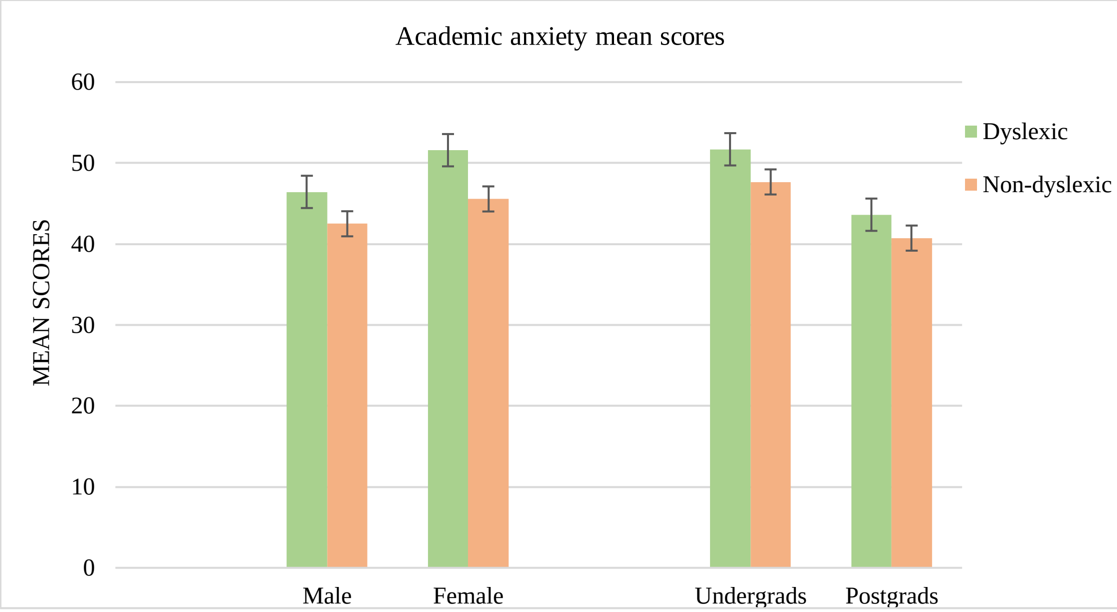


Figure 5.5 Mean scores of group, gender and level of study for Academic anxiety.
Note. Error bars indicate standard error.

Test anxiety

Significant differences were found between the dyslexic and non-dyslexic group on test anxiety, F (1, 274) = 8.78, p = .003. The dyslexic group reported higher scores than the non-dyslexic group. There was a main effect for gender, F (1, 274) = 6.00, p = .01, with the females reporting higher levels compared to the males. Pairwise comparisons showed that the significant gender differences were in the dyslexic group only, with the females scoring higher than the males (p = .01) (see Table 5.3). No gender differences were reported in the non-dyslexic group (p = .16). There was also a significant difference between the undergraduate and postgraduate group, F (1, 274) = 10.27, p = .002, with the postgraduate group reporting higher levels of test anxiety compared to the undergraduate group (see Fig. 5.6). There were no interaction effects in any combination between group, gender, and level of study in test anxiety, F (1, 274) = .18, p > .01.

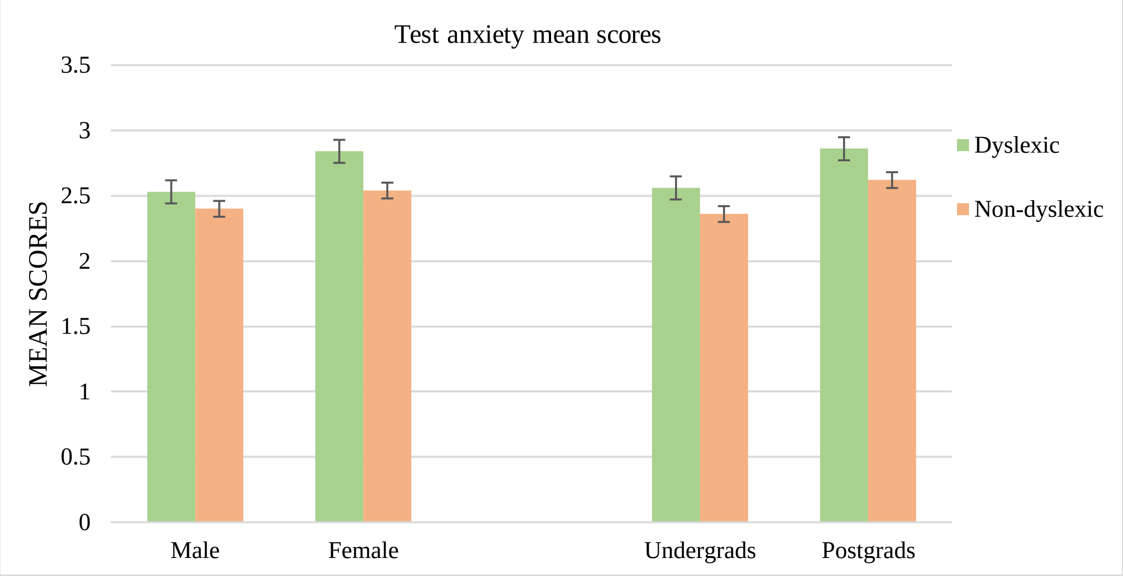


Figure 5.6 Mean scores of group, gender and level of study for Test anxiety.
Note. Error bars indicate standard error.

Depression

There was a significant main effect for group on depression, F (1, 274) = 11.53, p = .001. The dyslexic group reported higher levels than the non-dyslexic group. There was also a significant main effect for gender, F (1, 274) = 25.08, p < .001, with the females scoring higher than males. No differences were found between the undergraduate and postgraduate group on depression, F (1, 274) = .04, p = .83. The interaction effect between group and gender was significant, F (1, 274) = 7.44, p = .007 (see Fig. 5.7). Pairwise comparisons showed that the significant interaction was only between the dyslexic group and gender (p < .001), with the females scoring higher than males. There were no gender differences in the non-dyslexic group (p = .08). There was no interaction effect between any other combination (group and level of study, or gender and level of study), F (1, 274) = 1.77, p > .01.

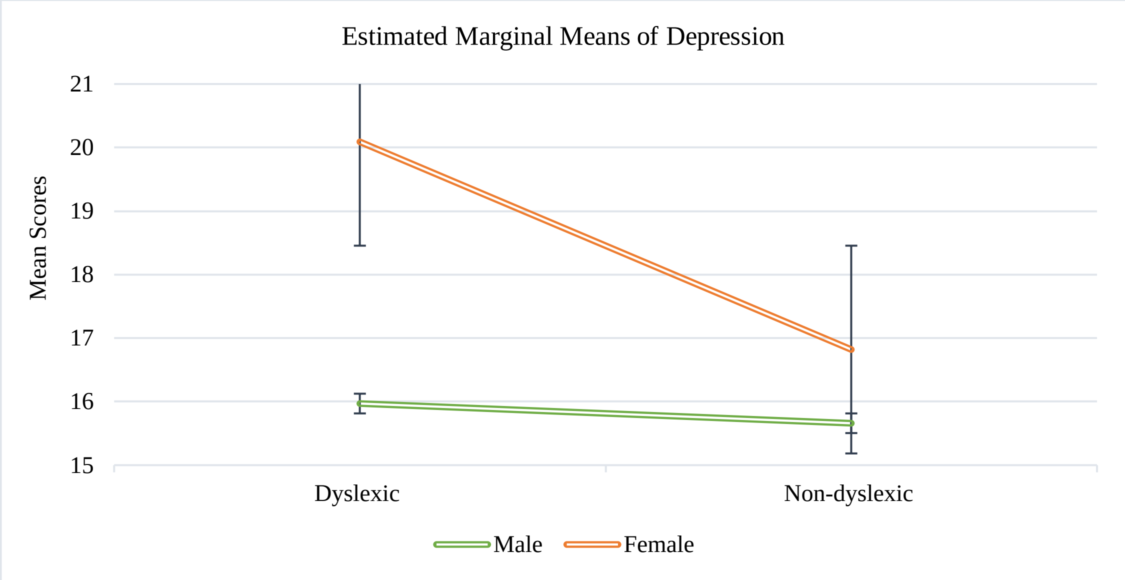


Figure 5.7 Interaction effect on Depression between group and gender

Self-esteem

A main effect for group was found on the self-esteem measure, $F(1, 274) = 10.44$, $p = .001$. The dyslexic group scored significantly lower compared to the non-dyslexic group (see Fig. 5.8). There was also a main effect for gender, $F(1, 274) = 12.73$, $p < .001$, with the males scoring higher than females. Pairwise comparisons showed significant gender differences in both the dyslexic ($p = .01$) and non-dyslexic group ($p = .009$). The males from both groups scored higher compared to females (see Table 5.3). No differences were found between the undergraduate and postgraduate group, $F(1, 274) = 3.18$, $p = .07$. There were no interaction effects among the combinations of group, gender and level of study, $F(1, 274) = .00$, $p > .01$.

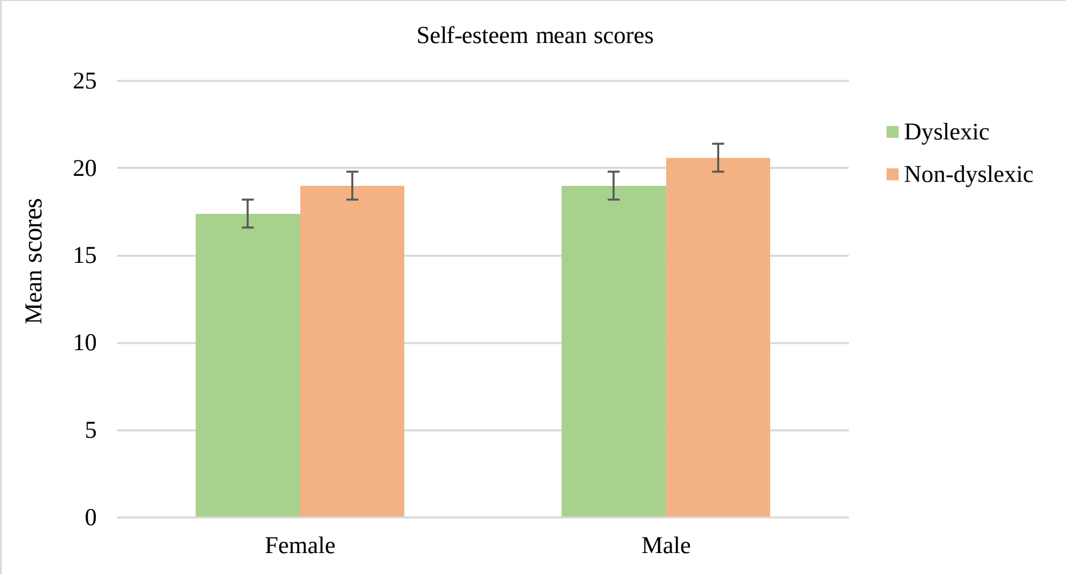


Figure 5.8 Mean scores of group, gender and level of study for Self-esteem
Note. Error bars indicate standard error.

5.5.2.2 Interaction effects between Group (dyslexic vs non-dyslexic) and HE level (undergraduate vs postgraduate).

A two-way ANOVA was conducted to investigate potential interaction effects between group and HE level. Although no interaction effects were reported for any of the measures, some significant differences were identified between the groups. Significant differences were found, after Bonferroni correction, in social anxiety ($p = .004$), and academic anxiety ($p = .001$) between the dyslexic and non-dyslexic students in the undergraduate group only, with the dyslexic group scoring higher in both measures compared to the non-dyslexic group (see Table 5.2). The dyslexic and non-dyslexic group did not differ in any of the measures in the postgraduate group.

5.6 Discussion

The purpose of Study 1 was to investigate the internalising problems experienced by university students with dyslexia. The study focused on different aspects of anxiety; specifically, in social, academic and test anxiety, along with depression and self-esteem symptoms. Overall, considering the three anxiety measures, the dyslexic students showed higher self-ratings on all three measures of anxiety, along with high levels of depression and low self-esteem. Overall, the results showed that even these highly successful students with dyslexia showed internalising problems of anxiety and depression.

In terms of overall prevalence of internalising disorder symptoms for the non-dyslexic group, a level of 24% was found for test anxiety (adding the prevalence for moderately high, high, and extremely high); 25% for moderate or severe depression, and 13.1% for low self-esteem. These data are comparable with those found in previous literature (Bruffaerts et al., 2018; Ibrahim et al., 2013). Of particular importance is the significantly more adverse ratings given by the dyslexic students on three measures, with prevalence of 36.3% for test anxiety, 33.6% for depression and 23.8% for self-esteem. These are, respectively, 1.51, 1.34 and 1.82 times higher than the prevalence for the non-dyslexic participants.

Hypothesis 1: Students with dyslexia would show higher levels of academic anxiety compared to non-dyslexic students.

The findings of Study 1 revealed the marked presence of academic anxiety symptoms in the dyslexic group of university students. The findings supported the first hypothesis and are in line with previous studies (Carroll & Iles, 2006; Riddick et al., 1999; Jordan et al., 2014). The academic anxiety symptoms experienced by dyslexic students could be explained by the reading and writing difficulties they may have, but also by the lack of time management, organization, and study skills (Mortimore & Crozier, 2006) skills that are important for successful academic life. The results of Study 1 have important implications for dyslexic students, as such students have previously shown deficits in working memory and concentration (Riddick et al., 1999), which are also important skills for succeeding in university academic studies. Another possible explanation of high academic anxiety in university students is the argument that dyslexic students have to spend longer time on and give more effort to academic studying compared to their non-dyslexic peers (Singleton, 1999), which in turn leads to heightened stress and anxiety.

Hypothesis 2: Students with dyslexia would show higher levels of social anxiety compared to non-dyslexic students.

Study 1 also revealed the presence of social anxiety in the dyslexic university students. The findings supported the second hypothesis and are in accordance with previous research on university undergraduate students with dyslexia (Carroll & Iles, 2006). The results indicated that anxiety is more general than understandable concerns over tests and academic performance and may permeate social life as well as academic life. This finding can be interpreted in a way that social situations for university students are also part of their academic life, and that their academic course friends are also part of their social life friendships (Carrol & Iles, 2006). This can have more worrying effects for dyslexic students, given that they experience higher anxiety in academic situations which also affects their social interactions.

Hypothesis 3: Students with dyslexia would show higher levels of test anxiety compared to non-dyslexic students.

The results indicated remarkable differences between the dyslexic and non-dyslexic students in terms of test anxiety. The dyslexic group reported significantly higher levels of test anxiety compared to the non-dyslexic group. The results of Study 1 supported the third hypothesis and are consistent with the test anxiety literature (Nelson et al., 2015; Gaudry & Spielberger, 1971; Nelson & Hartwood, 2011). The findings of study 1 have significant implications for dyslexic students, as test anxiety has been found to occur in examination settings (Putwain, 2005), which is the most common form of academic evaluation. Examination settings may be particularly stressful for students with dyslexia (Nelson et al., 2015) because of time management constraints as well as cognitive and memory difficulties, which are important skills for optimal performance in exams (Ackerman & Heggestad, 1997; Benjamin et al., 1981). The implications of these results are important for dyslexic students, as their anxiety is not only related to general academic performance and academic difficulties, but also to the specific situation of test-taking and examination settings. This is an important finding for the dyslexic students because underachievement in exams and tests does not necessarily mean that the dyslexic students did not adequately revise for the exams, but it could be the case that due to their dyslexia they had more stress regarding the exam, or that they did not have the sufficient time to finish the exam.

Hypothesis 4: Students with dyslexia would show higher levels of depression relative to non-dyslexic students.

Along with high levels of anxiety, the presence of depression is also evident in the present group of dyslexic students; a finding which is comparable to previous literature (Scott, 2004; Cleaver & Whitham, 1998; Wilson et al., 2009; Gregg et al., 1992). However, research is inconsistent in terms of differences in depression levels between dyslexic and non-dyslexic participants (Nelson & Gregg, 2012; Ghisi et al., 2016; Boetsch et al., 1996; Nelson & Liebel, 2017; Miller et al., 2005). An explanation of these contrasting findings is that according to Knivsberg and Andreassen (2008), the manifestation of internalising problems, such as depression and anxiety, depend on the severity and the characteristics of dyslexia. Therefore, students with milder symptoms of dyslexia might have also shown milder symptoms of internalising problems, or even comparable levels to non-dyslexic students. Newman et al. (2011), and Ghisi et al. (2016) attributed the similar levels of depression between dyslexic and non-dyslexic individuals to resilience skills. The authors concluded that dyslexic students who are capable of entering college or university have good resilience skills, which help them cover any depression or anxiety symptoms. Maughan et al. (2003) suggested a further explanation that family and social support play a significant role in a dyslexic individual's life.

Hypothesis 5: Students with dyslexia would show lower levels of self-esteem compared to non-dyslexic students.

The students with dyslexia reported significantly lower self-esteem compared to the non-dyslexic students. Hypothesis 5 was supported by the results of Study 1, which are also in line with previous literature (Riddick et al., 1999; Ghisi et al., 2016; Alexander-Passe, 2006). The Rosenberg self-esteem Scale does not include items related to academic self-esteem. Therefore, the results suggest that low self-esteem in dyslexic students is not only affected by academic difficulties, but it can potentially be affected by social factors too. A number of previous studies have reported that negative emotional and social experiences can also contribute to low self-esteem in individuals with specific learning difficulties (Hellendoorn & Ruijssenaars, 2000; Carawan et al., 2015. Alexander-Passe, 2015). Similar to Riddick et al (1999) study, it is not evident in the present study whether the dyslexic students showed low self-esteem based on their current experiences or whether their self-esteem is linked to past negative experiences, from childhood or adolescence, which might still affect their general self-esteem.

Hypothesis 6: Females would show higher levels of anxiety and depression, and lower levels of self-esteem compared to males.

The findings of Study 1 supported the last hypothesis, and they are consistent with previous research on gender differences in anxiety and depression (Chapel et al., 2005; Nelson et al., 2015; Hankin, Abramson, Mofit, Silva, McGee & Angell, 1998; Nolen-Hoeksema, 1990; Lewinsohn et al., 1998). The female participants in the present study reported higher levels of social, academic and test anxiety compared to males. Furthermore, consistent with previous studies of gender differences in depression (Weissman et al., 1996; Nolen-Hoeksema, 2001) the females in the current study reported a higher rate of depression as compared to males. The results of Study 1 are also in line with previous studies, which reported that males showed higher self-esteem compared to females (Bleidorn et al., 2016; Shaw et al., 2010; Costa et al., 2001). Consistent with the results of some previous studies (Nunez-Pena et al., 2016; Putwain & Daly, 2014; Rezazadeh, 2009; Carroll & Iles, 2006; Heath & Ross, 2014; Hales, 1990), the present results showed that the dyslexic females scored adversely higher in the anxiety measures, relative to the dyslexic males. It should be noted however, that although females from both groups (dyslexic and non-dyslexic) scored higher on the anxiety and depression measures, significant gender differences were only identified in the dyslexic group. Males from both groups on the other hand, scored significantly higher on self-esteem than females. Therefore, the presence of dyslexia could be a contributing factor to heightened anxiety and depression levels in females as compared to males.

There are different explanations of the prevalence of anxiety disorders and depression in females. One explanation suggests that women are more anxious and depressed than men due to biological differences between women and men (Lewinsohn et al., 1998). Another explanation suggests that women present more anxiety symptoms than men because of different experiences in life, and of different social roles in society (Lewinsohn et al., 1998). Nolen-Hoeksema (2001) proposes that although men and women may experience the same stressors in life, women respond differently to those stressors because of biological differences, and because of different coping styles comparative to men, which results in excessive stress and anxiety in women, which then leads to depression. Men usually use problem-focused coping strategies to respond to stressful situations, which involve direct strategies to respond to stress, whereas women use more frequently their emotions to cope with a stressful experience or to avoid it, a coping style which seems to be less effective than the one used by men (Endler & Parker, 1990; Kelly et al., 2008).

Moreover, Alexander-Passe (2006) suggests that females internalize the depressive symptoms with feelings of sorrow and pain, and therefore it is not a visible disability, whereas males more frequently externalize depressive symptoms as anger and aggressiveness. Similar to gender differences' explanation in anxiety disorders and depression, a possible explanation of gender differences in self-esteem also suggests that the gender gap in self-esteem might occur due to biological factors or different social gender roles and cultural influences between males and females, which consider males as being more confident compared to females due to stereotypical masculinity traits (Costa et al., 2001; Kling et al., 1999; Piccinelli & Wilkinson, 2018).

Due to lack of previous literature, there was no specific hypothesis in Study 1 about differences in psychological disorders between undergraduate and graduate students. However, some significant results emerged from these data. The two groups differed in academic anxiety and test anxiety. In particular, the undergraduate students reported higher academic anxiety relative to graduate students, which is consistent with Wyatt and Oswalt (2013) who found that undergraduate students showed high levels of anxiety due to academic difficulties and poor academic performance, however Wyatt and Oswalt did not include a graduate sample. A possible explanation for this result is that the transition from school or college to university is challenging for most students, and due to the fact that most of undergraduate students do not frequently attend classes for writing skills for assignments or dissertations, which is a new task for new university students, can cause severe academic anxiety. The graduate students in the present study reported higher test anxiety compared to the undergraduate students. This result was surprising, given that graduate students do not frequently have exams due to their research-based work. This is an interesting result that needs to be replicated in further studies.

Moreover, the results indicated that differences between the dyslexic and non-dyslexic students, in terms of HE level, were only identified in social and academic anxiety at the undergraduate level. At the postgraduate level, the dyslexic and non-dyslexic groups did not differ in internalising and emotional problems. It can be suggested therefore, that dyslexic students present with higher anxiety, particularly related to academic and social aspects of anxiety, at the undergraduate level. It is possible therefore, that anxiety related to academic performance is more common in undergraduate than postgraduate students, regardless of additional learning disorders. The results are consistent with those reported from the American College Health Association (2014), such that stress related to academic performance was more prevalent in undergraduate than graduate students. A possible explanation of this result could be attributed to different coping strategies among undergraduate and graduate students either for academic or more general, social, situations. Previous research suggested that avoidant coping was more common among undergraduate students to deal with stress, whereas graduate students used more psychological-related, active behaviour such as physical activities to overcome stressful situations (Hoalahan & Moos, 1987; Labrie et al, 2012; Pettit & DeBarr, 2011). Another important factor is the nature of undergraduate and postgraduate study. Undergraduate students are more likely to feel stressed about their academic work, as the undergraduate courses are by nature focused on excessive homework, grades, and time pressure; all of which are significant causes of stress for undergraduate students (Ross et al., 1999). In contrast, the nature of postgraduate studies is more personal and research oriented, with students being more conscious of pursuing to postgraduate courses and of the academic demands of these courses. Therefore, due to that, it is likely that postgraduate students do not show high levels of academic anxiety, but they rather show more anxiety related to financial difficulties, future career options, and lack of program support (Hudd et al., 2000).

In conclusion, the results of the present study are consistent with previous studies which found greater test anxiety for dyslexic students (Nelson et al., 2015), higher academic and social anxiety (Caroll & Iles, 2006), and lower levels of self-esteem in dyslexic students (Alexander-Passe, 2006; Ghisi et al., 2016; Nelson et al., 2015; Riddick et al., 1999). It does, however, contrast somewhat with the findings of Nelson and Liebel (2018) who found no such effect unless socially desirable responding was considered. It is worth noting that the participants in the latter study had very extensive one-to-one testing sessions, and so socially desirable responding was more of a risk than for the present study with anonymised online responding.

It is also important to note that, considering the three anxiety measures, the dyslexic students showed significantly higher self-ratings on all three measures, including the social anxiety measure. This indicates that the anxiety is more general than understandable concern over tests and academic performance and permeates social life as well as academic life.

In short, dyslexic University students not only have difficulties in reading-related skills, but as a group they have a higher risk of low self-esteem, depression, and anxiety than non-dyslexic students. These findings have substantial implications. Problems in self-esteem, anxiety and mental health are not only long-lasting but bear a risk of being self-fuelling, leading to chronic and long-term consequences.

Most western countries have passed disability legislation that requires schools and Universities to diagnose students for dyslexia and to provide support and accommodation for those students to minimize any problems caused by assessed work (Nicolson, 2019). Dyslexia diagnosis typically involves assessment of literacy related measures, working memory, writing speed and some intelligence measures, and therefore focuses primarily on the cognitive dimension. Not only does this approach fail to address the affective dimensions of dyslexia at university in terms of self-esteem, depression, and anxiety, but it may even exacerbate them by highlighting the 'disability' aspect while discounting the affective dimension (Nicolson, 2019).

It may be necessary to undertake a more holistic assessment, that considers both cognitive and affective dimensions for dyslexia and leads to interventions for both dimensions. In the same way as having a diagnosis of dyslexia does lead to better understanding of the underlying problems, and hence systematic, dyslexia-tailored literacy support interventions, it is possible that appropriate systematic, dyslexia-tailored affective support interventions can be developed, leading to more effective intervention than generic approaches for mental health issues.

5.7 Limitations

The results of the present study should be interpreted in light of the following limitations. First, the participants confirmed themselves that they either had dyslexia or they did not have dyslexia. The lack of self-report measures or standardised screening tests regarding dyslexia symptoms makes it difficult to generalise the results of the present study. However, according to Nicolson and Fawcett (1997), self-reports of participants as not having dyslexia have been proved to be considerably accurate. Second, the use of self-report measures to assess psychological and anxiety disorders could be interpreted as less reliable than having professional assessment. However, the self-identification method for mental health problems was used in a couple of previous studies (Wilson et al., 2009; Nelson & Gregg, 2012; Nelson et al., 2015; Ghisi et al., 2016). Third, the participants were asked to report anxiety and depressive symptoms for a short period of time (for the last two weeks). The results could have been different if they had reported anxiety and depressive symptoms for a longer period. Finally, the large number of incomplete measures in the study is a clear limitation. It is likely that this relates to the length of the study as well as the completion time, particularly when the measures are solely dependent on text, which can be a demotivating and aversive factor for all students but more so for dyslexic students who usually need more time to process and consider the questions. While further research would be necessary to test this hypothesis, it is likely that completion of the study would not 'wash out' the effect sizes found, in that if the non-completers do indeed find such text-based activities aversive, this would also apply to most school-based activities, and hence their academic stress levels would be higher than for the completers.

5.8 Conclusion

In conclusion, Study 1 revealed a high prevalence of affective problems in terms of self-esteem, depression, and anxiety in dyslexic University students. Given the immediate and chronic problems caused by these affective states, it is important to acknowledge the complexity of diagnosis and support for dyslexia, considering both cognitive and affective dimensions. The study has revealed the important implications of internalising problems on university students, which should be considered by university teachers and counselling services which need to offer substantial assistance. Following on from this chapter, which investigated the internalising problems of adult university students with dyslexia, the next chapter presents the internalising problems experienced by adolescents with dyslexia.

Chapter 6

Study 2: Internalising problems of dyslexic adolescents at risk of school failure

6.1 Introduction

This chapter reports on the second empirical study that aimed to investigate potential group and gender differences in regard to internalising problems, between dyslexic and non-dyslexic adolescents at risk of dropping out of school.

It has been estimated that in US 36% of students with learning difficulties and 59% of students with emotional problems drop out of school each year (Blackorby & Wagner, 1996). Adolescents who drop out are more likely to be led into poverty and unemployment compared to adolescents who complete secondary education (Kaplan et al., 2017; WHO, 2013). The predictive risk factors of dropping out of school include disengagement, behavioural problems, and low academic performance (Kennelly & Monrad, 2007). Finn and Rock (1997) found that school engagement was associated with academic resilience in adolescents at risk of dropping out. Low academic performance and high dropout rates are due to behavioural and emotional disengagement (Janosz et al., 2008). Rumberger and Rotermund (2012) concluded that students' disengagement is not only caused by individual factors but also by social and family factors that can affect students. Mental health problems are associated with poor academic performance in adolescents who drop out of school (Butterworth & Leach, 2018). A proportion of adolescents who are at risk of dropping out of school have Special Educational Needs, and there is evidence that children with dyslexia may experience heightened levels of stress and anxiety (Duane, 1991). Dupere et al. (2018) suggested that it is important to improve the educational performance of disadvantaged students by including mental health services in schools that face high dropout rates.

The psychological literature suggests that anxiety and emotional disorders are prevalent in childhood and adolescence; they begin in childhood and often peak in adolescence (Grills-Taquechel et al., 2012; Kessler et al., 2005; Zahn-Waxler et al., 2008). Evidence suggests that dyslexia is related to a number of psychological and emotional disorders, such as anxiety, depression and low self-esteem in childhood and adolescence (Arnold et al., 2005; Boyes et al., 2019; Carroll et al, 2005; Jordan & Dyer, 2017). Students with dyslexia can experience anxiety in different situations such as in typical school activities when they have to read aloud, work in a group project, or during exams, particularly because of their fear that they may be seen as incompetent by their teachers or classmates (Alexander-Passe, 2015). Social situations can also cause anxiety in dyslexic students due to low-self-esteem and low self-confidence problems (Alexander-Passe, 2015; Carroll & Iles, 2006). Students with dyslexia respond in different ways in stressful situations such as by avoiding tasks, making themselves sick so they are not able to attend the class, or taking a defensive position by highlighting their incompetence and inability in relation to tasks that they find difficult (Alexander-Passe, 2015).

A number of studies have reported that students with specific learning difficulties showed higher trait anxiety compared to their normally achieving peers (Arnold et al., 2005; Blicher et al., 2016; Carroll & Iles, 2006; Huntington and Bender, 1993). Spielberger (1966) defined state anxiety as the emotional responsiveness an individual feels at a given time. Reading anxiety can be assessed with a state anxiety measure, and it is important to identify whether a child or adolescent with dyslexia perceives reading as a threat or a challenge (Tsovili, 2004). Meyers and Martin (1974) reported that state anxiety is the effect of lacking skills or showing poor performance, rather than the cause of that. One Greek study (Tsovili, 2004) showed that dyslexic children and adolescents, who were assessed on state and trait anxiety, reported higher rates of state anxiety only compared to their non-dyslexic peers. Carroll and Iles (2006) assessed university students on state and trait anxiety and found that students with dyslexia scored higher on both the state and trait anxiety measures as compared to non-dyslexic students.

In contrast to studies that found an association between specific learning difficulties and internalising problems, other studies are more equivocal (Lindeblad et al., 2016; Nelson & Liebel, 2018; Miller et al., 2005; Novita, 2016; Tsovili, 2004). There are several explanations for these conflicting findings. Lindeblad et al. (2017) propose that teachers and educators in Sweden have good knowledge of dyslexia and other learning difficulties and are well prepared to teach students with these difficulties. Therefore, the teachers and the school may have built a supportive and safe environment for those students with additional learning needs. Tsovili (2004) also offers a similar explanation for the similar scores on trait anxiety between the dyslexic and non-dyslexic students. The author suggests that the dyslexic group scored similar to the non-dyslexic group due to the emotional support they were receiving from their family and friends in relation to their learning and reading difficulties. Miller et al. (2005) have suggested that the different results of the studies could be due to methodological issues, such as a small sample size, different diagnostic criteria for dyslexia, or even different analyses that were used to identify differences between the groups.

As discussed in the previous chapter (see chapter 5, section 5.1), test anxiety is considered a significant source of academic anxiety that affects academic performance and achievement in college and university students (Nelson et al., 2015; Putwain, 2007). Research suggests that children and adolescents can also suffer from test anxiety (Lufi et al., 2004; Swanson & Howell, 1996), and it has been reported that test anxiety starts at the early age of 7 when formal testing starts (Connor, 2003). Peleg (2009) investigated test anxiety and self-esteem in adolescents with and without specific learning difficulties and found that the adolescents with specific learning difficulties showed elevated levels of test anxiety and low levels of self-esteem compared to their non-dyslexic peers. Peleg also found that the adolescents with specific learning difficulties had impaired academic performance possibly due to feelings of distress. Students with test anxiety feel worried and fearful during an evaluative situation (Spielberger & Vagg, 1995). It has been estimated that around 40% of all students suffer from test anxiety (Gregor, 2005), but an even higher percentage of students with learning disabilities, minority students and women experience test anxiety (McDonald, 2001; Herzer et al., 2014; Strumph & Fodor, 1993; Whitaker-Sena et al., 2007). It has been found that students with high rates of test anxiety perform worse on tests and exams, receive lower grades, and have lower academic performance overall compared to students with lower rates of, or no test anxiety (Chapell et al., 2005; Segool et al., 2013; Whitaker-Sena et al., 2007). It has been estimated that around 20% of students who experience test anxiety, drop out of school due to repeated failures and low self-esteem (Wachelka & Katz, 1999). Previous research (Thomas & Gadbois, 2007; Wachelka & Katz, 1999) also suggests that there is comorbidity between test anxiety and low self-esteem, poor reading, negative thoughts towards school, and disruptive classroom behaviour.

The research on test anxiety and specific learning difficulties is quite sparse. Swanson and Howell (1996) tested 82 adolescents with specific learning difficulties and found a positive correlation between test anxiety and cognitive interference, and a negative correlation between test anxiety and study habits. Cassady and Johnson (2002) also found that test anxiety was positively correlated with students with specific learning difficulties, in terms of both physiological and cognitive reactions. However, these studies are not comparable to previous studies (Lufi & Darliuk, 2005), which did not find differences in the test anxiety scores between adolescents with and without specific learning difficulties.

As discussed in Chapter 5 (see section 5.1), university students with dyslexia suffer from low self-esteem and low self-confidence compared to typically achieving students. It has been suggested that self-esteem is high in childhood, decreases in adolescence, and increases during adulthood, before it starts decreasing again in older age (Robins et al., 2002). Although it is suggested that self-esteem increases in childhood, there is evidence that children and adolescents with specific learning difficulties have lower self-esteem and self-concept than those without specific learning difficulties (Elbaum & Vaughn, 2001). Low self-esteem in dyslexic children can be attributed to a number of different factors. Children with dyslexia are more likely to have negative experiences in school than typically achieving students, which can result in feelings of failing academically (Humphrey, 2002). Moreover, the academic and scholastic performance of students with learning difficulties is generally lower than those without specific learning difficulties, and they are more likely to be teased, bullied, or rejected by their peers (Eaude, 1999; Martinez & Semrud-Clikeman, 2004). Evidence also suggests that dyslexic students have higher dropout rates from school than typically achieving students, due to low self-esteem as a result of negative academic and school experiences (Alexander-Passe, 2015).

Students with specific learning difficulties may also feel less competent than their peers without specific learning difficulties, as they feel that they cannot take control of, or responsibility for their academic performance, which can result in lack of confidence and motivation to succeed (Ntshangase et al., 2008). Nash (2008) suggests that feelings of inadequacy and incompetence in school may possibly be transferred to other non-academic environments, such as in social situations with peers. In an interview study with 22 children with dyslexia, which also examined their parents' and teachers' reports, Riddick (2009) found that children with dyslexia described very negative feelings, such as disappointment, frustration, shame, sadness, anger, and embarrassment, first because of their specific learning difficulties, and second because they were teased by their peers. Evidence suggests that identifying low self-esteem problems in adolescents can help identify students at risk of anxiety and depression (Nguyen et al., 2019).

There are different views in the literature about the self-esteem concept. Rosenberg (1965) described self-esteem as a general, global structure, whereas others (Harter, 1985; Marsh, 1986) have divided self-esteem into different domains, such as academic, social, physical appearance, and behavioural conduct. Previous studies have reported poor general self-esteem in children with specific learning difficulties (Alexander-Passe, 2006; Elbaum & Vaughn, 2001), whereas other studies have reported lower self-esteem only in relation to academic and scholastic competence (Alexander-Passe, 2006; Humphrey & Mullins, 2004; Terras et al., 2009).

Alexander-Passe (2006) investigated the differences between dyslexic and non-dyslexic teenagers in regard to general self-esteem, as well as in different domains of self-esteem, namely academic, social, personal, and parental/home self-esteem. It was found that the dyslexic teenagers scored lower in global self-esteem, as well as in the different domains of self-esteem, except for social self-esteem domain, compared to non-dyslexic teenagers. Humphrey (2002) conducted a study with three groups of students aged 8 to 15 years old to assess their levels of self-esteem. The first group of students attended a mainstream school, the second group attended a specialist school for students with specific learning difficulties, and the third group was a control group without specific learning difficulties. The teachers also completed reports about the students' self-esteem. The teachers' results showed that the dyslexic group, both in the mainstream and specialist school, were continually asking for their teacher's help and reassurance. The teachers also reported that both the dyslexic groups avoided stressful situations and displayed humble behaviour. According to the students' self-report results, the dyslexic group in the mainstream school displayed lower rates of self-esteem in terms of their reading and writing ability compared to the other two groups. The dyslexic group in the mainstream school also reported lower levels of self-esteem in relation to spelling, intelligence and popularity compared to the control group, but not to the dyslexic group in the specialist school. Humphrey (2002) argues that, due to the lack of differences between the control group and the dyslexic group in the specialist school, dyslexic students in a specialist school develop higher self-esteem and more positive self-concept compared to dyslexic students in a mainstream school. This can possibly be explained by the fact that teachers in a specialist school are more likely to have more specialist training and more time to spend with students (Glazzard, 2012). Bear et al. (1991) argued that children with specific learning difficulties who are in integrated classrooms in mainstream schools may feel undervalued by their classmates, in terms of academic self-worth, particularly if students with specific learning difficulties compare themselves to normally achieving students.

Humphrey and Mullins (2004) suggested that the experience of dyslexia can develop negative feelings in students, as well as a negative impact on their self-esteem and self-confidence. Humphrey and Mullins found that the students with dyslexia mainly attributed their success to external uncontrollable factors, such as to luck of teachers, and not to their intelligence or their own effort, whereas the non-dyslexic students attributed their success to internal factors; a finding which is in line with the theory of 'learned helplessness' (Peterson et al., 1993). 'Learned helplessness' is a behaviour exhibited by individuals who experience repeated failures, and because of that, they refuse to make any effort or try harder, as they expect a failure rather than a successful outcome (Joiner & Wagner, 1995). Low self-esteem often leads to poor self-image and negative beliefs, particularly about failing (Riddick, 2009). Frederickson and Jacobs (2001) tested dyslexic and non-dyslexic children in a number of different variables including scholastic competence, athletic competence, social acceptance, physical appearance, behavioural conduct, and global self-worth. The results indicated differences between the groups only in regard to scholastic competence, with the dyslexic group showing lower levels of scholastic competence compared to their non-dyslexic peers. No other differences were found between the dyslexic and non-dyslexic groups on the rest of the variables. Frederickson and Jacobs (2001) suggested that dyslexia may be associated with specific areas of self-esteem, such as scholastic competence, and not with other general areas of self-esteem (such as global self-worth).

Despite the large amount of research on the association between dyslexia and anxiety disorders, it still remains controversial as to whether dyslexia leads to anxiety problems and poorer psychological wellbeing, or whether the two disorders simply co-occur based on the same biopsychosocial background (Jordan & Dyer, 2017; Whitehouse et al., 2009). Two models have been suggested concerning the interaction between anxiety and reading difficulties. According to the first model, anxiety impacts students' academic performance and learning achievement (Bryan et al., 2004; Grills-Taquechel et al., 2012). As noted earlier in the Introduction (see chapter 3, section 3.2.1), stress affects cognitive function, such as information processing and working memory, which are necessary skills for optimal academic performance (Kiely, 2014; Ialongo et al., 1994). According to the second model, anxiety emerges as a result of learning and reading difficulties (Spreen, 1989).

Evidence suggests that specific learning difficulties can predict early anxiety disorders (Kellam et al., 1983; Carroll et al., 2005). Therefore, children with specific learning difficulties are more prone to developing anxiety disorders due to repeated academic failures (Grills-Taquechel et al., 2012). Parhiala et al. (2015) also suggest that it is difficult to differentiate between whether dyslexia causes anxiety or vice versa, since children with dyslexia experience difficulties with psychosocial functioning (such as social skills, concentration, or attention) even before entering school. Therefore, a bi-directional model may exist, according to which anxiety and specific learning difficulties co-occur (Grills-Taquechel et al., 2012). Therefore, specific learning difficulties can cause anxiety in children, or in turn, high levels of anxiety can disrupt the learning process, and lead to difficulties with learning (Yasutake & Bryan, 1995).

As discussed in the previous chapter (see chapter 5, section 5.1), adult females tend to show higher levels of internalising disorders compared to males. A female preponderance of anxiety disorders is also evident in adolescence (Lewinsohn et al., 1998; Merikangas et al., 2010; Willcutt & Pennington, 2000; Zahn-Waxler et al., 2008). Other studies (Bender et al., 2015; Derdikman-Eiron et al., 2016) have reported gender differences in internalising disorders in adolescence, particularly in regard to anxiety disorders. Rudolph (2002) found that interpersonal stress is more prevalent in adolescent girls, as they are more likely to feel heightened stress in their friendships and relationships. Gender differences are also evident in the way that girls and boys experience stress, as well as in their reactivity to stressful situations (Rudolph, 2002). Psychosocial functioning has also been found to be different between boys and girls (Diprete & Jennings, 2012). In contrast to these studies, other studies have not found gender differences in anxiety between boys and girls (Hale et al., 2008; Nelemans et al., 2014; Leadbeater et al., 2012).

Research concerning gender differences in regard to anxiety in adolescents with dyslexia is scarce. A few studies have reported that anxiety disorders are more prevalent in adolescent girls with dyslexia (Darweesh et al., 2020; Willcutt & Pennington, 2000) compared to boys with dyslexia. Alexander-Passe (2008) found gender differences in both dyslexic and non-dyslexic school-aged children, but in relation to different sources of stress. In particular, the dyslexic girls showed higher stress levels in social and interpersonal (with peers and teachers) situations compared to dyslexic boys, whereas the dyslexic boys showed higher academic stress compared to dyslexic girls. The non-dyslexic girls also scored higher for stress related to social interactions (similar to the dyslexic girls) than non-dyslexic boys, and the non-dyslexic boys scored higher for academic stress (similar to the dyslexic boys) than the non-dyslexic girls. Alexander-Passe (2008) attributed the gender differences in stress to the old-fashioned way of thinking of the society and the family, whereby there is more pressure on males to succeed academically, as they will be the ones who contribute more, in terms of finance, to the family than females. On the other hand, social situations are more anxiety and stress provoking situations for girls (Terje & Bru, 2004). Interactions have also been reported between dyslexia, anxiety and depression in females that are more significant than in males (Darweesh et al., 2020).

However, other studies, (Carroll et al., 2005; Grills-Taquechel et al., 2012; Goldston et al., 2007; Nelson & Harwood, 2011) have not reported gender differences in anxiety disorders in adolescents (regardless of dyslexia). According to Rudolph (2002), these inconsistencies in results could possibly be attributed to the use of different measures of stress and anxiety, as well as the variability of the concepts used for stress and anxiety. However, since there is evidence that females and males differ in some aspects of anxiety, it is necessary to identify these differences early, as this will enable the relevant educational, academic, and healthcare systems to provide the appropriate interventions and treatments to males and females depending on their needs (Afifi, 2007).

Concerning gender differences in self-esteem, research suggests that boys have higher general self-esteem compared to girls in adolescence (Bolognini et al., 1996; Quatman & Watson, 2001). Previous studies have found differences between boys and girls, not only in global self-esteem but also in different domains of self-esteem; girls reported lower self-esteem with regards to appearance (Bolognini et al., 1996; McKinley & Hyde, 1996; Scalas & Marsh, 2008), whereas boys reported lower self-esteem with regard to athletic competence (Bolognini et al., 1996; Bowker, 2006; Jacobs et al., 2002). Lower self-esteem in girls was attributed to environmental and social influences, such as images of models promoted in the media, or the importance of appearance in girls during adolescence, which can affect their self-confidence and self-esteem (Kling et al., 1999). Whereas lower self-esteem in boys was attributed to judgement and influences from their peers concerning physical activity in adolescence (Bolognini et al., 1996). Furthermore, Bolognini et al. (1996) assessed the relationship between gender, self-esteem, and mental health problems (including anxiety and depression) and found more significant interactions for girls than for boys. In general, however, higher levels of self-esteem in males can be attributed to the social view that males are stronger than females due to masculinity traits (Marsh, 1987). Derdikman-Eiron et al. (2011) investigated gender differences in self-esteem and mental health problems (including anxiety and depression) in adolescents with and without symptoms. Significant gender differences in well-being were found in the group that presented symptoms, except for self-esteem, for which boys from both groups reported higher levels than girls. In addition, significant negative associations were found between higher levels of anxiety and lower levels of self-esteem only for boys, as well as between higher levels of depression and lower levels of self-esteem only for boys. Terras et al. (2009) investigated self-esteem and socioemotional and behavioural difficulties in dyslexic and non-dyslexic children and did not find any group differences related to self-esteem but only to socio-emotional and behavioural problems.

Research on gender differences in self-esteem in adolescents with dyslexia is scarce. Alexander-Passe (2006) found that the dyslexic adolescents girls reported lower general and academic self-esteem compared to boys. An important finding was that self-esteem was associated with depressive symptoms in girls but not in boys (Alexander-Passe, 2006; Bolognini et al., 1996), and there is evidence that girls are twice as likely as boys to present with depression. Boyes et al. (2019) reported that self-esteem was negatively correlated with gender and both internalising and externalising disorders in children with dyslexia.

A Norwegian cross-sectional study investigated the relationship between gender, stress, and emotional conditions in adolescents. The results indicated that the girls scored higher in all of stress measures and emotional conditions than boys, whereas the boys scored significantly higher on self-esteem than the girls. Significant positive correlations were found between stress and emotional conditions, and negative correlations between self-esteem and emotional conditions; however, gender was not a moderator in the correlations (Moksnes et al., 2010). Other studies (Alesi et al., 2013; Grills-Taquechel et al., 2012; Terras et al., 2009) have found comparable levels of self-esteem in dyslexic girls and boys. Parhiala et al. (2015) did not find significant correlations between internalising or externalising problems in dyslexic girls and boys. It has been suggested that self-esteem increases from adolescence to adulthood, and thus any gender differences would be more evident with age (Pepi et al., 2006). This can be explained by the fact that boys and girls normally follow the different gender role expectations and gender stereotypes as they become older and more independent (Arens & Hasselhorn, 2014).

6.2 Rationale and aim of Study 2

There has been an increasing interest in the field of mental health, and in early identification and diagnosis of anxiety and depressive symptoms in school-aged students (Jordan & Dyer, 2017; Alesi et al., 2012). Adolescence is characterized as a time of intense stress, as a result of changes in socio-emotional development, brain development, social interactions with peers, as well as great desire for independence (Casey et al., 2010). According to Emerson and Hatton (2007) children and adolescents with specific learning difficulties, including dyslexia, are six times more likely to present with anxiety disorders and mental health problems than peers without specific learning difficulties. For that reason, Study 2 was carried out with adolescents, as adolescence is characterized as a transitioning period in life with many psychological changes, and it is regarded as the onset of anxiety and psychological disorders.

Although evidence suggests that children with dyslexia are more prone to anxiety and emotional disorders (Burden, 2008; Jordan & Dyer, 2017; Jordan et al., 2014; Carroll et al., 2005,), some of these studies did not look at children with dyslexia only but also included children with other comorbid difficulties. In that case, the results might be biased when conclusions are made. Dyslexia and socio-emotional difficulties, including anxiety and self-esteem are often studied together as they are considered as psychological and socio-emotional consequences of dyslexia (Novita, 2016; Eissa, 2010).

Furthermore, despite early research on stress and anxiety in the academic and school environment, there is limited research in the UK on “examination” stress and anxiety (Putwain, 2007). Gallagher et al. (1996) found that examinations were the greatest reported cause of stress and anxiety for secondary school students. Students with specific learning difficulties report higher rates of test anxiety (Sena et al., 2007; Zeidner, 1990; Peleg, 2009), however the relevant research is very limited in the UK, particularly with reference to test anxiety in adolescence.

Despite research on internalising problems of adolescents with dyslexia (Arnold et al., 2005; Carroll & Iles, 2006; Alexander-Passe, 2006), there has been no systematic analysis on mental health problems in students with dyslexia, particularly on different domains of anxiety disorders. Study 2 investigated the psychological problems of dyslexic and non-dyslexic adolescents who were at risk of dropping out of school by assessing symptoms of anxiety and self-esteem. Study 2 sought to build a psychological profile of adolescents with dyslexia and explore potential differences in psychological and emotional well-being between dyslexic and non-dyslexic adolescents at risk of dropping out from school.

6.3 Hypotheses for Study 2

Based on past research that was discussed in section 6.1, the following hypotheses were reported in study 2.

Based on previous literature (Arnold et al., 2005; Blicher et al., 2016; Carroll & Iles, 2006;) (see section 6.1), which has demonstrated a relationship between specific learning difficulties and state and trait anxiety, hypothesis 1 was:

- Hypothesis 1a: It was predicted that dyslexic adolescents will show higher levels of state anxiety, on the Spielberger State and Trait anxiety scale (1970), compared to non-dyslexic adolescents.
- Hypothesis 1b: It was predicted that dyslexic adolescents will show higher levels of trait anxiety, on the Spielberger State and Trait anxiety scale (1970), compared to non-dyslexic adolescents.

Based on previous research (Cassady & Johnson, 2002; Peleg, 2009) (see section 6.1) which has demonstrated a relationship between dyslexia and test anxiety, hypothesis 2 was:

- Hypothesis 2: It was predicted that dyslexic adolescents will show higher levels of test anxiety, on the Westside Test Anxiety Scale (2004), compared to non-dyslexic adolescents.

Based on previous research (Alexander-Passe, 2008; Elbaum & Vaughn, 2001; Riddick, 2009) (see section 6.1) which has demonstrated a relationship between dyslexia and self-esteem, hypothesis 3 was:

- Hypothesis 3: It was predicted that dyslexic adolescents will show lower levels of self-esteem, on the Culture-Free Self-Esteem Inventory (2002), compared to non-dyslexic adolescents.

6.4 Methodology

6.4.1 Ethical considerations

Study 2 received ethical approval from the Department of Psychology Research Ethics committee in accordance with the University of Sheffield's Research Ethics Approval Procedure. Permission to conduct this study in the school premises was obtained from the School Head and the Learning Provider. After approval from the School Head, an Invitation Letter, a Participant Information Sheet, and an Informed Consent Form were sent to parents via school. If the parent consented and the child wished to participate, they were invited to sign the consent form and return it to school.

Constant liaison with relevant staff ensured none of the participants felt particularly emotionally vulnerable regarding their dyslexia, in line with Singer's (2005) suggestion that dyslexic children are at an increased risk of intense emotional reaction. The participants were told the aims of the study at the onset and again after completion of the study and were encouraged to ask as many questions as they wanted. The participants were informed that they could withdraw from the study at any time without giving any reason. None of them withdrew from the study.

6.4.2 Participants

Study 2 was conducted in collaboration with the Sheffield Futures Organization (www.sheffielffutures.org.uk) which assisted with the recruitment of participants. The

Sheffield Futures Organization is a UK government - funded initiative tasked with improving retention of adolescents at risk of dropping out from education and offers a number of services to young people to help them with all different aspects of their lives. The Organization supports students in school and in community youth clubs by offering support for anti-social behaviour and any problems in school in order to help them stay in school post-16 education. Sheffield Futures was approached as a portal to different secondary schools in Sheffield, to help with the recruitment of a large number of participants.

A sample of 45 students participated in Study 2. Two groups of students were identified by the Learning Support Provider. The Learning Support Provider had a learning support and pastoral care support role for students with further educational needs. The first group was adolescents with dyslexia, and the second group was adolescents without dyslexia, aged 14 and 15 years, from Year 10. The mean age of the sample was 14.4 years of age. A total of 45 students were recruited (20 females, 25 males); of those students, 20 had dyslexia (8 females, 12 males), and 25 students did not have dyslexia (12 females, 13 males). None of the students with dyslexia had comorbidity with any other developmental or neurological disorder (e.g. ADHD, SLI, autistic spectrum disorder). The students who were identified as having dyslexia had a formal/suspected diagnosis of dyslexia either from the educational psychologist within the school or from a diagnostic Centre outside the school. The non-dyslexic adolescents were not known to have a previous diagnosis of learning or other developmental difficulties. All the participants were selected by the Learning Provider as they showed signs of disengaging from school and having low school grades.

6.4.3 Materials and Apparatus

All the measures used in the study were chosen for age appropriateness, reliability and validity. The measures have been used after consulting with the learning provider regarding the suitability of the vocabulary used in the instruments. It is important to note that the measures in the current study were not used as diagnostic tools for clinical anxiety disorders but rather to identify and describe the symptoms of anxiety disorders.

State – Trait Anxiety Inventory (STAI)

The State – Trait Anxiety Inventory (STAI) is a self-report measure designed to assess the intensity of feelings of anxiety. The STAI has two subscales: the State Anxiety and the Trait Anxiety. State and Trait anxiety was first proposed by Spielberger et al. (1970) to investigate the construct of anxiety, and the relationship to behaviour and learning. The items of the STAI included ones from the Taylor Manifest Anxiety Scale (TMAS; Taylor, 1953), ones from Cattell's 16 Personality Factor Questionnaire (Cattell, 1949) and ones from Spielberger et al. (1970) Questionnaire. The scale has been used with normal adolescent (Cameron et al., 2007) and adult samples, as well as with patient samples. The STAI adult form was used in the present study, designed for norm groups (over 13 years old) including high school students, and it was also used in previous research with adolescents (Beauchemin et al., 2008).

The State Anxiety scale (S-Anxiety) refers to a current state of anxiety, experienced in specific situations, and the participants have to answer how they feel 'right now' on a given occasion. The items used in this scale refer to unpleasant feelings of apprehension, tension, nervousness, and worry. The Trait Anxiety Scale (T-Anxiety) is used to assess dispositional anxiety (a general tendency to perceive situations as threatening) and feelings of stress, worry and discomfort, experienced on a daily basis, and also to indicate chronic anxiety symptoms. The STAI has 40 items, with 20 items for each of the S(tate)-Anxiety and T(rait)-Anxiety subscales. Responses for the State Anxiety Scale indicate intensity of current feelings "at this moment", and they are rated on a 4-point scale, from 1) not at all, through 2) somewhat, 3) moderately so, to 4) very much so. S-Anxiety items include: "I feel calm"; "I feel upset".

Responses for the T-Anxiety Scale indicate frequency of feelings in "general", rated on a 4-point scale, from 1) almost never, through 2) sometimes, 3) often, to 4) very much so. T-Anxiety items include: "I worry too much over something that really doesn't matter" and "I am a steady person". Both scales include items of absent and present feelings of anxiety. For instance, 'I feel secure' is an item referring to absent feelings of anxiety, whereas 'I feel worried' is an item referring to present feelings of anxiety.

Item scores of each scale are added to generate the total score for each scale. Positively stated questions are reversed before calculating the total score. Scores range between 20 and 80 for each subscale; higher scores indicate higher anxiety levels. A cut point of 39-40 has been suggested (Knight et al., 1983) to detect clinically significant symptoms for the State and Trait anxiety scales; however, other studies (Kvaal et al., 2005) have suggested a higher cut-off score of 54-55 for older adults. Internal consistency coefficients have ranged from .83 to .94 for the State scale, and from .86 to .91 for the Trait scale for high school students and adolescents (Gaudry et al., 1975; Spielberger et al., 1983). Test-retest reliability coefficients have ranged from .31 to .86 over a 2-month interval (Spielberger et al., 1983). In the present study, Cronbach's α was .85 for the State Anxiety scale, and .87 for the Trait Anxiety scale, both of which showed good internal consistency.

Westside Test Anxiety Scale

The Westside Test Anxiety scale was also used in Study 1 and is described in chapter 5 (see section 5.4.4).

Culture-Free Self-Esteem Inventory – Third Edition

The Culture-Free Self-Esteem Inventory is described according to the manual. The CFSEI-3 is a self-report measure designed by Battle (2002) to assess personal traits and characteristics in children and adolescents. There are three forms of the inventory: i) the Primary, assessing ages 6 through 8; ii) the Intermediate, assessing ages 9 through 12; and iii) the Adolescent, assessing ages 13 to 18. For the present study, the Adolescent version was used to assess self-esteem. According to the Manual, the CFSEI-3 takes 15 to 20 minutes to administer and produces a total score, the Global Self-Esteem Quotient (GSEQ), which shows overall performance. Responses are in the form of yes or no. A yes response was scored as 1; a no response was scored as 0. The CFSEI-3 yields three types of normative scores: standard scores for the subscales, a composite called the Global Self-Esteem Quotient (GSEQ), and percentiles. According to the CFSEI-3 manual, standard scores provide the clearest indication of a student's subscale performance. CFSEI-3 subscale standard scores have a mean of 10 and a standard deviation of 3. The measure consists of 67 items, separated in five subscales:

- Academic Self-Esteem measures an adolescent's perception of his/her ability to perform academic tasks – items include: 'Are you satisfied with your schoolwork?'.
- General Self-Esteem measures an adolescent's overall perceptions of self-worth – items include: 'Are you happy most of the time?'.
- Parental/Home Self-Esteem measures an adolescent's perceptions of his/her status at home, including subjective perceptions of how the individual feels his/her parents view him/her – items include: 'Are you comfortable telling your parents about your problems?'.
- Personal Self-Esteem measures an individual's perceptions of anxiety and self-worth – items include: 'Are you often upset about something?'.

• Social Self-Esteem measures an individual's perception of the quality of his/her relationships with peers – items include: 'Do you spend most of your free time alone?'.

The total score of the scale is calculated by summing the subscales' standard scores that create the Global Self-Esteem Quotient. According to the manual, the Global Self-Esteem Quotient is the most reliable score. On the CFSEI-3, the quotient is a standard score that has a mean of 100 and a standard deviation of 15. GSEQs from 90 to 110 are considered normal and account for almost 50% of the population. Scores outside that range are considered problematic and warrant diagnostic attention. Unusually high scores GSEQs (i.e., above 110) may indicate socially desirable responses or a deliberate attempt to present a very positive self-image. The GSEQ may reflect especially high self-esteem, mature socio-emotional development, or exceptional mental health. Very low GSEQs (i.e., below 90) indicate a problem such as poor self-esteem, immature behaviour patterns, negative feelings, or unsatisfactory adjustment. The following cut-off scores are suggested in the manual: a Quotient < 70 indicates very low self-esteem, a Quotient between 70 and 79 indicates low self-esteem, a Quotient between 80 and 89 indicates below average self-esteem, a Quotient of 90 to 110 indicates average self-esteem, a Quotient of 111 to 120 shows above average self-esteem, a Quotient between 121 and 130 shows high self-esteem, and a Quotient > 130 indicates very high self-esteem. Percentiles, or percentile ranks, represent values that indicate the percentage of the distribution that is equal to or below a particular score. For example, a percentile of 56 means that 56% of the standardization sample scored at or below the student's score (Battle, 2002).

According to the GSEQ manual, the measure also includes some items which yield a Defensiveness Score. The Defensiveness Score is not a measure of self-esteem; it is a lie scale. Endorsement of these items is a rudimentary indication of the extent to which a student's responses are guarded. The items that comprise this score are designed to measure how comfortable students feel to disclose socially unacceptable or undesirable behaviours. One of the statements of this subscale is, ‘I always tell the truth’. The student who responds yes to this item, claiming to always tell the truth, would appear to be more reluctant to display his/her true feelings. The CFSEI-3 provides cut-off scores that are based on normalized data from the normative sample. Any Defensiveness Scores at or above the recommended cut-off scores fall in the upper 25% of the range of scores. The recommended cut-off score is: 4 out of 8 (Battle, 2002). According to Battle (2002), the CFSEI-3 demonstrated good reliability and validity through correlations with other measures of self-esteem, from .51 to .85 for related subscales, and .56 to .90 for the total self-esteem scale. Test-retest reliability coefficients lied between .68 to .98, with most scores being above .75. In the present Study, Cronbach’s α was .81for the total Self-esteem scale.

6.4.4 Rationale for the measures used

The *State – Trait Anxiety Inventory (STAI)* (Spielberger et al., 1970) has been used previously in studies of students with specific learning difficulties and anxiety. Arnold et al. (2005) used the Trait Anxiety Inventory in their study, in tandem with a behavioural and a depression scale, to explore the differences between adolescents with specific learning difficulties and adolescents without. They found that adolescents with specific learning difficulties scored higher on trait anxiety than typically achieving students.

The State Anxiety scale was included in the study as it is more likely for individuals with anxiety to present their anxiety symptoms under conditions perceived as very challenging, in terms of their specific anxiety concerns (Barlow, 1988). The scale has also shown good internal consistency and test-retest reliability, which made it a reliable measure to use.

The Westside Test Anxiety Scale (WTAS) has been used in previous studies with students from different educational levels, such as adolescents, secondary and high school students and students in higher education. Uwakwe and Akanbi (2017) used the scale in their study to examine differences between secondary school students with learning disabilities and students without, and to study the effectiveness of Dialectical Behavior Therapy in reduction of test anxiety. Although it was found that there were no significant differences between students with and without learning disabilities, it was found that students who participated in the DBT had a reduction in text anxiety levels after the intervention. The Westside Test Anxiety Scale has also been used in many studies with students to examine test anxiety levels after participating in a test anxiety reduction intervention. Driscoll (2006) conducted a tense-release intervention study with college and high school students using the Westside Test Anxiety Scale. The results showed that the intervention group showed a benefit of 1.5 SD at post-test compared to the control group. The WTAS was chosen for this study as it has been proved to be a reliable and valid measure of test anxiety, as well as because it has previously been used in studies with stress-reduction interventions. Changes in anxiety as measured by the Westside Scale have been found to positively correlate with changes in test performance (Miller et al., 2005). As it was mentioned before, the current study is divided into two parts; the second half of the study examined the effectiveness of a Mindfulness intervention on test anxiety as well as on other psychological measures. Therefore, this measure was considered reliable and appropriate to use in this study.

The Culture-Free Self-Esteem Inventory has been used in previous studies with adolescents with dyslexia. Alexander-Passe (2006) used the CFSEI to investigate differences between dyslexic and non-dyslexic teenagers. It was found that the dyslexic teenagers scored lower in the Global self-esteem as well as in each CFSEI subscale, except the Social self-esteem subscale, compared to non-dyslexic teenagers. Ntshangase et al. (2008) studied adolescent boys with and without learning disabilities on self-esteem. They used the CFSEI and found that there were no significant differences between the two groups of boys for each subscale of the CFSEI as well as for the Global self-esteem. Thomson (1996) studied three groups of students over an 18-month period and found that the CFSEI could identify how students' social and academic self-esteem improved after following special teaching methods designed for students with dyslexia. The designer of the scale (Battle, 2002) was a special needs teacher, and thus the measure was designed to use with children with special educational needs.

6.4.5 Procedure

Permission to conduct the study was granted by the school officials. Parents and students were notified and provided an explanation of the study, and parents had to give their permission and sign the consent forms for their children to participate in the study. Prior to the data collection, the parent consent forms along with the students' assent were obtained by the Experimenter. Students were tested in groups of five in a quiet classroom; they all completed the measures individually, with the learning provider being present in the beginning of the assessment. Each student was given a packet of questionnaires to complete, which were distributed and collected by the Experimenter. All questionnaires were filled out on the paper with pen or pencil.

The test battery included the State-Trait Anxiety Inventory, the Westside Test Anxiety Scale, and the Culture–Free Self-Esteem Inventory. The measures were given in that order so that students could complete the anxiety measures first; in particular, starting with measures of general anxiety (state and trait anxiety), followed by a more specific anxiety measure (test anxiety), ending the assessment with measures of self-esteem.

Students were taken out of the classroom for approximately 30 minutes with the consent of the teacher. Before the assessment began, the researcher explained the purpose of the study and gave instructions of how the students would complete the study. Students were encouraged to read the directions on top of each measure of how to respond to the questions, to answer honestly and to ask the Experimenter any questions if they did not understand any of the questions or how to answer a question (only a few students asked for a clarification of how to respond to the questions). Students were informed that their responses would be kept confidential and neither their parents, or teachers or classmates could see their responses, except the Experimenter and the research group. Soon after the students completed the measures, the Experimenter checked that the questionnaires were completed correctly (e.g., there were no information missing, unanswered questions, or no questions marked with two answers). Students who had information missing or left some questions unanswered, were asked to complete them all, and students who gave more than one answer to a question were asked to select only the answer that was most representative of them.

6.5 Results

6.5.1 Descriptive statistics

Table 6.1 reports the mean scores and standard deviations by group, and gender, along with effects sizes, for each variable.

Table 6.1 Mean scores and standard deviations by group and gender, along with effect sizes, for each variable

	Gender	Dyslexics Mean (SD)	Non-dyslexics Mean (SD)	Total (gender) Mean (SD)	Effect size
State anxiety	Male	41.83 (5.59)	37.54 (4.71)	39.60 (5.50)	0.79
	Female	41.00 (5.73)	37.25 (5.86)	38.75 (6.00)	
	Total (group)	41.50 (5.51)	37.40 (5.18)	-	
Trait anxiety	Male	48.17 (6.20)	42.77 (4.64)	45.36 (6.00)	0.96
	Female	46.50 (7.33)	43.91 (4.14)	44.95 (5.60)	
	Total (group)	47.50 (6.53)	43.32 (4.35)	-	
Test anxiety	Male	3.06 (.31)	2.87 (.50)	2.96 (.42)	0.71
	Female	3.25 (.53)	2.80 (.31)	3.00 (.46)	
	Total (group)	3.13 (.41)	2.84 (.41)	-	
Self-esteem	Male	90.92 (7.48)	95.15 (4.76)	93.12 (6.45)	-1.15
	Female	89.75 (7.92)	96.17 (4.32)	93.60 (6.67)	
	Total (group)	90.45 (7.47)	95.64 (4.49)	-	

6.5.1.1 Distribution of categorical scores.

Figures 6.1 and 6.2 show the distribution of categorical scores for each variable and for each group. The distribution of scores was checked with frequencies. Figure 6.1 shows that half of the students in the dyslexic group (50%) revealed a distribution with high frequency of scores falling into the ‘high anxiety’ category (scores > 40) in the state anxiety variable, while only 28% of the students in the non-dyslexic group showed high levels of state anxiety.

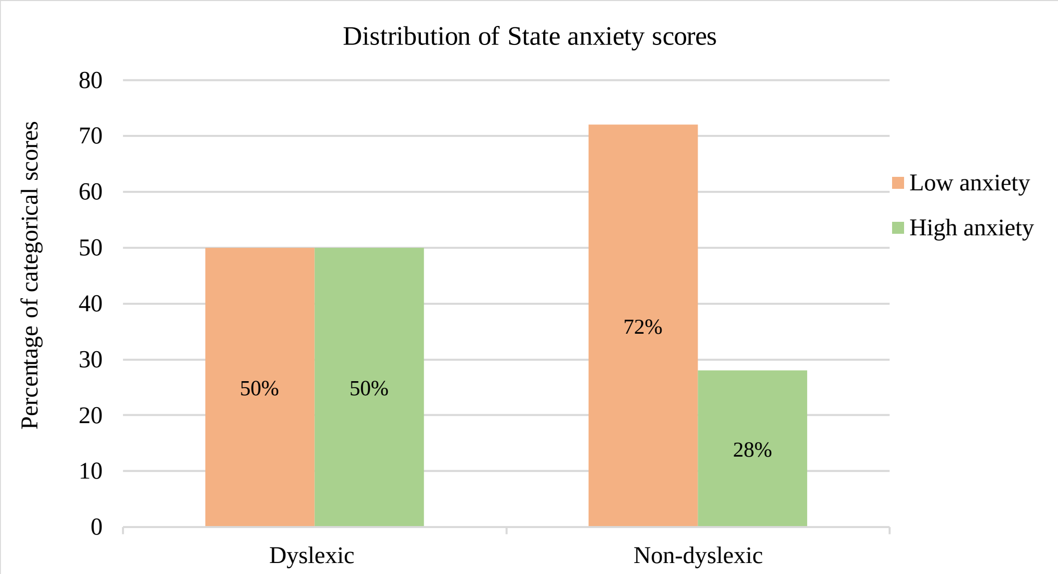


Figure 6.1 Distribution of state anxiety categorical scores

More than half of the dyslexic group revealed a distribution with high frequency of scores (80%) in the 'high trait anxiety' category, as well as more than half of the students in the non-dyslexic group (64%) scored within the 'high trait anxiety' category (see Fig. 6.2).

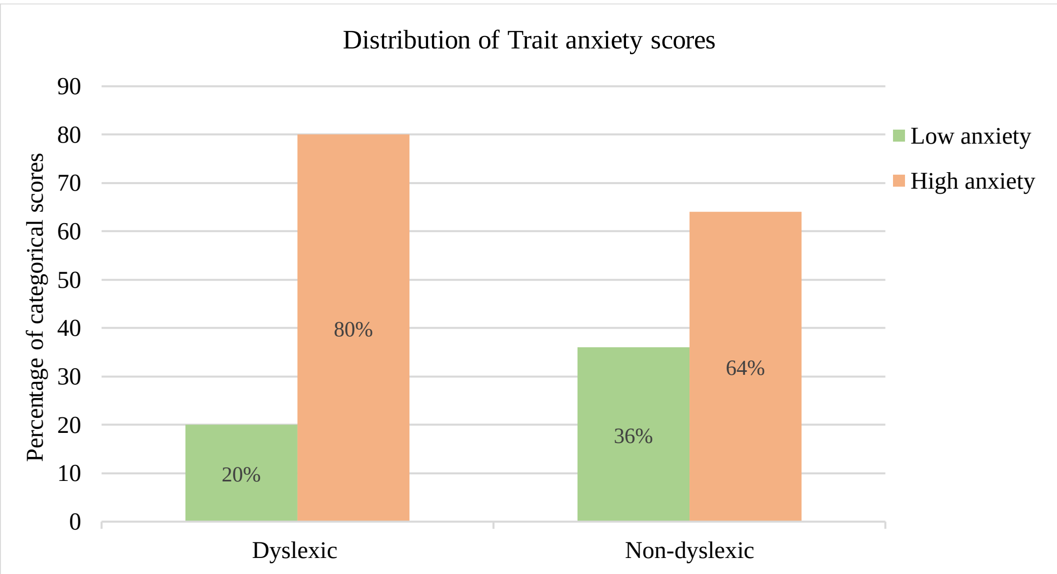


Figure 6.2 Distribution of trait anxiety categorical scores

Figure 6.3 shows that the dyslexic group revealed a distribution with high frequency of scores (35%) in the 'moderately high', and 'high normal' (35%) test anxiety category, followed by lower scores in the 'high' (20%) test anxiety category. A low frequency of scores (5%) was revealed in the 'normal' and in the 'extremely high' test anxiety category. The dyslexic group showed no scores in the 'low' test anxiety category. The non-dyslexic group showed a distribution with high frequency of scores in the 'high normal' (40%) category, followed by lower scores (28%), in the 'normal' test anxiety category, 'moderately high' (24%) test anxiety category, and a very low frequency in the 'high' test anxiety category (8%). Students in this group showed no scores within the 'extremely high' and 'low' test anxiety category.

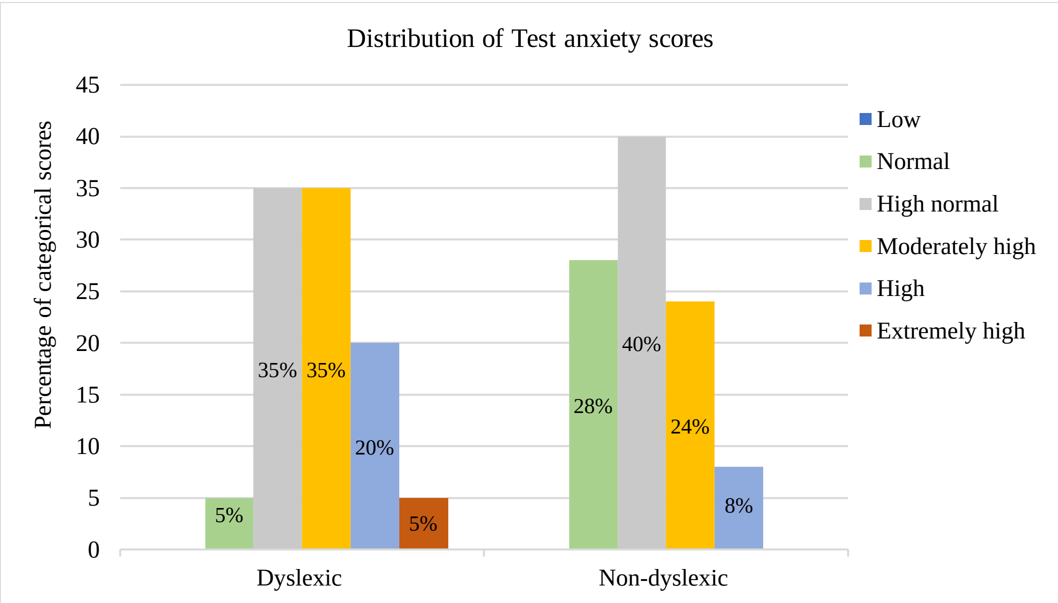


Figure 6.3 Distribution of test anxiety categorical scores

Figure 6.4 shows that half of the students in the dyslexic group showed the highest frequency of scores in the 'average' self-esteem category, followed by lower scores (40%) within the 'below average' category, and a very low frequency (10%) in the 'low' self-esteem category; the dyslexic group showed no scores in the 'very high', 'high', 'above average', and 'very low' category. By contrast, most students in the non-dyslexic group revealed a distribution with high frequency of scores (92%) in the 'average' self-esteem category, and a very low frequency (8%) of scores in the 'below average' self-esteem category. The non-dyslexic group did not show scores in the rest of the categories.

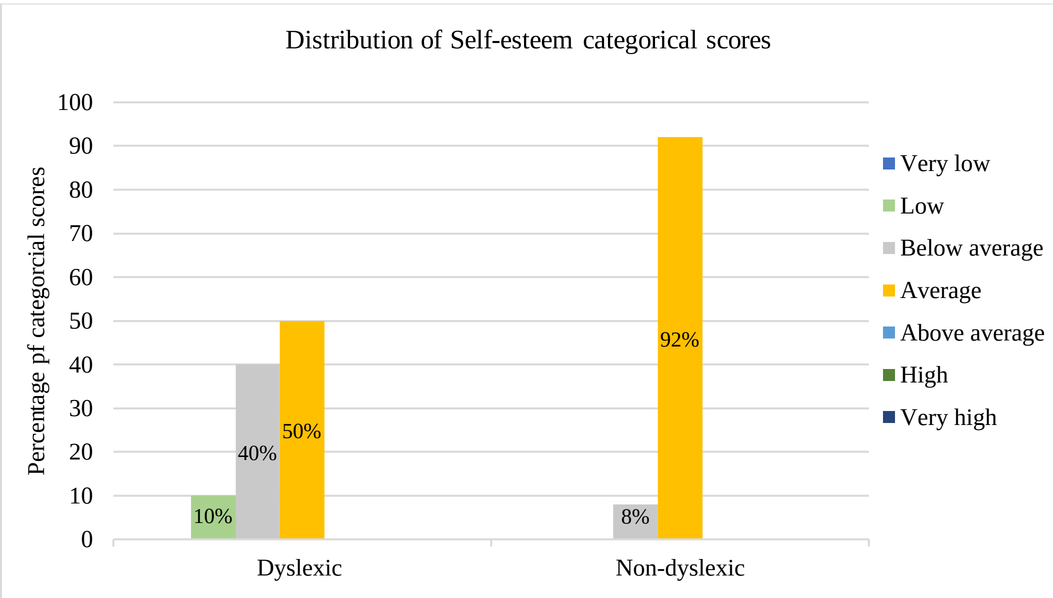


Figure 6.4 Distribution of Self-esteem categorical scores

6.5.2 Statistical analysis

The normality of data was checked using a Shapiro-Wilk test, along with the inspection of histograms, which showed that the data was normally distributed. The examination of boxplots indicated that there were a few outliers in the data, however, they were not significant outliers, and hence it was not necessary to remove them from the analysis. A series of two-way between group ANOVAs were conducted to explore the impact of group (dyslexic vs non-dyslexic) and gender on the examined measures, and to explore any interaction effects between them. The Levene's test showed that the assumption of equality of error variances was met for all the variables ($p > .05$). Due to the small sample size, and comparisons being significant in the same direction, p-values were not adjusted. This method was also suggested by previous research (Gallant & Nicolson, 2017; Moran, 2003; Moore, McCabe, & Craig, 2017). Although the Bonferroni correction is a method used in research, this approach can lead to Type II errors and to underestimation of the results (Perneger, 1998; Mitchell, 1998).

6.5.2.1 Between group and gender statistical tests.

On all the anxiety measures, higher scores indicate higher levels of anxiety; on the self-esteem measure, higher scores indicate higher levels of self-esteem.

State anxiety

A two-way ANOVA showed a significant main effect for group in state anxiety, $F(1, 41) = 5.90$, $p = .02$, with the dyslexic group reporting significantly higher levels of anxiety compared to the non-dyslexic group. There were no gender differences in state anxiety (see Table 6.1 for mean scores and Standard deviations), $F(1, 41) = .11$, $p = .73$, or an interaction effect between group and gender, $F(1, 41) = .03$, $p = .87$.

Trait anxiety

The results revealed a significant difference between the groups in trait anxiety, with the dyslexic group scoring significantly higher than the non-dyslexic group, $F(1, 41) = 5.70$, $p = .02$. No differences were found between males and females, $F(1, 41) = .02$, $p = .87$, and no interaction effect between group and gender, $F(1, 41) = .71$, $p = .40$.

Test anxiety

There was a significant main effect for group on test anxiety, $F(1, 41) = 6.19$, $p = .01$, with the dyslexic group scoring higher compared to the non-dyslexic group. There was no main effect for gender, $F(1, 41) = .27$, $p = .60$, and no interaction effect between group and gender, $F(1, 41) = .99$, $p = .32$.

Self-esteem

A Two-way ANOVA was conducted to test for group differences for the Global Self-Esteem Quotient. A separate analysis was conducted for the self-esteem subscales. By viewing self-esteem as a multidimensional entity, there was a significant main effect for group, $F(1, 41) = 8.24$, $p = .006$, with the dyslexic group scoring lower than the non-dyslexic group on the Global Self-esteem Quotient (see Table 6.1). There was no main effect for gender on the Global Self-esteem Quotient, $F(1, 41) = .00$, $p = .97$, and no interaction effect between group and gender, $F(1, 41) = .34$, $p = .56$.

Table 6.2 presents the means and standard deviations, for the dyslexic and non-dyslexic group, along with effect sizes, for each self-esteem subscale.

Table 6.2 Means and standard deviations, along with effect sizes, for the self-esteem subscales

Self-esteem subscale	Sample Group	Mean	Standard deviation	Effect size
Academic	Dyslexic	7.65	1.60	-1.19
	Non-dyslexic	9.36	1.44	
General	Dyslexic	10.0	1.97	0.21
	Non-dyslexic	9.60	1.89	
Parental/Home	Dyslexic	7.75	1.71	-1.16
	Non-dyslexic	10.0	1.93	
Social	Dyslexic	8.85	1.70	-0.05
	Non-dyslexic	8.92	1.47	
Personal	Dyslexic	8.90	2.07	-0.13
	Non-dyslexic	9.12	1.62	
Defensiveness	Dyslexic	3.10	.79	0.30
	Non-dyslexic	2.68	1.38	

Figure 6.5 presents the distribution of categorical scores (converted to self-esteem category ratings) for the dyslexic group for each of the self-esteem subscales.

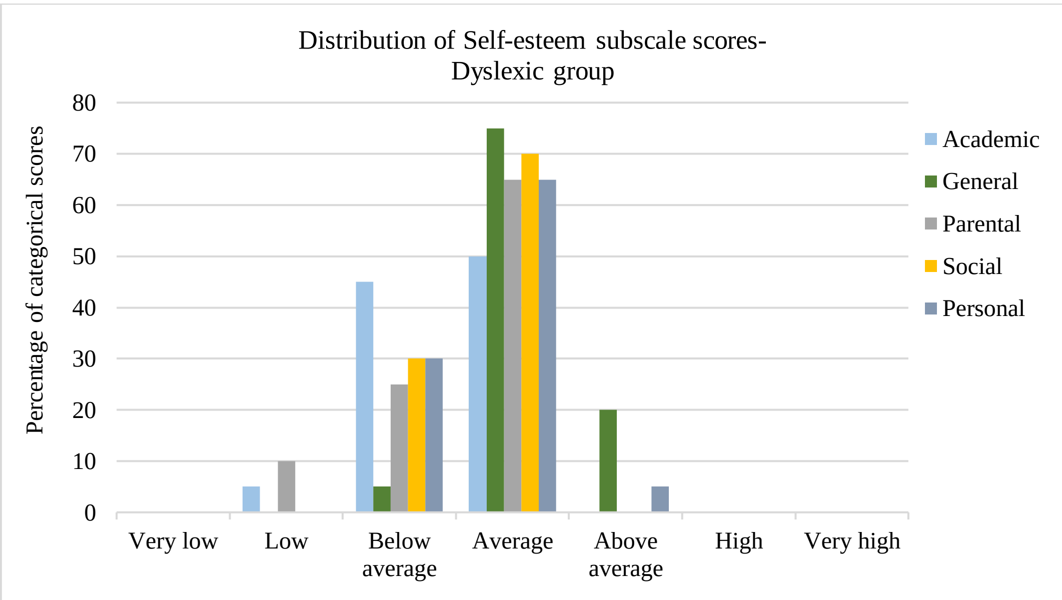


Figure 6.5 Distribution of Self-esteem subscales categorical scores for the dyslexic group

Figure 6.6 presents the distribution of categorical scores for the non-dyslexic group for each of the self-esteem subscales. Across both groups, no scores fell within the *very low*, *high*, or *very high* categories.

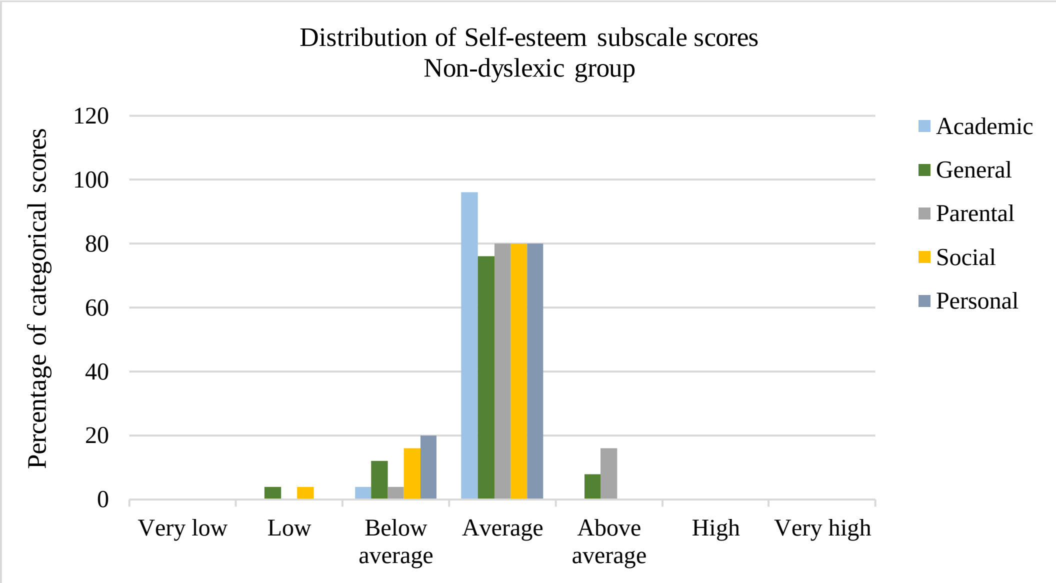


Figure 6.6 Distribution of Self-esteem subscales categorical scores for the non- dyslexic group

An Independent Samples t-test was conducted for the normally distributed data, and a Mann-Whitney U test for the non-normally distributed data, to test for differences between the groups in each of the self-esteem subscales. The results showed that there were significant differences between the groups only in two facets of self-esteem. An independent samples t-test showed that the dyslexic group scored lower on the Academic self-esteem subscale compared to the non-dyslexic group (see Table 6.2 for mean scores), t (43) = -3.770, $p < .001$.

A Mann-Whitney U test showed that the dyslexic group scored lower on the Parental/Home self-esteem subscale compared to the non-dyslexic group U= 102.5, p = .001. No differences were found between the groups on the rest of the subscales; General (U = 232.0, p = .67), Social (U = 249.5, p = .99), Personal (U = 227.5, p = .60), Defensiveness (U = 212.0, p = .36) (see Table 6.3 for mean ranks).

Table 6.3 Mean Rank of the self-esteem subscales

Self-esteem subscale	Group	Mean Rank	Sum of Ranks
General	Dyslexic	23.90	478.00
	Non-dyslexic	22.28	557.00
Parental/Home	Dyslexic	15.63	312.50
	Non-dyslexic	28.90	722.50
Social	Dyslexic	23.03	460.50
	Non-dyslexic	22.98	574.50
Personal	Dyslexic	21.88	437.50
	Non-dyslexic	23.90	597.50
Defensiveness	Dyslexic	24.90	498.00
	Non-dyslexic	21.48	537.00

6.5.2.2 Correlations by gender for the total sample.

A Pearson correlation test was conducted to assess the relationship between gender and all the measures (see Table 6.4 and Table 6.5). Overall, correlations between anxiety measures and self-esteem were low for both boys and girls of the total sample. Significant positive correlations were only reported between state and trait anxiety for boys and girls.

Table 6.4 Correlations among all study variables for boys (n=25)

Measures	1	2	3	4
1. State anxiety	-	.83**	.27	-.08
2. Trait anxiety			.39	-.07
3. Test anxiety				-.16
4. Self-esteem				-

Note. $p < .001$

Table 6.5 Correlations among all study variables for girls (n=20)

Measures	1	2	3	4
1. State anxiety	-	.50*	.38	.08
2. Trait anxiety			.35	-.16
3. Test anxiety				-.21
4. Self-esteem				-

Note. $p < .001$

6.6 Discussion

Hypothesis 1a and 1b: It was predicted that the dyslexic adolescents will show higher levels of state and trait anxiety, on the Spielberger State and Trait anxiety scale (1970), compared to the non-dyslexic adolescents.

The findings of the present study reported considerable differences between the dyslexic and non-dyslexic adolescents in state and trait anxiety. However, although the scores of the dyslexic group were in the clinical range (> 40) for both state and trait anxiety, they were not considerably higher than the cut off scores. It cannot be concluded, therefore, that the dyslexic students were suffering with clinical symptoms of anxiety. The data showed that half of the dyslexic students scored high in state anxiety compared to 28% of the non-dyslexic students. It is notable that 80% of the dyslexic group scored high in trait anxiety compared to 64% of the non-dyslexic group, which also scored in the clinical range. The results of Study 2 supported the first hypothesis and are consistent with previous research (Livingston, et al., 2018; Boyes, et al., 2019; Carroll et al., 2005; Nelson & Harwood, 2011), which found that students with dyslexia or specific learning difficulties reported higher rates of anxiety problems as compared to typically achieving students. Arnold et al. (2005) found that adolescents with reading problems reported significantly higher rates of trait anxiety and somatic complaints compared to their peers without reading difficulties. Adolescence is a complicated and difficult period for most adolescents; however, it seems that it is even more stressful for adolescents with specific learning difficulties, due to the demanding academic and scholastic performance, which leads adolescents with specific learning difficulties to feel more frustrated and disappointed. Tsovili (2004) on the other hand, did not find differences between dyslexic and non-dyslexic children and adolescents in trait anxiety, but only in state anxiety after administering a reading task.

The findings of Study 2 showed that the dyslexic adolescents scored higher on state anxiety as compared to non-dyslexic adolescents, although they were not assessed on a reading task. This finding could mean that dyslexic children may perceive as a threat or as a difficult task anything that relates to reading or requires concentration, as it was the case in the present study, in which students had to complete and comprehend a series of questionnaires. Moreover, it has been suggested that state anxiety levels can be affected by trait anxiety levels (Stake et al., 1995; Wilken et al., 2000), which could also be the case for the adolescents in the present study who experienced high rates of trait anxiety. The results of Study 2 also provide further evidence to support the view that anxiety-related symptoms are evident in adolescents (Krohne & Hock, 2011; Van Ameringen, et al., 2014; Mugnaini, et al., 2009) and can also persist into adulthood, based on the results of Study 1, which showed that university students with dyslexia experienced higher rates of anxiety as compared to their non-dyslexic peers. The literature suggests that internalizing problems (such as anxiety, stress, depression) often increase with age (Wilson et al., 2009), therefore adults with specific learning difficulties may suffer with higher rates of anxiety because they do not receive the same support and provision they need, as they were receiving during their school years. However, as discussed in the introduction (see section 6.1), other studies (Lindeblad et al. 2019; Nelson & Liebel, 2017) did not find an association between dyslexia or specific learning difficulties and anxiety.

Hypothesis 2: It was predicted that the dyslexic adolescents will show higher levels of test anxiety, on the Westside Test Anxiety Scale (2004), compared to the non-dyslexic adolescents.

The results of Study 2 demonstrated, as hypothesized, that the adolescents with dyslexia scored significantly higher in test anxiety compared to the non-dyslexic adolescents. However, although the dyslexic group reported significantly higher rates than the non-dyslexic group, only 20% scored in the high anxiety category compared to 8% in the non-dyslexic group, and only 5% of the dyslexic group scored in the extremely high anxiety category. Most of the dyslexic students scored in the normal high and moderately high categories. Therefore, although the dyslexic group had higher anxiety levels than the non-dyslexic group, they did not score within the clinical range. This finding is consistent with previous studies (Wachelka & Katz, 1999; Pelek, 2009; Cassady & Johnson, 2002) which found high levels of test anxiety in students with specific learning difficulties. This finding is important for the dyslexic students, as academic achievement and academic success highly depend on test performance. Dyslexic students may perceive the exams and evaluative situations as a threat which consequently leads to high test anxiety (Peleg, 2009). Moreover, according to Swanson and Howell (1996), test anxiety is a risk factor for students with specific learning difficulties, who already possibly experience more academic failures due to insufficient learning skills. The finding of the present study shows that students with dyslexia feel more anxious when test-taking and being evaluated, which can potentially hinder their performance, as shown that general anxiety affects memory and cognitive skills, which are necessary for a successful performance (Swanson & Howell, 1996; Nelson et al., 2015).

The results of the present study are in contrast to previous studies (Lufi, et al., 2004; Lufi & Darliuk, 2005) which did not point to differences in test anxiety levels between adolescents with and without specific learning difficulties. A possible explanation for such results could be that students with specific learning difficulties may have developed some strength to deal with anxiety symptoms, and get adapted to daily negative experiences, especially those related to their school performance (Smith, 1991; Lufi et al., 2004; Lufi & Darliuk, 2005). The results of Study 2, regarding test anxiety, are also consistent with the results of Study 1 regarding test anxiety levels of the university dyslexic group. The results of both studies showed that the dyslexic group reported significantly higher rates of test anxiety compared to the non-dyslexic group, which indicates that test anxiety is a significant source of anxiety for both adolescents (Swanson et al., 1996; Lufi et al., 2004) and young adult students (Gaudry & Spielberger, 1971). The results show that adolescents and adult students perceive exams, and possibly the academic environment as threatening, thus they experience high levels of test anxiety during test-taking situations.

Hypothesis 3: It was predicted that the dyslexic adolescents will show lower levels of self-esteem, on the Culture-Free Self-Esteem Inventory (2002), compared to the non-dyslexic adolescents.

The findings of the present study indicate that adolescents with dyslexia in this sample scored lower in global self-esteem than the non-dyslexic adolescents, which supported the third hypothesis of this study. Although the dyslexic group showed lower levels of self-esteem compared to the non-dyslexic group, half of the dyslexic adolescents showed average levels of self-esteem, and 40% showed below average levels. The results of the present study showed that adolescents with dyslexia can have lower levels of self-esteem in some domains, but higher levels in other domains. In particular, the dyslexic group in the current study scored significantly lower in the Academic self-esteem subscale, and in the Parental/Home subscale, whereas no differences between the groups were reported for the General, Social, and Personal self-esteem subscales. A similar pattern of results to the Global self-esteem levels was identified in the Academic and the Parental/Home subscales levels, in which although the dyslexic group scored lower than the non-dyslexic group, half of the dyslexic adolescents showed average levels in the Academic subscale, and more than half showed average Parental/Home self-esteem levels. Thus, although the levels in these self-esteem subscales were lower than the non-dyslexic group, they did not fall within the low or very low levels of self-esteem.

The results of the present study are consistent with that of Casey et al. (1992) who found that students with reading difficulties showed lower levels of Scholastic competence but average levels of Global self-worth. Similarly, Snowling et al. (2007) found that adolescents with dyslexia reported lower levels of scholastic competence compared to the non-dyslexic group. Novita (2016) also reported that children with dyslexia showed lower self-esteem levels in the school setting as compared to their non-dyslexic peers. The results of the present study provide further evidence that adolescents with dyslexia did not only lack self-esteem in general situations, but more importantly in academic situations and in the home/family environment. It is evident from the results that dyslexia has a negative impact on self-esteem of adolescents, and this can probably be due to inferior feelings compared to their peers (Eissa, 2010).

Dyslexic students may have low self-esteem in academic situations due to repeated school failures, and less academic success compared to their normally achieving peers (Eissa, 2010). Ingesson (2007) reported that the teenagers and young adults with dyslexia, who participated in an interview study, stated that the school experience was very negative for them, and always felt like being different or inferior to their non-dyslexic peers. Riddick (1996) also reported that dyslexic children felt disappointment, anger, and embarrassment in front of their non-dyslexic peers, blaming their specific learning difficulties for these feelings. The results of the present study are also partially consistent with the results of Alexander-Passe (2006), regarding the levels of Global self-esteem, and the domains of Academic, and Parental/Home self-esteem, which were found to be lower in the dyslexic group than the non-dyslexic group. A possible explanation for low levels of academic self-esteem in dyslexic students could be due to feelings of 'learned helplessness' that are experienced by dyslexic students, mainly because of the repeated failures they have experienced during their school life, which makes it difficult for them to try harder and put more effort in academic situations (Joiner & Wager, 1995). In terms of the Parental/Home self-esteem subscale, the results indicated that the dyslexic group in the present study showed significantly lower levels than the non-dyslexic group. Previous research suggests that family and parents' support play an important role in building and maintaining positive self-image and self-esteem in children with specific learning difficulties (Palombo, 2001).

Nalavany and Carawan (2011) reported that the presence or absence of family support can influence positively or negatively the emotional experiences of individuals with specific learning difficulties, which in turn leads to low or high levels of self-esteem. The important role of parental and family support in individuals with dyslexia is also supported by Hellendoorn and Ruijjssenaars (2000) who reported in their study that adults with dyslexia perceived their parental support as the 'most powerful source of help' (p.237) during elementary school.

Previous research has reported gender differences in internalising disorders (including anxiety and depression), and self-esteem in typically developing adolescents (Bender et al., 2012; Derdikman-Eiron et al., 2011; Bolognini et al., 1996), as well as in dyslexic adolescents (Willcutt & Pennington, 2000; Darweesh et al., 2020; Alexander-Passe, 2007; Boyes et al., 2019; Alexander-Passe, 2006), with girls showing higher levels of anxiety compared to males. The results of the present study are not in line with previous studies though, as girls and boys in both groups showed comparable levels in all measures of anxiety, as well as in self-esteem. Although the literature reports that males and females use different coping strategies to respond to stressful situations (Endler & Parker, 1990), such differences in coping styles might have not been cultivated in adolescents yet. The present findings are in line with previous literature (Terras et al., 2009; Alesi et al., 2013; Grills-Taquechel et al., 2012; Hale et al., 2008), which reported comparable levels of internalising problems and self-esteem in dyslexic girls and boys. An explanation of these results suggests that gender differences in self-esteem begin to emerge after adolescence, as students age (Pepi et al., 2006), and girls start to follow the female stereotypes while boys follow the male stereotypes, respectively (Arens & Hasselhorn, 2014). It should also be noted that boys and girls from both groups scored similar in all of the measures, with scores being relatively high in both groups. As mentioned before, the non-dyslexic group was not a typical achieving group of adolescents; therefore, the specific characteristics of the group may have made it difficult to account for any gender differences within and between the groups.

Correlations among gender, anxiety and self-esteem were investigated in the present study, as previous research has suggested that psychosocial variables, such as self-esteem, are related to anxiety, particularly for girls. Previous studies have reported significant gender correlations between anxiety disorders and self-esteem in typically achieving adolescents, particularly for girls, except for self-esteem which was correlated more with boys than with girls (Bolognini et al., Derdikman-Eiron et al., 2011). The results of the present study, however, did not show gender associations with internalising problems and self-esteem, comparable to the results of Moksnes et al. (2010), which although reported an association between self-esteem and emotional conditions in adolescents, these were not moderated by gender. In general, in the present study, there were no significant correlations between anxiety disorders and self-esteem either for the girls or the boys.

6.7 Limitations

The results of the present study should be interpreted considering the following limitations. The first concern is the generalisability of the results due to the small sample size. Second, the assessment of anxiety problems and self-esteem was only based on students' self-reports and not on teacher's and parent's ratings. There are conflicting views in the literature regarding the most accurate sources of information for internalising and externalising problems of children and youth. Herjanic and Reich (1997) state that children are the most accurate sources of information regarding internalising problems, because the symptoms may not be observable by parents or teachers. Whereas clinicians believe that parent's reports are more accurate than children's reports, and thus they only depend on parents' ratings when making diagnoses for anxiety disorders. Third, the participants in the present study were not randomly chosen by the researcher, but they were chosen by the Learning Support Provider, as these participants were considered to benefit more from the present study.

6.8 Conclusion

Overall, the results of Study 2 suggested that dyslexic adolescents present significantly higher rates of internalizing problems, such as general anxiety, particularly state and trait anxiety, along with anxiety in more specific situations, such as when test taking. The results of the present study shed light on an important issue; the early identification and intervention for internalizing problems. It is important to diagnose and offer appropriate intervention for anxiety and emotional problems at a young age, as anxiety problems that are not addressed early are more likely to get more severe and lead to psychiatric disorders, such as depression, conduct disorder, and anxiety disorders in adulthood (Cicchetti, 1998), as it was also evidenced by the results of Study 1. Following on from this chapter, the next chapter investigates the effectiveness of a mindfulness-based intervention, in a school setting, and discusses the benefits of applying mindfulness in adolescents with psychological problems and low cognitive performance.

Chapter 7

Study 3: Positive Education and Positive Psychology in School – Effects of a mindfulness-based intervention on dyslexic and non-dyslexic adolescents

7.1 Introduction

The present chapter reports on the third empirical study, which aimed to investigate the effectiveness of a mindfulness-based intervention on anxiety disorders in a group of dyslexic and non-dyslexic adolescents at risk of dropping out of school.

As discussed in chapter 6, a significant amount of research has demonstrated that the prevalence of anxiety disorders and depression among adolescents is very high, nearly 32% (Merikangas et al., 2010; Coughlan et al., 2014). Depression has been reported to be a major cause for adolescents dropping out of school (WHO, 2013). Adolescents with dyslexia experience even higher rates of anxiety disorders compared to non-dyslexic adolescents, which are often related to academic and social pressures (Sanger et al., 2018; Nelson & Gregg, 2012; Alexander-Passe, 2006; Fischer et al., 1996). The psychological symptoms of dyslexia, such as anxiety and emotional disorders, often remain undiagnosed, and there may be no interventions until later in adulthood (Pradhan et al., 2017). Mental health problems that are left untreated can have negative effects on students' psychological well-being and functioning (McKeering & Hwang, 2019; McGorry et al., 2014). Previous researchers (Carawan et al., 2016; Scorza et al., 2018; Angold et al., 1999) have highlighted the importance of early diagnosis and early intervention for dyslexia and psychological problems, as dyslexic adults continue to experience psychological problems due to untreated or undiagnosed dyslexia and mental health problems. Positive education suggests the teaching of both well-being skills and skills related to academic success and achievement (Seligman et al.,2009). Positive psychology interventions, including mindfulness, have been used in the last few years in schools as a way to increase positivity, well-being, and empathy (Vago & Silbersweig, 2012).

The field of positive psychology was developed by Seligman and Csikszentmihalyi (2000) and is the study of positive emotions, such as happiness and pleasure, positive character traits such as interests and talents, and positive institutions, such as school and family. Positive psychology focuses on positive traits, such as life satisfaction, happiness, gratitude, well-being, and compassion (Peterson, 2006).

Seligman incorporated positive psychology into positive education, which is defined as the traditional education for both academic and life skills, and for life happiness (Seligman et al., 2009). Positive education is described as a paradigm that combines positive psychology with teaching to support schools and students to flourish and develop skills to increase positive well-being (Norrish et al., 2013). Positive education is an approach that focuses not only on academic teaching, but also on increasing positive emotions and psychological well-being (Seligman et al., 2009; Schiavon et al., 2020). Previous researchers have found that increased well-being is associated with improved learning, better attentional skills, and creative thinking, which are necessary skills for school performance (Frederickson & Branigan, 2005; Estrada, Isen, & Young, 1994). Evidence suggests that interventions that promote well-being, positive emotions, resilience, and engagement in learning can be taught in schools (Seligman et al., 2009; Norrish et al., 2013). Schools are the most appropriate settings to promote interventions for well-being as students spend most of their time in school, and schools can provide the spaces and equipment that are accessible to all students, as well as the appropriate practitioners to implement the interventions (Bond et al., 2007).

Although mindfulness practice is not a direct intervention of positive psychology, it is one of the tools of positive psychology, as mindfulness teaches the appropriate skills to improve positive emotions, well-being, empathy, life satisfaction, and quality of life (Baer, 2003; Vago, & Silbersweig, 2012).

Jon Kabat-Zinn (1994), the founder of Mindfulness-Based Stress Reduction (MBSR), defines mindfulness as 'paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally' (p.4). According to Chambers et al. (2009), mindfulness creates more accepting and non-judgmental emotions, rather than trying to avoid or overcome emotions. The first mindfulness technique was the mindfulness-based stress reduction (MBSR) intervention introduced by Kabat-Zinn (1982). Later, the mindfulness based cognitive therapy (MBCT) was introduced by Segal et al., (2002). Psychological treatments include some elements of mindfulness techniques such as acceptance and commitment therapy (Hayes et al., 1999). Mindfulness techniques teach cognitive awareness and self-awareness, promote self-acceptance, and help the mind disengage from thoughts that create stress and subsequent psychological problems (Biegel et al., 2009; Brown et al., 2007). Previous researchers have identified self-awareness, attention, and focus on breath as the core characteristics of mindfulness (Brown & Ryan, 2003; Napoli et al., 2005).

A number of studies have documented the benefits of mindfulness for physical and mental health in adults. The positive physical effects include reducing pain and improving physical conditions such as psoriasis, and psychosomatic disorders (Grossman et al., 2004; Simpson & Mapel, 2011). Mindfulness-based interventions have also been proved to be effective for mental health problems, such as in improving stress and anxiety disorders, depression, emotional disorders, and psychological wellbeing (Baer, 2003; Bohlmeijer et al., 2010). A meta-analysis study reported moderate effect sizes (d = .50-.59) on a number of physical and mental health measures (Grossman, et al., 2004). Based on Cohen (1988), the categories of effect sizes for interventions are labelled as small (0.2), medium (0.5), and large (0.8). The effectiveness of mindfulness-based interventions is also evident in younger and older adults in terms of improving executive function, sustained attention, working memory, and intellectual skills (Zeidan et al., 2010; Chambers et al., 2008).

Mindfulness-based practice is a relatively new concept in psychotherapy, especially for children and adolescents. However, there is an increasing body of research that demonstrates that in the last few years schools have started introducing mindfulness-based interventions in their curricula to help students with anxiety and emotional disorders and promote health and psychological well-being for students (Sanger, et al., 2018; Pepping et al., 2016; Zenner et al., 2014; Johnson et al., 2017). Most studies have modified the MBSR programmes used with adults in order to suit the adolescents' needs (Tan & Martin, 2013; Diaz-Gonzalez et al., 2018). Edwards et al (2014) investigated the effects of an MBSR for Teens programme, designed by Biegel et al. (2014), on 20 Latino middle school students. The participants followed an 8-week programme which included different practices, such as hatha yoga and walking meditation, together with some didactic presentations about mindfulness practice. The participants were assessed at 3 time-points on a number of self-report measures including mindfulness, self-compassion, perceived stress, anxiety, and depression. The results showed that the mindfulness group significantly increased their mindfulness and self-compassion scores, and significantly decreased their stress and depression scores.

A similar study was also conducted by Diaz-Gonzalez et al. (2018) who assessed the effects of the MBSR for Teens programme, by Biegel et al. (2014), on adolescents from a mental health facility in Spain. The participants followed an 8-week programme which included the same practices that were followed in Edwards et al. (2014) study. The adolescents from Diaz-Gonzalez et al. (2018) study were assessed at pre-test and post-test on a number of self-report measures including state and trait anxiety, perceived stress, self-esteem, and mindfulness. The results showed significant differences between the groups on state anxiety, with the mindfulness group scoring lower than the control group. The intervention also had a significant impact on the mindfulness group in regard to reducing high levels of trait anxiety and stress.

Childhood and adolescence might be the most appropriate developmental stages to teach mindfulness as children are open to learning new skills and concepts (Rempel, 2012; Semple et al., 2005). According to Rempel (2012), teaching mindfulness to children and youths can prepare them and teach them how to cope with future challenges. It is important for adolescents to learn how to cope with stressful and challenging situations, not only in school but also in social life, and to regulate their emotional responses; mindfulness appears to be a suitable intervention to teach that (Compas et al., 2001; Tan & Martin, 2013; Rawlett & Scrandis, 2015). In addition, coping mechanisms were found to act as mediators between stress and emotional responses (Tan & Martin, 2013). It has been evidenced that practicing mindfulness can increase the mechanism of thinking, which in turn helps emotional regulation – a key feature for academic success (Broderick & Jennings, 2012).

Previous studies (Semple et al., 2005; Emerson et al., 2017a) have found that school-based settings might be the most appropriate and convenient places for students (including those at risk of school failure; Rawlett & Scandris, 2015) to practice mindfulness in groups, as this is more cost-effective compared to individual clinic-based settings. Additionally, they can feel that they play the most important role in the intervention as mindfulness is a self-management practice, and thus it allows them to be the most important element in their own development (Semple et al., 2005). Mindfulness can teach children to regulate their focus and attention, to stop their mind wandering, and to cope with challenging situations and negative feelings and thoughts (Zenner et al., 2014). According to research (Semple et al., 2005; Rempel, 2012), since attention is the core characteristic of anxiety, mindfulness training is a potential psychoeducational intervention that can help reduce anxiety and improve students’ focus and attention.

Preliminary evidence of school-based mindfulness interventions suggests psychological benefits of mindfulness on adolescents (Biegel et al., 2009; Kuyken et al., 2013) such as reduced depression, reduced stress, and reduced anxiety levels, as well as improved well-being and positive affect (Huppert & Johnson, 2010; Raes et al., 2014). Hundred and two adolescents aged 14 to 18 years old, who had been diagnosed with psychiatric disorders, participated in a randomized control trial mindfulness study (Biegel et al., 2009). The adolescents were tested for a range of mental health symptoms such as stress, state and trait anxiety, depression, and self-esteem. The intervention group showed improvements in most measures, including state and trait anxiety, and in sleep quality. Another study (Kuyken et al., 2013) tested the efficacy of a mindfulness-based intervention with 522 adolescents aged 12 to 16 years old, in regard to well-being, stress, depression, and mindfulness skills at posttest and follow-up. The results indicated less depressive and stress symptoms, and greater well-being post treatment. Other studies have reported benefits of mindfulness programmes for adolescents in relation to ADHD (van de Weijer-Bergsma et al., 2011; van der Oord et al., 2011), internalizing and externalizing symptoms (Lee et al., 2008), and aggression (Franco et al., 2016). Previous research has shown that adolescents who improved their mindfulness skills obtained useful resources to cope with negative and difficult circumstances in life (Baer et al., 2012).

Test anxiety is a core factor that influences academic performance, and it is also an important cause of academic underperformance (Nivenitha & Nagalakshmi, 2016). Mindfulness training has been found to significantly reduce test anxiety. Shahidi et al. (2017) reported test anxiety reduction and improved emotion regulation in female high school students after practicing mindfulness for eight weeks; the mindfulness benefits lasted for three months after the initial testing. Cunha & Paiva (2012) investigated the differences between students with low and high-test anxiety regarding self-criticism, acceptance, and mindfulness skills. Students who suffered with high test anxiety reported greater levels of negative self-criticism as well as lower levels of self-acceptance and mindfulness skills. Cunha & Paiva concluded that high levels of self-criticism along with low levels of self-acceptance and low levels of mindfulness skills are crucial for the development and maintenance of test anxiety. Therefore, a mindfulness-based intervention could help students with test anxiety notice, recognize, and accept thoughts related to self-criticism without judgement. Mindfulness practice could also help highly anxious students improve their psychological wellbeing as well as their test performance.

Some preliminary results have reported the benefits of mindfulness interventions for self-esteem in adolescents and adults (Pepping et al., 2013; Rassmussen & Pidgeon, 2011). Similarly, Tan and Martin (2013) reported reduced distress and improved self-esteem in a group of adolescents with mental health problems after participating in a 5-week mindfulness-based practice. Similar results were reported in a study (Lau & Hue, 2011) with adolescents who participated in mindfulness practice; they showed enhanced personal growth and well-being, and reduced symptoms of depression compared to a control group. In contrast to previous studies, White (2012) explored the effects of mindful yoga on self-esteem and self-awareness in a group of fourth and fifth grade girls who either followed an 8-week yoga session or were allocated to the control group. The results indicated increased self-esteem and self-awareness for both groups post-intervention.

The attainment of mindfulness skills in adolescents has been reported in a few studies; however, not every study that investigated the benefits of mindfulness included a validated mindfulness measure. Mindfulness awareness, along with attentional and behavioural skills, were improved in adolescents with externalizing problems after participating in an MBSR practice for eight weeks (Bogels et al., 2008). Low mindfulness was found to be correlated with high levels of anxiety, depression, and poor functioning in adolescents (Pepping et al., 2016). Previous research (Pepping et al., 2016; Tan & Martin, 2013) has suggested that emotion regulation is a key feature in keeping anxiety and mental health problems at low levels. Emotion regulation refers to the processes by which 'individuals influence which emotions they have, when they have them, and how they experience and express these emotions' (Gross, 1998, p. 275). Pepping et al. (2016) reported a positive relationship between mindfulness and emotion regulation skills. Therefore, individuals with low mindfulness skills may find it harder to cope with negative emotions and thoughts, which in turn may lead them to maintain high levels of anxiety, depression, and other mental health problems.

Mindfulness practice has not only been found to associate with improvements in mental health, but also in cognitive functioning, attentional control (Jha et al., 2007; Valentine & Sweet, 1999), and other cognitive processes in adolescents, including executive function, working memory, and attention (Semple, 2010; Zeidan et al., 2010) – features that are necessary for successful learning. Childhood and adolescence might be the most appropriate time for the practice of mindfulness, as executive functioning, cognitive processes, and self-regulation develop at these developmental stages (Dunning et al., 2019). Self-regulation is a mechanism that is used to monitor, evaluate, and alter one's thoughts, emotions, and actions (Baumeister & Monroe, 2014). The literature suggests that self-regulation, including executive control and executive attention, is a core component of successful academic performance and reading achievement (Checa et al., 2008; Howse et al., 2003). Moore and Malinowski (2009) found that self-regulation of emotions enhances cognitive performance.

Saltzman and Goldin (2008) conducted an 8-week mindfulness-based intervention with 31 children aged 9 to 11. The children's parents participated in the mindfulness intervention too. The mindfulness instructors were teachers who had long-standing experience of mindfulness. The results indicated significant improvements in attention, meta-cognition, and emotional reactivity both in the children and their parents. A study (Quach et al., 2016) with 196 adolescents compared the effects of mindfulness practice to hatha yoga and to a waitlist control group on working memory skills, stress, and anxiety. The mindfulness group improved their performance on working memory compared to the hatha yoga and the control group, but no differences were found between the groups in terms of their stress and anxiety levels. Natesh et al., (2014) explored the relationship between mindfulness, visuo-spatial working memory, and state anxiety in children. Visuo-spatial working memory was tested using the Corsi-Blocks task, in which the participants had to remember a sequence of blocks both in a forwards and backwards version. The results showed significant positive correlations between mindfulness and visuo-spatial working memory, and state anxiety.

Children aged 7 and 8 years, who reported high levels of anxiety, were found to have improved attention and concentration skills along with reduced anxiety levels after participating in a 6-week trial mindfulness programme (Semple et al., 2005). Semple et al. (2005) suggested that mindfulness can be effective even for young children as it can teach children that the primary role of mindfulness is self-management of attention. Training the attention to focus on specific actions (e.g., breath) can help negative thoughts and emotions to be experienced in an accepting and non-judgmental way.

Although there is ample research on the effects of mindfulness on cognitive processes such as working memory, and self-rated attention, there is less research that has systematically assessed the possible cognitive benefits of mindfulness on fluency. The available studies were conducted with adult samples, and to the best of the researcher’s knowledge, there is no previous study that has examined the effects of mindfulness on fluency in adolescents. A US study (Zeidan et al., 2010) explored the benefits of a brief meditation, in university students, on psychological well-being and cognition, such as verbal fluency, working memory and attention. Working memory was assessed using a forward/backward digit span task, and the Symbol Digit Modalities Test (Smith, 1982), and verbal fluency was assessed with the Controlled Oral Word Association Test (COWAT; Benton 1989), which measures immediate memory span and requires participants to provide as many words as possible starting with specific letters. The results showed significant psychological well-being improvements, such as a reduction in state anxiety scores, and improved mindfulness skills for the intervention group. Cognitive improvements were also reported, such as in verbal fluency, attention, and working memory. However, the mindfulness group did not improve in the forward/backward digit span task.

A more recent study (Lueke & Lueke, 2019) examined the effect of mindfulness on cognitive performance, such as verbal learning and memory, in university undergraduate students. Verbal fluency was tested with the Controlled Oral Word Association Test (COWAT; Benton et al., 1994). Attention was measured with the Color-Word Interference Test (CWIT; Delis et al., 2001), an extension of the Stroop task, which is comprised of four conditions including colour naming, word reading, inhibition, and inhibition/switching. No improvements were reported for the intervention group, either in verbal fluency or in memory. Another study (Wetherell et al., 2017) explored mindfulness effects in older adults with neurocognitive difficulties and stress problems. Participants were assessed on memory and cognitive control, including verbal fluency, and on clinical symptoms, including depression and anxiety. The results indicated improvements in memory and clinical symptoms, but no changes were shown post-treatment in cognitive control, including the verbal fluency task.

Students with specific learning difficulties and/or ADHD are more likely to experience mental health problems as well as executive function and cognitive impairments (Beauchemin et al., 2008; Haydicky et al., 2012). Research into mindfulness and specific learning difficulties is sparse. Some preliminary research conducted by Beauchemin et al. (2008), with a sample of 34 learning-disabled adolescents, who practiced mindfulness meditation for five weeks, showed that the participants reported a decline in state and trait anxiety, as well as improvements in their social skills and academic performance. Similarly, Haydicky et al. (2012) reported improved externalizing behaviour and conduct problems, as well as enhanced executive function in a group of adolescent boys aged 12 to 18, with specific learning difficulties, ADHD, and anxiety problems, after practicing mindfulness for 20 weeks. Evidence also suggests that children with dyslexia, aged 8 to 10, who participated in a mindfulness-based psychotherapy programme reported improved overall school performance, self-esteem, and behaviour scores, as well as enhanced working memory and decreased distractibility; the improvements lasted for more than six months (Pradhan et al., 2017). An important limitation of this study though is the lack of a control group.

Sarita and Kaur (2017) reported significant improvements in planning and self-regulation skills in students with dyslexia after participating in a 6-week mindfulness programme. Tarrasch et al. (2016) explored the effectiveness of a mindfulness-based intervention on reading, attention, and psychological well-being in university students diagnosed with dyslexia and/or ADHD. Reading was assessed using a screening reading test. Four functions of the attention model were assessed (sustained, spatial, executive, and orienting of attention); the psychological measures included mindfulness, perceived stress, life satisfaction, depression, state and trait anxiety, and sleep disorders. The results indicated significant improvements in most of the measures; in particular, the intervention group improved in terms of reading errors and in all four functions of attention. Significant improvements were also shown in most of the psychological measures, including mindfulness, stress, state anxiety, depression, and sleep disturbances.

7.2 Rationale and aim of Study 3

The onset of anxiety disorders emerges in childhood or adolescence with the main symptoms ranging from mild to high anxiety (Beesdo et al., 2009). Siegel and Dickstein (2011) emphasized that the early diagnosis and treatment of anxiety disorders is necessary. Creswell et al. (2014) noted that anxiety disorders in adolescence typically have an impact on academic performance, social life, and family life, and if left untreated they usually persist into adulthood, and increase the rate of other psychiatric disorders (Pine et al., 1998; Woodward & Fergusson, 2001) as well as suicide attempts later in life (Jacobson et al., 2008).

Therefore, it is important that early identification and prevention of anxiety disorders take place in childhood or early adolescence, so that the appropriate interventions can start early too. Previous research investigated the effectiveness of clinical psychology interventions such as Cognitive Behavioral Therapy (CBT) (Sauter et al., 2009; Seligman & Ollendick, 2011). However, a number of adolescents continued to suffer with anxiety after the CBT therapy (Sauter et al., 2009). There is less research on the effectiveness of Positive Psychology interventions, such as Mindfulness, in youth compared to adults. Although less studied, mindfulness interventions with youths have reported reduced distress and anxiety levels along with improved self-awareness skills (Sarita & Kaur, 2017). An 8-week mindfulness-based stress reduction course with adolescents in outpatient mental health found that participants reported reduced anxiety and depression, as well as improved self-esteem at post-test (Biegel et al., 2009).

Based on the results found in Study 2, in which the adolescents with dyslexia reported higher levels of anxiety, and lower levels of psychological well-being, the first aim of Study 3 was to gauge the effectiveness of a mindfulness-based intervention in reducing anxiety and improving psychological well-being for adolescents with higher levels of anxiety. As mentioned above, research in mindfulness practice is limited in relation to adolescents with specific learning difficulties, including dyslexia. Therefore, Study 3 aimed to address this gap in the literature, as the positive outcomes of mindfulness could also have a positive impact on dyslexic students' psychological wellbeing. Since attention deficits is a basic symptom of anxiety, improving the regulation of attention could potentially lead to anxiety reduction (Semple et al., 2005). Mindfulness-based practices focus on attention and present moment-awareness techniques, skills that most dyslexic individuals struggle with. It should be noted however, that the aim of the study was not to evaluate the effectiveness of the mindfulness intervention only in dyslexic adolescents who reported high levels of anxiety, but rather to explore the intervention outcomes on a group of adolescents.

The second aim of the study was to explore the effects of mindfulness on cognitive performance in adolescents. As mentioned in the introduction (see section 7.1), most of previous research has investigated the effectiveness of mindfulness on memory and attention, however less research assessed mindfulness and its effects on fluency, especially on adolescents. Therefore, the present study was designed to examine the potential benefits of mindfulness on verbal fluency and working memory in adolescents. Furthermore, as mentioned in the introduction (see section 7.1), previous research (Beauchemin et al., 2008; Haydicky et al., 2012; Pradhan et al., 2017) suggests that adolescents with specific learning difficulties are more likely to present with executive function and cognitive impairments compared to adolescents without specific learning difficulties. Therefore, the second aim of the study was extended to explore the benefits of mindfulness practice on cognitive performance of adolescents, with a focus on those with dyslexia.

The rationale of the present study is that mindfulness practice can teach students the appropriate skills to cope with stress and anxiety during the important developmental period of adolescence (Biegel et al., 2009; Rempel, 2012). Furthermore, mindfulness practice has the potential to teach students the skills needed to interact better with peers, parents, and teachers; skills that are necessary to enhance their social and academic performance (Pepping et al., 2016; Semple et al., 2010; Zeidan et al., 2010). The benefits of teaching mindfulness to students include the development of self-awareness skills and emotion regulation in challenging and difficult situations (Thompson & Gauntlett-Gilbert, 2008).

7.3 Hypotheses for Study 3

As mentioned before (see section 7.1), research in mindfulness and specific learning difficulties is limited. Therefore, the hypotheses do not specifically refer to the dyslexic adolescents compared to non-dyslexics, but they rather refer to all the adolescents who participated in the mindfulness intervention.

Based on previous research (Biegel's et al., 2009; Diaz-Gonzalez et al., 2018), which demonstrated that a group of adolescents showed lower levels of state and trait anxiety after participating in an MBSR intervention, hypothesis 1 was:

- Hypothesis 1a: It was predicted that the mindfulness intervention group will improve and score lower on state anxiety at post-test, on the Spielberger State and Trait anxiety scale (1970), compared to the control, no intervention, group.

- Hypothesis 1b: It was predicted that the mindfulness intervention group will improve and score lower on trait anxiety at post-test, on the Spielberger State and Trait anxiety scale (1970), compared to the control, no intervention, group.

Based on previous research (Seidi & Ahmad, 2018; Shahidi et al., 2017), which has demonstrated that test anxiety was reduced in high school and university students, after participating in mindfulness meditation, hypothesis 2 was:

- Hypothesis 2: It was predicted that the mindfulness intervention group will improve and score lower on test anxiety at post-test, on the Westside Test Anxiety Scale (2004), compared to the control, no intervention group.

Based on previous research and theoretical assumptions (Biegel et al., 2009; Tan & Martin, 2012) that mindfulness training improves self-esteem, hypothesis 3 was:

- Hypothesis 3: It was predicted that the mindfulness intervention group will improve and score higher on self-esteem at post-test, on the Culture-Free Self-Esteem Inventory (2002), compared to the control, no intervention group.

Based on previous research (Quach et al., 2016; Zeidan et al., 2010), which has demonstrated that mindfulness training improves executive function, particularly working memory and memory retrieval, hypothesis 4 was:

- Hypothesis 4a: It was predicted that the mindfulness intervention group will improve and score higher on the Backwards Digit Span task at post-test, on the DST-A (Fawcett & Nicolson, 2004), compared to the control, no intervention group.
- Hypothesis 4b: It was predicted that the mindfulness intervention group will improve and score higher on the Verbal Fluency task at post-test, on the DST-A (Fawcett & Nicolson, 2004), compared to the control, no intervention group.

- Hypothesis 5: It was hypothesized that the intervention group would still be significantly better than the control group, on all the aforementioned measures, in follow-up time.

7.4 Methodology

7.4.1 Ethical Considerations

The ethical approval received for this study was the same as for Study 2 (see section 6.4.1).

7.4.2 Participants

The sample of Study 3 was identical to that described in Study 2, as the present study was a follow-up design to Study 2. A sample of 45 students (20 females and 25 males) participated in the study; of those students, 20 had dyslexia. Participants were randomly assigned to the mindfulness intervention group or the control group; 23 students were assigned to the mindfulness group (11 students with dyslexia), and 22 students to the control group (9 students with dyslexia). Participation was voluntary, and all the students, who agreed to participate, completed the study to the end.

7.4.3 Mindfulness Intervention: Experimental Design and Stages of the intervention

The aim of Study 3 was to investigate the effects of mindfulness intervention on a group of adolescents (dyslexic and non-dyslexic), along with the effects on cognitive performance. The study was designed as a pretest – posttest – follow-up experiment. Therefore, a repeated measures design was used. Participants were asked to complete a number of self-report measures and a battery of cognitive tests one week before taking part in the intervention (pretest), one week after completing the intervention (posttest), and were also asked to repeat the same battery of tests 3 months after completing the intervention (follow-up). The self-report measures and the battery of cognitive tests are presented later in section 7.4.4.

Stage one: Pre-intervention

All the participants (from the intervention and the control group) completed the self-report measures and the battery of cognitive tests a week before the mindfulness intervention, separated in groups of three (15 students in each group).

Stage two: Intervention - MBSR (Mindfulness Based Stress Reduction) and Procedure

Twenty-three students participated in the mindfulness intervention over the eight weeks period. The intervention started a week after the students had completed the self-report measures and the cognitive tests. Following previous research with adolescents (Biegel et al., 2009; Edwards et al., 2014), the present intervention study followed the manualized intervention created by Biegel (2010), named Mindfulness Based Stress Reduction for Teens (MBSR-T; Biegel, 2010). Biegel modified the MBSR program for adults by Kabat-Zinn (1994) to be more suitable for adolescents. Participants attended 8 weekly sessions of 50-min each in a large, spacious, classroom in school. The students who participated in the intervention were separated into two groups (12 in one group and 11 in the other one) so that they could have more space in the classroom where the intervention took place. The mindfulness sessions were delivered by the researcher who had previously attended various mindfulness workshops while maintaining her own personal practice. Clear instructions were given to students before and during the practice. The Learning provider attended and participated in all the sessions and provided significant support to students in order to maintain their focus and attention on the intervention, when needed.

The sessions included the following experiential mindfulness practices, adopted by Biegel et al. (2009), and Biegel (2010): initial yoga postures, body scan meditation, sitting meditation, and walking meditation. The focus of these practices was to strengthen the ongoing awareness of the present moment mind-body experience, such as from a cognitive, emotional, and sensory approach. The main purpose was to enhance the ability of remaining mindful during practice sessions and in daily life. The sessions also included some didactic presentations and relevant experiences shared by the participants.

The mindfulness sessions included the following eight practices created by Biegel (2010):

Week 1: 'Examining Stress and an Introduction to Mindfulness'. The first session explored the nature of stress including the main causes and symptoms of stress (emotional and physical); the session also included a brief discussion with the students about what mainly makes them feel stressed. The first session also included an introduction to mindfulness, followed by a brief exercise of how to become aware of the five senses.

Week 2: 'Foundations of Mindfulness'. In the second session, it was explained what mindfulness is and how someone can remain mindful in everyday life. In this session the students practiced a mind-body connection exercise, and they were encouraged to share with the group a recent experience or situation they've been in, and share their thoughts, feelings, and how they approached the situation.

Week 3: 'Working with What Is'. The third session explored how important it is to allow all the emotions and feelings to be part of someone's experience. The students examined the way they usually manage their negative emotions and discussed how they could manage those negative emotions by remaining mindful.

Week 4: 'Cultivating Self-Care and Awareness of Positive Experience'. In the fourth session, the students practiced a walking meditation, followed by a brief exercise to help them cultivate feelings of self-care and self-awareness of positive experiences, after having a conversation with the researcher and the learning provider of what they thought these terms mean. The students were asked to recall a pleasant life moment and describe how they were feeling at that time. They were also asked to write some activities they mostly enjoy and encouraged to plan to do one or two of those activities weekly and keep a calendar of them.

Week 5: 'Working with Thoughts and Unpleasant Events'. In the fifth session, the students were taught the techniques of how to deal with unpleasant thoughts and events. Students were encouraged to use an Unpleasant Events calendar to help them learn how to reduce the negative feelings and self-judgement around unpleasant events. Afterwards, the students were taught some mindfulness techniques to help them gain awareness of their bodies, practice deep breathing exercises, and then revisit the stressful situation again.

Week 6: 'Coping Strategies, Letting Go, and Forgiveness'. The sixth session focused on helping students develop coping strategies, learn how to let go, and engage in forgiveness. After breathing meditation instructions were given, students were taught how to focus on their breath in order to relax. The students were then asked to discuss in small groups some helpful and unhelpful ways to coping with stress. At the end of the session, the students practiced an exercise on how to not prevent painful emotions, but how they could work through them, as this is a healthy way to achieve psychological well-being.

Week 7: 'Building Mindful Resilience'. In the seventh session, the students were taught how to develop resilience through mindfulness practice. The students were asked to complete a 'My purpose' exercise in this session, where they had to identify what were the most important things to them and what they dreamt of doing (either while still at school or later in life). The students were also asked to identify their most positive qualities.

Week 8: 'Review and Intentions for the Future'. The last session focused on summarizing all the previous practices. The students were asked to identify which activities were the most helpful to them and which they found unhelpful; and set some goals to enhance their well-being (in particular, 3 short-term and 3 long-term goals).

Stage three: Post-intervention

Post-intervention assessments were completed by all the students a week after the eight-weeks intervention had finished, to allow for an investigation of any potential improvements after the intervention programme. The students completed the same self-report measures and the battery of cognitive tests that they had completed pre-intervention.

Stage four: Follow-up intervention

Follow-up intervention assessments were completed by all students (from the intervention and the control group) three months after the intervention had finished. The assessment included the same self-report measures and the battery of cognitive tests that the participants had completed pre-intervention.

7.4.4 Materials and Apparatus

The materials used to assess state and trait anxiety, test anxiety, and self-esteem in the current study were the same as reported in Study 2 (chapter 6). The Mindfulness Attention Awareness Scale (MAAS-A) and two further cognitive tests were also included in the current study.

Mindfulness was measured using the MAAS-A Scale for adolescents 14-18 years old (Brown et al., 2011) which assesses a core characteristic of mindfulness, namely, a receptive state of mind, in which attention, informed by a sensitive awareness of what is occurring in the present, simply observes what is taking place. This is in contrast to the conceptually driven mode of processing, in which events and experiences are filtered through cognitive appraisals, evaluations, memories, beliefs, and other forms of cognitive manipulation (Brown et al., 2011). Mindfulness is defined in the MAAS-A as ‘a receptive state of attention that, informed by an awareness of present experience, simply observes what is taking place’ (Brown et al., 2011, p. 1024).

The MAAS-A scale (Brown et al., 2011) was adapted from the Mindful Attention Awareness Scale for adults (Brown & Ryan, 2003). This measure focuses on the present moment as a key element of mindfulness. The MAAS-A has the same items as the MAAS scale, except for one item that was not appropriate to use with adolescents (‘I drive places on ‘automatic pilot’ and then wonder why I went there’). This item was excluded by the author (Brown et al., 2011) and so it was also excluded from Study 3. The MAAS-A scale assesses trait mindfulness, a dispositional characteristic, which is a relatively long-lasting trait of being mindful in life more often (Brown & Ryan, 2003). The MAAS-A scale comprised 14 items, which were all negatively worded, and responses were based on a 6-point Likert Scale (1 = almost always; 6 = almost never). The total score was calculated by computing the mean of the 14 items; higher scores indicated higher levels of trait mindfulness. Mindfulness items included: ‘I find myself doing things without paying attention’. According to Brown et al. (2011), the MAAS-A showed good internal reliability (α = .82–.84) with a normative sample of adolescents. The scale also showed good internal reliability (α =. 86) with a sample of anxiety and mood disordered adolescents, aged 14 to 18. Strong correlations with indicators of well-being and adaptive functioning suggest that the MAAS-A Scale is a valid measure of mindfulness.

Although there are no norms for the MAAS-A Scale, Brown et al. (2011) conducted a study with adolescents from US schools (n = 131), from which the following means and standard deviations were generated: male adolescents (M = 3.72, SD = .74), female adolescents (M =

3.72, SD = .75). The MAAS-A scale was chosen for study 3, as according to Brown and Ryan (2003) this measure is more accessible and appropriate for individuals with little or no prior mindfulness training, which was the case for the participants in Study 3.

Two cognitive tests were also administered in the study derived from the Dyslexia Screening Test (DST-S) (Fawcett & Nicolson, 2004). Unpublished norm data by the authors, and previously used by Reynolds et al. (2003), allows for decile scores to be derived for each test. Decile scores ranging from 1-3 correspond to risk categories (1 = high risk, 2 = moderate risk, 3 = mild risk), and deciles scores above 4 correspond to normal, non-risk, category for having reading disorders (Fawcett & Nicolson, 2004).

Verbal Working Memory

The Backwards Digit Span was a test that measured the number of digits the participant could remember in the correct order. The digits were read aloud by the Researcher one per second.

The participant first started with a practice, and then moved on to the main test. The score emerged from the total number correct in the main test. In order to score one mark, the whole list should have been correct, otherwise no score was given for a list if the digits were in the wrong order.

Example of digits used in the practice.

Stimuli	Correct answer
92	29
134	431
1567	7651

(i) Executive Function/Memory Retrieval Fluency

The Verbal fluency test assessed how many words beginning with S the participant could think of in a minute. The participant first started with a practice, saying words starting with g, and then continued to the main test for one minute. The scoring for this test emerged by noting 1 point for each different valid word.

7.5 Results

7.5.1 Descriptive statistics

The means and standard deviations for all the measures, by group, for each time point, are presented in Table 7.1.

Table 7.1 Means and standard deviation across three time points (pre-intervention, post-intervention, follow-up

Measures	Group	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	3-month follow-up Mean (SD)
State anxiety	Intervention	37.87 (5.08)	33.30 (3.29)	33.39 (3.35)
	Control	40.63 (6.00)	39.45 (6.51)	40.86 (6.16)
Trait anxiety	Intervention	43.78 (4.58)	39.52 (5.00)	40.04 (3.71)
	Control	46.63 (6.57)	46.59 (6.94)	47.09 (7.27)
Test anxiety	Intervention	2.99 (.43)	2.26 (.44)	2.74 (.52)
	Control	2.94 (.44)	2.88 (.49)	3.03 (.53)
Self-esteem	Intervention	93.52 (6.43)	98.70 (8.07)	97.70 (9.12)
	Control	93.14 (6.67)	91.86 (8.08)	92.82 (7.35)
Mindfulness	Intervention	3.36 (.66)	3.57 (.61)	3.82 (.52)
	Control	3.23 (.76)	3.20 (.71)	3.23 (.69)
Verbal fluency task	Intervention	3.57 (.99)	4.09 (.79)	3.87 (.76)
	Control	3.36 (1.43)	3.27 (1.32)	3.09 (.87)
Backwards Digit Span task	Intervention	2.52 (.85)	3.35 (.98)	3.00 (.85)
	Control	2.32 (1.04)	2.36 (.79)	2.05 (.72)

7.5.2 Statistical analysis

A 3 (Time) x 2 (Group) Repeated Measures Mixed-Design analysis of variance (ANOVA) was carried out to assess the impact of the proposed mindfulness intervention in adolescents, across three time periods (pre-intervention, post-intervention, and follow-up) on a variety of outcome measures. The between-subjects variable was Group (two levels: Intervention and Control), and the within-subjects variable was Time (three levels: pretest, posttest, and follow-up). The data was checked for normality using the Shapiro-Wilk test, along with the inspection of histograms, and the data were approximately normally distributed. The examination of boxplots indicated that there were a few outliers in the data, particularly four outliers, however, they were not significant outliers, and therefore it was not necessary to remove them from the analysis. Due to the small sample size, and comparisons being significant in the same direction, p-values were not adjusted. This method was also suggested by previous research (Gallant & Nicolson, 2017; Moran, 2003; Moore et al., 2017). Biegel et al. (2009) also reported uncorrected probabilities in their mindfulness intervention study. In order to facilitate comparison of the improvements in performance, from pre-test to post-test, and to follow-up time, and to measure the magnitude of the observed effect, effect sizes were calculated separately for the control and the intervention group (see Fig. 7.8 and fig. 7.9). The effect sizes were calculated by extracting the mean difference of two time points divided by the standard deviation of the control group, which is a form of Cohen (1988), applied to change analysis. No change would result in an effect size of 0, whereas a score of + 1.0 would indicate a change of one standard deviation unit. Cohen (1988) suggests that the categories of 0.2 be labelled as small, of 0.5 be labelled as medium, and of 0.8 be labelled as large. Cohen's d categories were also applied by previous research in mindfulness interventions as an indication of improvement from pre- to -post intervention (Emerson et al., 2017a; Emerson et al., 2017b). The formula used to calculate the effect sizes is presented below:

$$ES = \frac{MT2control - MT1control}{SDcontrolT1}$$

$$ES = \frac{MT2intervention - MT1intervention}{SDcontrolT1}$$

*M represents the Mean scores

7.5.2.1 Between group statistical tests.

Self-report measures

State anxiety

All the mean scores for state anxiety remained in the normal, nonclinical, range across the three time periods for both groups. A reduction in the mean scores in post-test and follow-up time indicated an improvement in state anxiety. The assumption of homogeneity of intercorrelations was checked using Box's M statistic which showed that it was not met for State anxiety ($p < .05$). A log transformation was performed on this variable; however, the log-transformed results were the same as the non-log transformed data. Therefore, the ANOVA, non-log transformed, results are reported in the study in order to enable the interpretation of the results. The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $x^2(2) = 14.02$, $p = .001$, therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .779$). The means and standard deviations are presented in Table 7.1.

There was a significant main effect of time, $F\ (2, 86) = 21.11$, $p < .001$, $\eta^2 = .329$. Bonferroni post-hoc tests revealed a significant difference between pre-test and post-test, $p < .001$, and between pre-test and follow-up, $p < .001$. There was no difference between post-test and follow-up ($p = .16$). The main effect comparing the two groups was also significant, $F\ (1, 43) = 14.01$, $p = .001$, $\eta^2 = .246$. There was a significant interaction between time and group, $F\ (2, 86) = 13.98$, $p < .001$, $\eta^2 = .245$ (see Fig. 7.1).

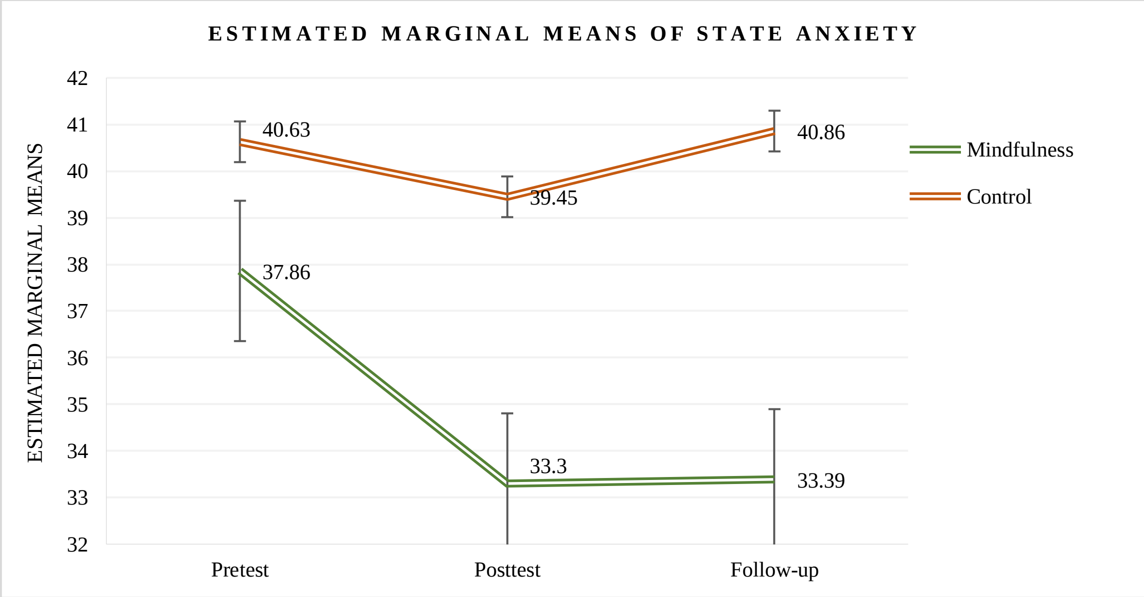


Figure 7.1 Interaction effect on State anxiety between time and group

Note. Error bars indicate standard error.

Bonferroni post-hoc tests showed no significant difference between the groups at pre-test ($p = .10$). There was a significant difference between the groups at post-test ($p < .001$), with the intervention group scoring lower in state anxiety compared to the control group. Significant differences between the groups were also found at follow-up ($p < .001$), with the intervention group scoring lower in state anxiety compared to the control group.

Trait anxiety

The mean scores for trait anxiety were within the clinical range for both groups at baseline and dropped to non-clinical range for the mindfulness group in post-intervention and follow-up time but remained within the clinical range for the control group across the three time points. A reduction in the mean scores in the mindfulness group, at post-test and follow-up, indicated an improvement in trait anxiety. The assumption of homogeneity of intercorrelations was met ($p > .05$). The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity was met,

$x^2(2) = 3.52$, $p = .17$. The means and standard deviations are presented in Table 7.1. There was a significant main effect of time, $F(2, 86) = 12.61$, $p < .001$, $\eta^2 = .227$. Bonferroni post-hoc tests showed that there was a substantial difference between pretest and posttest ($p < .001$), and between pretest and follow-up ($p < .001$). No differences were found between posttest and follow-up ($p = .76$). There was a significant main effect of group, $F(1, 43) = 11.73$, $p = .001$, $\eta^2 = .214$, and a significant interaction between time and group, $F(2, 86) = 14.68$, $p < .001$, $\eta^2 = .255$ (see Fig. 7.2).

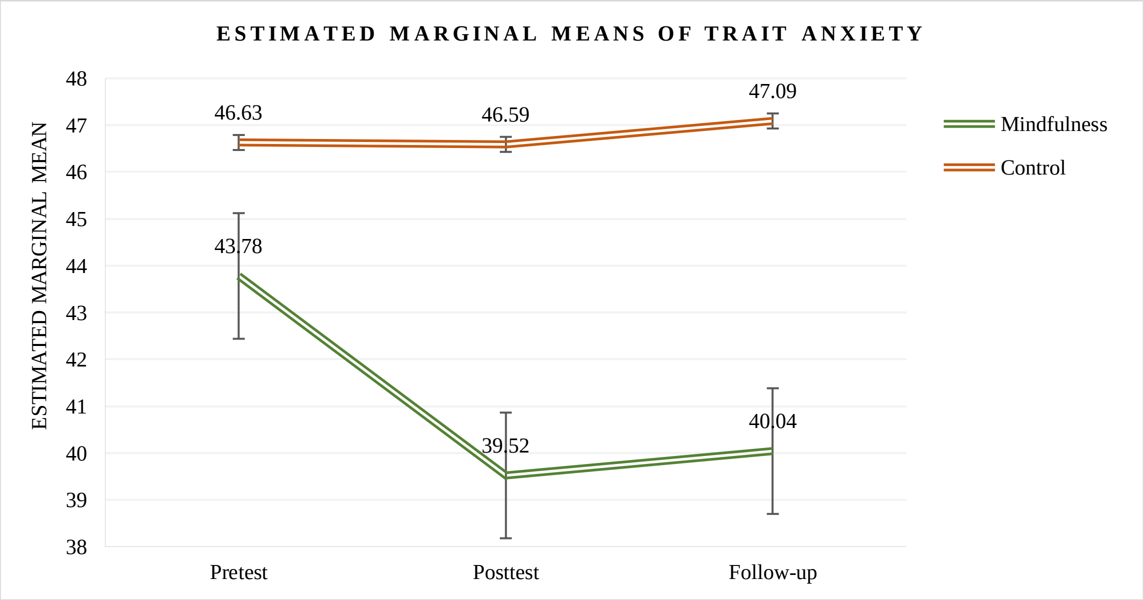


Figure 7.2 Interaction effect on Trait anxiety between time and group

Note. Error bars indicate standard error.

Bonferroni post-hoc tests revealed that there was no difference at pre-test between the two groups ($p = .09$). Significant differences between the groups were found at posttest ($p < .001$), and at follow-up ($p < .001$), with the intervention group showing lower levels on trait anxiety at both times compared to the control group.

Test anxiety

The mean scores for the intervention group were in the high normal test anxiety range at baseline, which dropped to normal test anxiety range at post-intervention and increased again to the high normal test anxiety range at follow-up. For the control group, the mean scores were in the high normal test anxiety range at pre-intervention and post-intervention, but slightly increased to moderately high at follow-up (see Table 7.1). The assumption of homogeneity of intercorrelations was met ($p > .05$). The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity was violated $x^2(2) = 6.316$, $p = .043$, therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .877$). There was a significant main effect of time, $F(2, 86) = 33.65$, $p < .001$, $\eta^2 = .439$. Bonferroni post-hoc tests showed that there was a significant difference between pre-test and post-test ($p < .001$), and between post-test and follow-up ($p < .001$). There was no difference between pre-test and follow-up ($p = .41$). There was a significant main effect of group, $F(1, 43) = 4.81$, $p = .03$, $\eta^2 = .101$, and a significant interaction between time and group, $F(2, 86) = 20.80$, $p < .001$, $\eta^2 = .326$ (see Fig. 7.3).

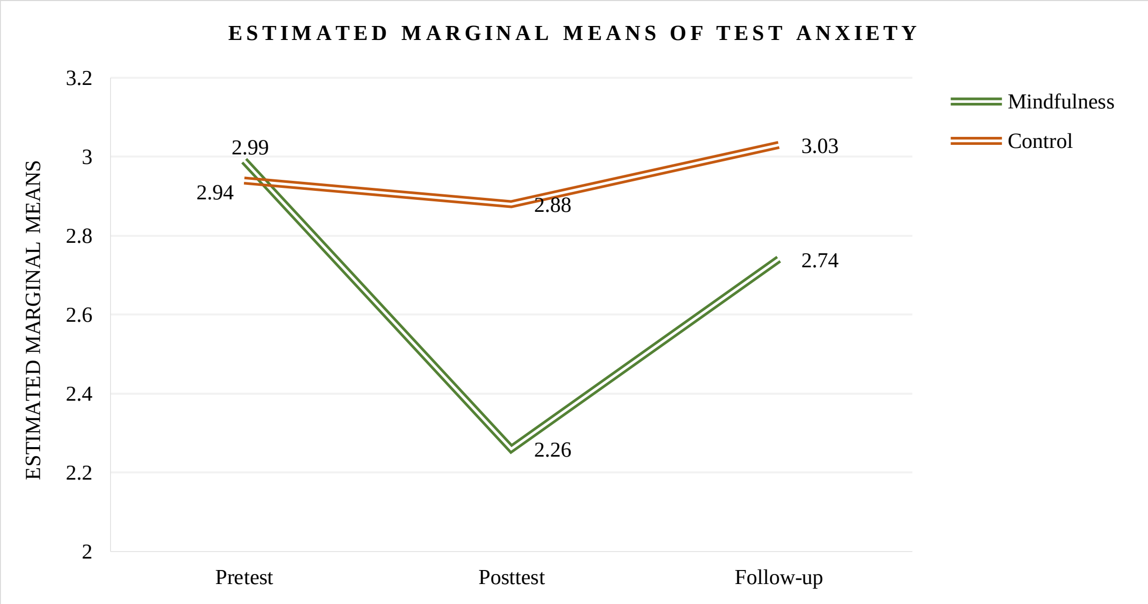


Figure 7.3 Interaction effect on Test anxiety between time and group

Note. Error bars indicate standard error.

Bonferroni post-hoc tests revealed that there was no difference between the groups at pre-test, $p = .70$. Significant differences between the groups emerged at post-test, $p < .001$, with the intervention group scoring significantly lower compared to the control group. No differences were revealed between the groups at follow-up, $p = .07$.

Self-esteem

The mean scores for both groups remained in the average self-esteem category across the three time points. An increase in the mean scores in the intervention group indicated an improvement in self-esteem. The assumption of homogeneity of intercorrelations was met ($p > .05$). The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's test of Sphericity indicated that the assumption of sphericity was violated, $x^2(2) = 8.18$, $p = .02$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .850$). The means and standard deviations are presented in Table 7.1. There was a significant main effect of time, $F(2, 86) = 4.74$, $p = .02$, $\eta^2 = .099$. Bonferroni post-hoc tests showed that the difference between pre-test and post-test approached significance ($p = .05$). There was no main effect of group, $F(1, 43) = 3.58$, $p = .06$, $\eta^2 = .077$, however there was a significant interaction between time and group $F(2, 86) = 10.33$, $p < .001$, $\eta^2 = .194$ (see Fig. 7.4).

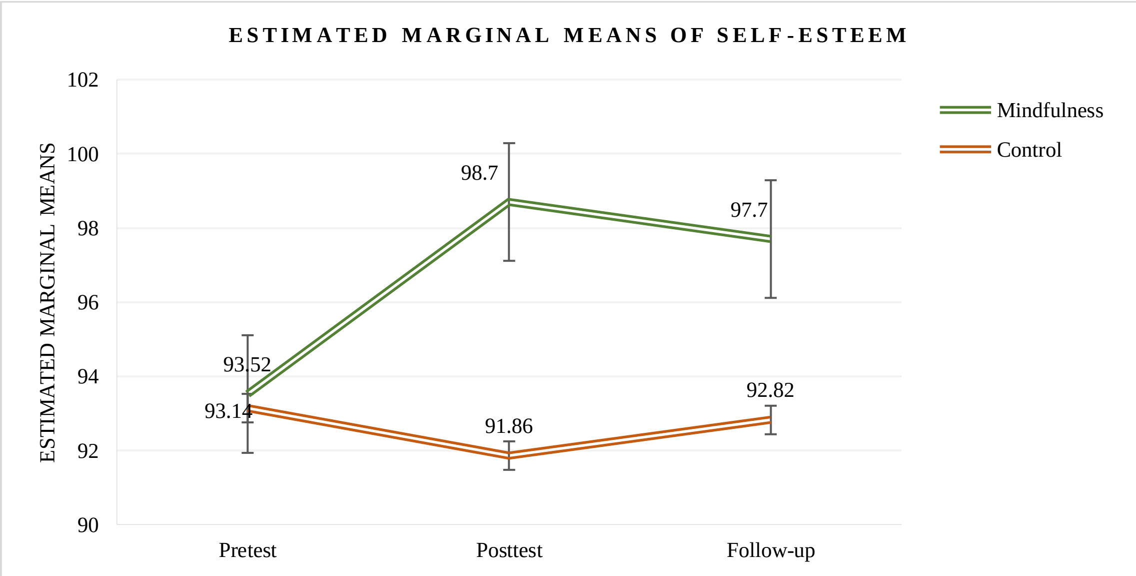


Figure 7.4 Interaction effect on Self-esteem between time and group
Note. Error bars indicate standard error.

Bonferroni post-hoc tests showed that there were no significant group differences at pre-test, $p = .82$. Significant differences between the intervention and the control group were found at post-test, $p = .003$, and at follow-up, $p = .04$, with the intervention group scoring higher than the control group.

Mindfulness

For the mindfulness measure, higher scores indicated higher levels of mindfulness skills. Mindfulness scores increased for the intervention group at post-test and follow-up time, however the control group did not increase mindfulness scores through time. The assumption of homogeneity of intercorrelations was not met ($p < .05$). The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's Test indicated that the assumption of sphericity had been violated, $x^2(2) = 8.52$, $p = .014$, therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .845$). The means and standard deviations are presented in Table 7.1. There was a significant main effect of time, $F(2,86) = 32.21$, $p < .001$, $\eta^2 = .428$. Bonferroni post-hoc tests showed that there were significant differences among all the three time points. There was a significant difference between pre-test and post-test, $p = .005$; between post-test and follow-up, $p < .001$; and between pre-test and follow-up, $p < .001$. There was no main effect of group, $F(1, 43) = 3.48$, $p = .07$, $\eta^2 = .075$, but there was a significant interaction between time and group $F(2, 86) = 31.17$, $p < .001$, $\eta^2 = .420$ (see Fig. 7.5).

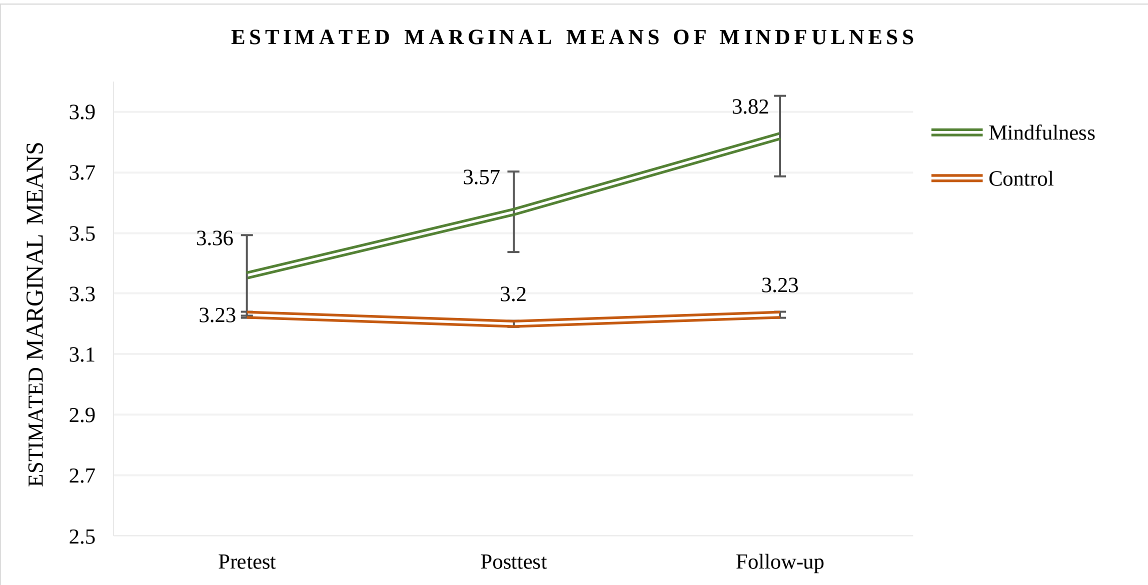


Figure 7.5 Interaction effect on Mindfulness between time and group
Note. Error bars indicate standard error.

Cognitive tasks

Verbal Fluency task

An increase in the mean scores at post-test and follow-up indicated an improvement in verbal fluency task scores, and hence better performance. An inspection of histograms showed that the data were approximately normally distributed. The assumption of homogeneity of intercorrelations was checked using Box's M statistic which showed that it was met for the verbal fluency task ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity was met, $x^2(2) = .62$, $p = .73$. The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). The means and standard deviations are presented in Table 7.1.

There was no main effect of time, $F\ (2, 86) = 1.819$, $p = .17$, $\eta^2 = .041$. The main effect comparing the two groups (intervention vs control) was significant, $F\ (1, 43) = 4.605$, $p = .04$, $\eta^2 = .10$, and there was a significant interaction between time and group, $F\ (2, 86) = 3.730$, $p = .03$, $\eta^2 = .080$ (see Fig. 7.6).

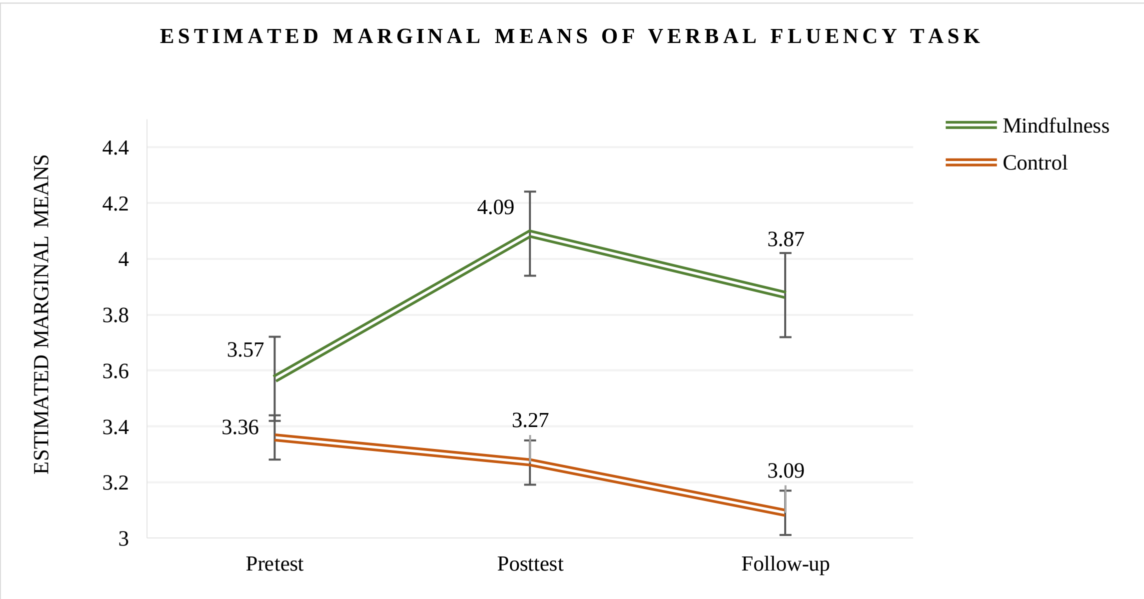


Figure 7.6 Interaction effect on Verbal Fluency task between time and group

Note. Error bars indicate standard error.

Bonferroni post-hoc tests showed a significant difference between the groups at post-test ($p = .02$), with the mindfulness group showing better performance on the verbal fluency task compared to the control group. A significant difference between the groups was also found at follow-up ($p = .003$). Although the mindfulness group still performed better on the task at follow-up than the control group, their performance decreased compared to their performance at post-test.

Backwards Digit Span task

An increase in the mean scores at post-test and follow-up indicated an improvement in Backwards digit span scores. An inspection of histograms showed that the data were approximately normally distributed. The assumption of homogeneity of intercorrelations was checked using Box's M statistic which showed that it was met for the Backwards Digit Span task ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity was met, $x^2(2) = 5.078$, $p = .08$. The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). The means and standard deviations are presented in Table 7.1.

There was a significant main effect of time, $F(2, 86) = 7.312$, $p = .001$, $\eta^2 = .145$. Bonferroni post-hoc tests revealed a significant difference between pre-test and post-test, $p < .001$, and between post-test and follow-up, $p = .02$. There was no difference between pre-test and follow-up ($p = 1.0$). The main effect comparing the two groups was also significant, $F(1, 43) = 10.22$, $p = .003$, $\eta^2 = .192$. There was also a significant interaction between time and group, $F(2, 86) = 6.894$, $p = .002$, $\eta^2 = .138$ (see Fig. 7.7).

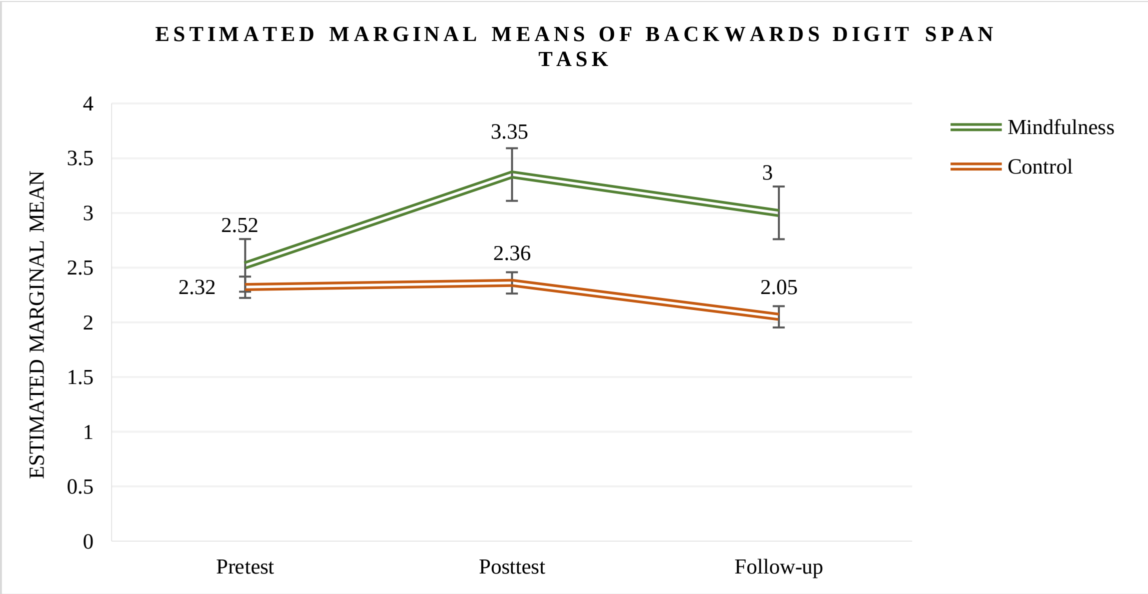


Figure 7.7 Interaction effect on Backwards Digit Span task between time and group

Note. Error bars indicate standard error.

Bonferroni post- hoc tests showed no difference between the groups at pre-test ($p = .47$). There was a significant difference between the groups at post-test ($p = .001$), with the mindfulness group showing better performance on the task compared to the control group. Significant differences between the groups were also found at follow-up ($p < .001$), with the intervention group still performing better than the control group; however, the intervention group's performance decreased at follow-up compared to their performance at post-test.

Repeated measures ANOVA was also conducted to check for gender differences between the groups, however no differences were found at any time point, except for gender differences in self-esteem at post-test ($p = .013$) and follow-up ($p = .015$).

7.5.2.2 Within group statistical tests.

Self-report measures

Based on previous studies (Semple et al, 2005; Bogels et al., 2008; Biegel et al., 2009; Beauchemin et al., 2008) which used a within-participant pre-post design to explore the effects of mindfulness training within the intervention group, a one-way Repeated Measures Analysis of variance was undertaken for each measure in the present study, for the intervention and the control group separately. For the control group none of the set of ANOVAs approached significance. It is necessary to clarify that the term ‘practical change or practical improvement’, that is used later, was used instead of the term ‘clinical change’, since the present study was not comprised of a clinical sample. The term ‘practical change’ was also used to differentiate from the term ‘statistical significance’ in the results.

For the mindfulness group, the ANOVA analyses of the change from pre-test to post-test and to follow-up time were significant for all the measures. In particular, the data showed statistically significant improvement for state anxiety from pre-test to post-test (Mean difference = 4.56, $p < .001$), as well as practically significant improvement, justified by a medium effect size (ES = -0.75) (see Fig. 7.8). There was no significant improvement from post-test to follow-up ($p = 1.0$, ES= -0.03). A significant change was found from pre-test to follow-up (Mean difference = 4.47, $p < .001$), and a practically significant change (ES = -0.72).

The improvement in trait anxiety scores from pre-test to post-test was significant (Mean difference = 4.26, $p < .001$). Despite reaching statistical significance, the practical change was medium, due to a medium effect size (ES = -0.64) (see Fig. 7.8). The trait anxiety scores were also significantly lower from pre-test to follow-up (Mean difference = 3.74, $p < .001$); however, no practical change was observed, due to a medium effect size (ES = - 0.6). No change was found from post-test to follow-up ($p = 1.0$, ES = 0.1).

The change in test anxiety scores was significant from pre-test to post-test (Mean difference = .73, $p < .001$), and there was also a practically significant change, justified by a large effect size (ES = -1.64) (see Fig. 7.8). From post-test to follow-up, there was a statistically significant change as the scores in test anxiety significantly decreased (Mean difference = -.48, $p < .001$, ES = 1.09). Although there was a statistically significant change from pre-test to follow-up ($p = .03$), the effect size decreased to medium (ES = -0.55), suggesting that there was no practical improvement from pre-test to follow-up.

A statistically and practically significant change was observed in self-esteem scores, from pre-test to post-test (Mean difference = -5.17, $p < .001$, ES = 0.78) (see Fig. 7.8). Although there was a statistically significant change (Mean difference = -4.17, $p = .01$) from pre-test to follow-up, there was no practical change, due to a medium effect size (ES = 0.62). No change was observed from post-test to follow-up ($p = .79$, ES = 0.15).

The results showed statistically significant changes in mindfulness scores from pre-test to post-test (Mean difference = -.21, $p = .001$), from post-test to follow-up (Mean difference = -.24, $p < .001$), and from pre-test to follow-up (Mean difference = -.45, $p < .001$); however, no practical changes were observed at any time point, due to small and medium effect sizes (see Fig. 7.8).

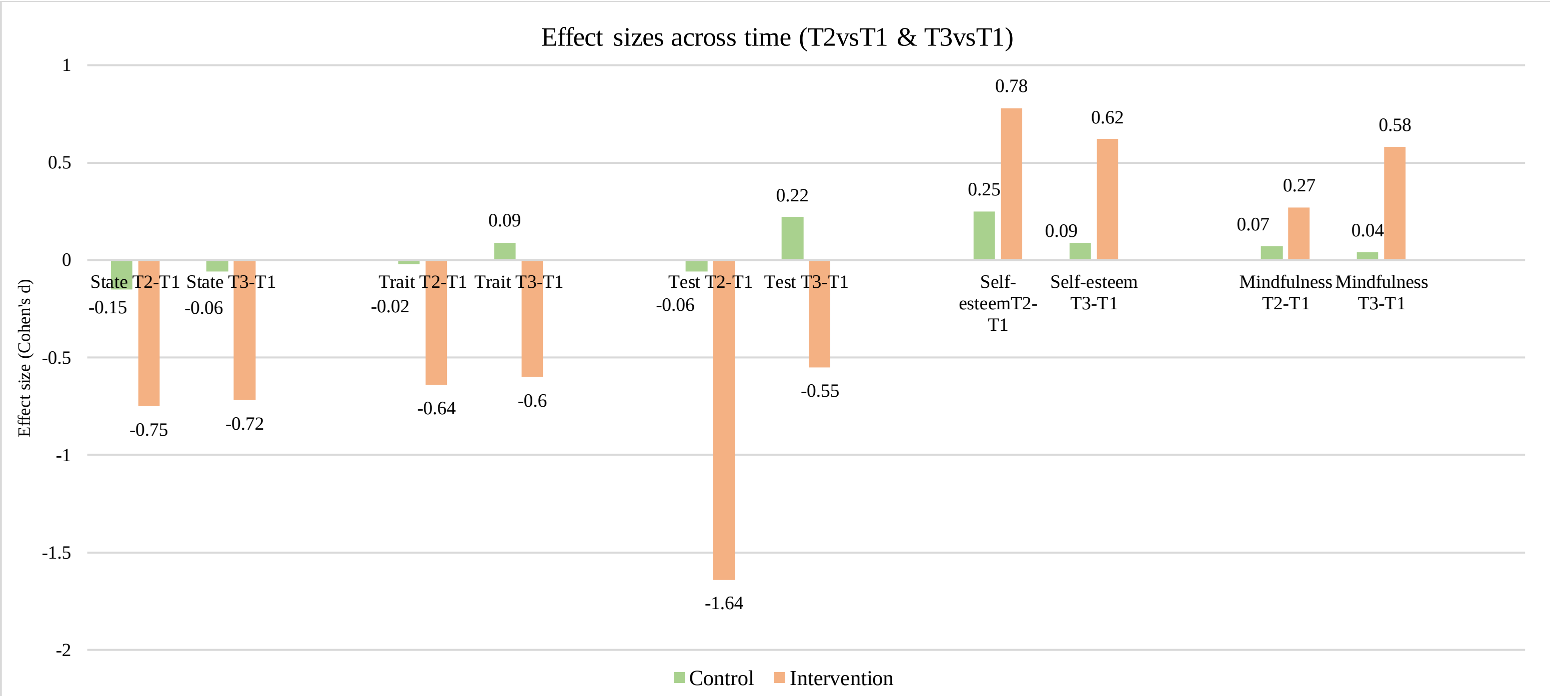


Figure 7.8 Effect sizes upon each variable, by group, across time. The effect sizes reported in this graph are between pre-test and post-test & between pre-test and follow-up.

Cognitive tasks

For the control group none of the set of ANOVAs approached significance. For the mindfulness group, the ANOVA analyses of the change from pre-test to post-test and to follow-up time were significant for both cognitive tests. In particular, the data showed an approximately significant improvement for the verbal fluency task from pre-test to post-test (Mean difference = -.522, p = .04), but no practical improvement, due to a small effect size (ES = 0.36). There was no improvement from post-test to follow-up (p = .61, ES= 0.21), or from pre-test to follow-up (p = .33, ES = -0.15).

For the Backwards Digit Span task, there was a significant change from pre-test to post-test (Mean difference = -.826, p < .001), and a practically significant change justified by a large effect size (ES = 0.79) (see Fig. 7.9). There was no change from post-test to follow-up (p = .09, ES = -0.33), but the change from pre-test to follow-up was significant (Mean difference =

-.478, p = .03), without a practical change though, due to a small effect size (ES = 0.46) (see Fig. 7.9).

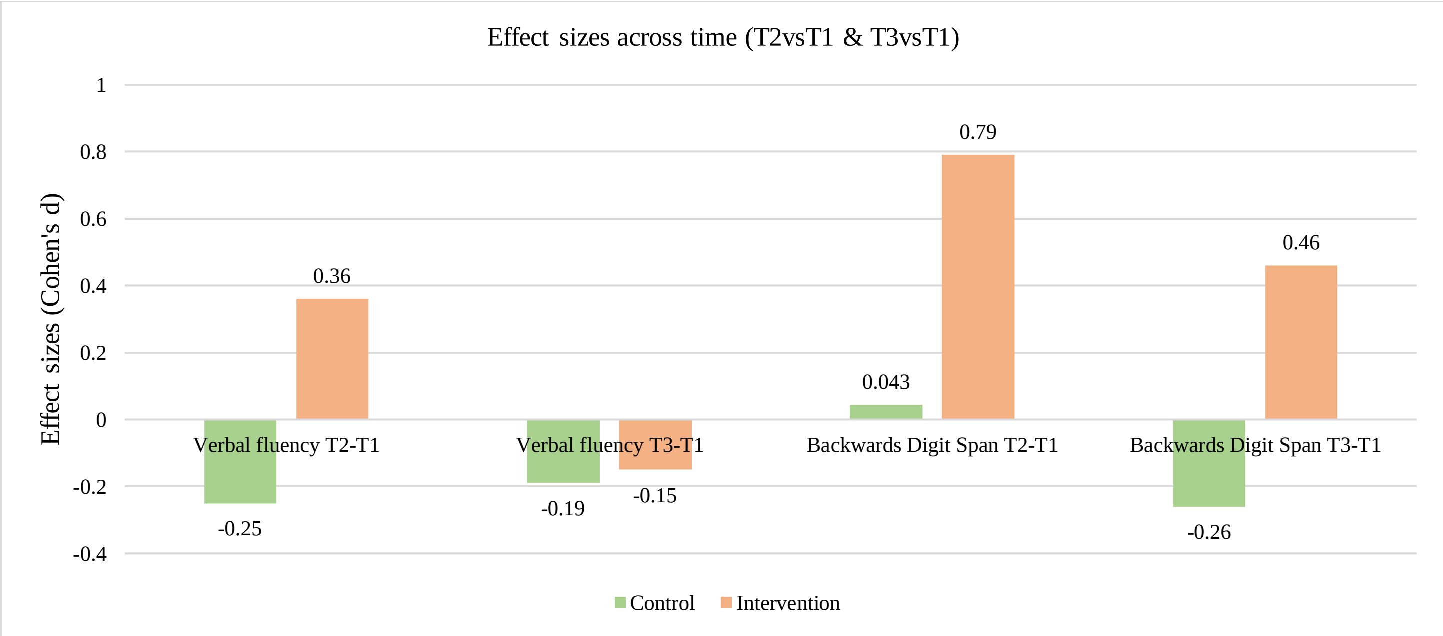


Figure 7.9 Effect sizes upon each variable, by group, across time. The effect sizes reported in this graph are between pre-test and post-test & between pre-test and follow-up

7.5.2.3 Between Group (dyslexic vs non-dyslexic) statistical tests for the intervention group.

A one-way Repeated Measures Analysis of Variance, with Time the within factor, and Group (dyslexic vs non-dyslexic) the between factor, was undertaken separately on the relative improvement for the intervention group only. It should be noted that the Bonferroni correction for multiple comparison was not applied in the data because all the comparisons were significant in the same direction and thus uncorrected probabilities were reported.

The means and standard deviations for the dyslexic and non-dyslexic group in the Mindfulness group, for all the measures, for each time point, are presented in Table 7.2.

Table 7.2 Means and standard deviations for the dyslexic and non-dyslexic group in the mindfulness group across time

Measures	Mindfulness Group	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	3-month follow-up Mean (SD)
State anxiety	Dyslexic	39.54 (3.86)	35.18 (2.48)	34.73 (2.61)
	Non-dyslexic	36.33 (5.73)	31.58 (3.06)	32.17 (3.59)
Trait anxiety	Dyslexic	44.00 (4.80)	38.81 (6.37)	40.18 (3.65)
	Non-dyslexic	43.58 (4.58)	40.17 (3.51)	39.91 (3.92)
Test anxiety	Dyslexic	3.14 (.47)	2.40 (.37)	2.84 (.46)
	Non-dyslexic	2.87 (.38)	2.13 (.48)	2.66 (.57)
Self-esteem	Dyslexic	91.82 (7.82)	94.82 (7.81)	93.45 (8.62)
	Non-dyslexic	95.08 (4.64)	102.25 (6.80)	101.58 (8.03)
Mindfulness	Dyslexic	3.29 (.59)	3.44 (.56)	3.67 (.46)
	Non-dyslexic	3.43 (.73)	3.70 (.65)	3.96 (.56)
Verbal fluency task	Dyslexic	2.91 (.70)	3.82 (.60)	3.45 (.52)
	Non-dyslexic	4.17 (.83)	4.33 (.89)	4.25 (.75)
Backwards Digit Span task	Dyslexic	2.00 (.63)	2.91 (.83)	2.82 (.60)
	Non-dyslexic	3.00 (.74)	3.75 (.96)	3.17 (1.03)

Self-report measures

State anxiety

The assumption of homogeneity of intercorrelations was checked using Box's M statistic which showed that it was met ($p = .85$). The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $x^2(2) = 7.16$, $p = .03$, therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .769$). The means and standard deviations are presented in Table 7.2. There was a significant main effect of time, $F(2, 42) = 28.96$, $p < .001$, $\eta^2 = .580$. The main effect comparing the two groups was significant, $F(1, 21) = 5.374$, $p = .03$, $\eta^2 = .204$. There was no interaction between time and group, $F (2, 42) = .292$, $p = .69$, $\eta^2 = .014$. Bonferroni post-hoc tests showed no difference between the groups at pre-test ($p = .13$), or at follow-up ($p = .07$). There was a significant difference between the groups at post-test ($p = .006$), with the non-dyslexic group showing lower scores of state anxiety compared to the dyslexic group, but slightly higher scores compared to their own scores from pre-test.

Trait anxiety

The assumption of homogeneity of intercorrelations was met ($p = .33$). The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity was met, $x^2(2) = 3.08$, $p = .21$. The means and standard deviations are presented in Table 7.2. There was a significant main effect of time, $F (2, 42) = 26.91$, $p < .001$, $\eta^2 = .562$. There was no main effect of group, $F (1, 21) = .016$, $p = .90$, $\eta^2 = .001$. There was no interaction between time and group, $F (2, 42) = 1.18$, $p = .32$, $\eta^2 = .053$. Bonferroni post- hoc tests did not show any differences between the groups at any time point.

Test anxiety

The assumption of homogeneity of intercorrelations was met ($p = .63$). The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $x^2(2) = 6.95$, $p = .03$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .773$). The means and standard deviations are presented in Table 7.2. There was a significant main effect of time, $F (2, 42) = 44.22$, $p < .001$, $\eta^2 = .678$. No differences were found between the dyslexic and non-dyslexic group at any time point, $F (1, 21) = 1.95$, $p = .18$,

η^2 = .085. There was no interaction between time and group, F (2, 42) = .215, p = .65, η^2 = .010. Bonferroni post- hoc tests did not show any differences between the groups at any time point.

Self-esteem

The assumption of homogeneity of intercorrelations was met (p = .60). The Levene's test showed that the assumption of equality of error variance was met (p > .05). Mauchly's Test of Sphericity indicated that the assumption of sphericity was met, $x^2(2) = 2.63$, p = .27. The means and standard deviations are presented in Table 7.2. There was a significant main effect of time, F (2, 42) = 12.14, p < .001, η^2 = .366, and a significant main effect of group, F (1, 21) = 5.01, p = .04, η^2 = .193. There was no interaction between time and group, F (2, 42) = 2.901, p = .07, η^2 = .121. Bonferroni post- hoc tests showed significant differences between the groups at post-test (p = .02), and at follow-up (p = 0.3), with the non-dyslexic group showing higher self-esteem scores at both times compared to the dyslexic group and compared to their own scores at pre-test.

Mindfulness

The assumption of homogeneity of intercorrelations was not met (p = .01). A log transformation was performed on this variable; however, the ANOVA results were the same to the non-log transformed data, and therefore the ANOVA results were reported to facilitate the interpretation of the results. The Levene's test showed that the assumption of equality of error variance was met (p > .05). Mauchly's Test of Sphericity indicated that the assumption of sphericity was met, $x^2(2) = 5.160$, p = .08. The means and standard deviations are presented in Table 7.2. There was a significant main effect of time, F (2, 42) = 38.20, p < .001, η^2 = .645, but no main effect of group, $F(1, 21) = .881$, $p = .36$, $\eta^2 = .040$, and no interaction between time and group, $F(2, 42) = 1.146$, $p = .33$, $\eta^2 = .052$. Bonferroni post-hoc tests did not show differences between the groups at any time point.

Cognitive tasks

Verbal Fluency task

The assumption of homogeneity of intercorrelations was met ($p = .39$). The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity was met, $x^2(2) = .296$, $p = .86$. The means and standard deviations are presented in Table 7.2. The results indicated a significant main effect of time, $F(2, 42) = 4.623$, $p = .015$, $\eta^2 = .180$. The main effect comparing the two groups was also significant, $F(1, 21) = 14.22$, $p = .01$, $\eta^2 = .404$. There was no interaction between time and group, $F(2, 42) = 2.225$, $p = .12$, $\eta^2 = .096$. Bonferroni post- hoc tests showed a significant difference between the groups at pre-test ($p = .001$), and at follow-up ($p = .008$), with the non-dyslexic group performing significantly better at both times than the dyslexic group. There was no difference between the groups at post-test ($p = .12$).

Backwards Digit Span task

The assumption of homogeneity of intercorrelations was met ($p = .60$). The Levene's test showed that the assumption of equality of error variance was met ($p > .05$). Mauchly's Test of Sphericity indicated that the assumption of sphericity was met, $x^2(2) = .578$, $p = .75$. The means and standard deviations are presented in Table 7.2. The results indicated a significant main effect of time, $F(2, 42) = 14.68$, $p < .001$, $\eta^2 = .411$, and a significant main effect of group, $F(1, 21) = 6.205$, $p = .02$, $\eta^2 = .228$. There was no interaction between time and group, $F(2, 42)$

= 2.433, p = .10, η^2 = .104. Bonferroni post- hoc tests showed a significant difference between the groups at pre-test (p = .002), and at post-test (p = .04), with the non-dyslexic group performing better at post-test compared to the dyslexic group and compared to their own performance at pre-test. No difference was found between the groups at follow-up (p = .34).

7.6 Discussion

The objective of Study 3 was to investigate the benefits and the effectiveness of an 8-week mindfulness practice, based in a school setting, on internalizing problems and on cognitive performance of adolescents with and without dyslexia. Significant time effects were found for most of the measures used in the study, and the benefits of mindfulness practice lasted in some cases even for three months after post-testing. Subgroup analysis between dyslexic and non-dyslexic adolescents in the intervention group showed significant differences for some internalizing measures and for cognitive measures either at post-test or at follow-up time.

Hypothesis 1a: It was predicted that the mindfulness intervention group will improve and score lower on state anxiety at post-test, on the Spielberger State and Trait anxiety scale (1970), compared to the control, no intervention, group.

Hypothesis 1b: It was predicted that the mindfulness intervention group will improve and score lower on trait anxiety at post-test, on the Spielberger State and Trait anxiety scale (1970), compared to the control, no intervention, group.

The current study evaluated the effects of mindfulness training on state and trait anxiety in a group of adolescents aged 14 and 15 years. Those adolescents in the intervention group performed better than the control group, an outcome which supports the hypotheses that mindfulness practice would have a positive effect on anxiety. The results of the present study are in line with a previous study (Kuyken et al., 201) which reported a reduction in anxiety and stress levels in adolescents after participating in mindfulness training. The results are also consistent with Biegel et al. (2009), and with Diaz-Gonzalez et al. (2014), in terms of reduced state and trait anxiety levels, but also in terms of the same intervention procedure that was used in these two previous studies and in Study 3. All the studies followed the same mindfulness curriculum designed by Biegel (2010), entitled MBSR for Teens, and the results from the three studies were all positive in regard to the intervention used. It seems from the results that mindfulness could help students overcome not only the anxiety symptoms that occur at a specific moment, but also general feelings of anxiety. The results from Study 3 are also in line with the results from Edwards et al. (2014) study, which reported reduced scores of anxiety and stress in a group of adolescents who followed the 8-week MBSR for Teens programme by Biegel (2010). The effect size of state anxiety in the mindfulness group in the present study was also significant, which demonstrates a practical change and improvement in the intervention group post treatment.

A medium effect size was identified in trait anxiety, which demonstrated an improvement in trait anxiety scores in the intervention group post treatment. Using the STAI cut-offs, 30.4% of the intervention group showed high levels of state anxiety, and the same percentage decreased their state anxiety scores at post-test. In contrast, 40.9% of the control group showed high state anxiety levels, of which only 13.6% improved their scores at post-test. Reliable improvements were also identified in trait anxiety of the intervention group, of which 65.2% showed high levels at baseline. From this percentage (65.2%), 40% improved trait anxiety scores post-intervention.

As mentioned earlier (see section 7.1), research is sparse on the benefits of mindfulness on anxiety problems in adolescents with specific learning difficulties. The results of the present study indicated that mindfulness training can alleviate stress and anxiety levels in adolescents with or without dyslexia equally. In the current study, similar numbers of adolescents with and without dyslexia in the intervention group showed high levels of state anxiety at baseline, however only the non-dyslexic adolescents showed a reduction in state anxiety scores posttreatment. The same trend was not found in trait anxiety scores though, as there was no difference either at baseline or at post-test between the dyslexic and non-dyslexic adolescents in the intervention group; both groups showed improvements in trait anxiety post treatment. The results of the current study are in line with Beauchemin et al. (2008), in which adolescents with specific learning difficulties improved state and trait anxiety levels after taking part in a 5-week mindfulness meditation practice. However, Beauchemin et al.'s study lacked a control group, so the comparison between the two studies should be interpreted with caution. The results are also in accordance with Tarrasch et al. (2016) who reported improvements in university students with dyslexia and/ or attention deficits after practicing mindfulness. The intervention group showed improvements in reading and attention, as well as on a range of psychological well-being measures, such as in state anxiety, stress, mindfulness, and depression.

Hypothesis 2: It was predicted that the mindfulness intervention group will improve and score lower on test anxiety at post-test, on the Westside Test Anxiety Scale (2004), compared to the control, no intervention group.

The current study evaluated the effects of mindfulness training on test anxiety in a group of adolescents. Those adolescents in the intervention group performed better than the control group, an outcome which supports the hypothesis that the intervention group would improve their test anxiety scores after participating in mindfulness training. As discussed earlier (see section 7.1), Semple et al. (2005) suggest that attention is one of the core symptoms of anxiety, therefore for the optimal performance in examinations and test taking situations, students need to keep control of attention, and focus on the exam papers, skills which can be improved with mindfulness training. The results of the present study are in line with previous studies (Shahidi et al., 2017; Seidi & Ahmad, 2018) which reported reduced test anxiety and greater emotional control in students after completing a mindfulness course. Kabat-Zinn (1990) claimed that individuals who are in state of calmness and concentration are better able to control their thoughts, feelings, and stress. Therefore, mindfulness practice can teach students to concentrate and control their anxiety and emotions during an examination and test-taking situation. Breath exercises, as one of the core components of mindfulness, have been proved beneficial for individuals who experience high anxiety (Kabat-Zinn, 1994), therefore focusing on breath during an exam could help students feel more in control and deal better with test anxiety symptoms.

Cunha and Paiva (2012) suggested that test anxiety can be deteriorated by high self-criticism and low self-acceptance along with the lack of mindfulness skills. Therefore, mindfulness training can teach students to be non-judgmental over their feelings and emotions and learn to accept them. A significant large effect size of test anxiety in the intervention group in the current study can also justify the effectiveness of mindfulness practice in exams and test taking situations. A reliable improvement was also identified in test anxiety in the intervention group, from which 86.9% scored high at baseline, and 80% improved post-treatment. The dyslexic and non-dyslexic adolescents did not differentiate in terms of improvements post-treatment. Both groups scored similarly at baseline and showed high levels of test anxiety, and equally both groups reduced their scores in test anxiety after completing the mindfulness training.

Hypothesis 3: It was predicted that the mindfulness intervention group will improve and score higher on self-esteem at post-test, on the Culture-Free Self-Esteem Inventory (2002), compared to the control, no intervention group.

It was hypothesized that the intervention group would improve self-esteem after practicing mindfulness, and the hypothesis was supported by the present data. Mindfulness training was proved efficient in enhancing self-esteem in adolescents who reported low levels of self-esteem, and subsequently of general well-being. Most of the participants in the study reported average self-esteem scores at baseline, with 30% in the intervention group reporting below average self-esteem compared to 22.7% in the control group. 21% in the intervention group increased to average self-esteem scores post-treatment, compared to null in the control group. Findings from the present study are in accordance with previous studies (Biegel et al., 2009; Tan & Martin, 2012), in which self-esteem and well-being improvements were reported after the participants practiced mindfulness over a period.

Along with the statistical significance of self-esteem from baseline to post-test, a medium effect size may also support the benefits of mindfulness training in improving self-esteem in adolescents. The results suggest that the adolescents who practice mindfulness can become more mindful in everyday life and have greater self-esteem and self-acceptance. Pepping et al. (2013) suggest that mindfulness contributes to improvement of self-esteem through the ability to stay focused at the present moment, without judging and reacting to feelings, emotions, or stress. This practice can lead to better psychological well-being, and ultimately to great self-esteem. Enhancing positive views about oneself with mindfulness practice, while letting go of the negative thoughts, can lead to improved self-esteem (Pepping et al., 2013). Previous research (Brown & Ryan, 2003) has reported positive correlations between mindfulness skills and self-esteem, which suggests that individuals who practice mindfulness regularly can ultimately cultivate positive feelings of self-esteem and self-acceptance.

As mentioned earlier (see section 7.1), research is sparse on the effectiveness of mindfulness in psychological well-being of students with specific learning difficulties. The findings from the present study showed that there were no differences between the dyslexic and non-dyslexic adolescents in the intervention group on self-esteem at baseline, however the non-dyslexic group improved their self-esteem scores post-treatment and 3-months follow-up compared to the dyslexic adolescents. Although the result should be interpreted with caution due to small sample sizes, it seems that students with specific learning difficulties may struggle to cultivate self-worth and positive feelings about themselves. The findings of the present study are in contrast to Pradhan et al. (2017) study in which dyslexic students showed higher self-esteem after practicing mindfulness, the effects of which sustained 6 months after post-test. A limitation of Pradhan et al. study though is the lack of a comparison control group.

Hypothesis 4a: It was predicted that the mindfulness intervention group will improve and score higher on the Backwards Digit Span task at post-test, on the DST-S (Nicolson and Fawcett, 2004), compared to the control, no intervention group.

Hypothesis 4b: It was predicted that the mindfulness intervention group will improve and score higher on the Verbal Fluency task at post-test, on the DST-S (Nicolson and Fawcett, 2004), compared to the control, no intervention group.

One of the hypotheses of Study 3 was that the intervention group would show improvements on working memory and cognitive tasks after practicing mindfulness. The intervention group performed better on both cognitive tasks administered in the study, namely on the Backwards Digit span task and the Verbal Fluency task. Therefore, the outcomes of the present study supported the hypothesis. A large effect size of the Backwards digit span task in the intervention group adds on the effectiveness of mindfulness practice in working memory. Using the DST-S cut offs, 69.5% in the intervention group scored within the at-risk categories on the verbal fluency task at baseline, compared to 50% in the control group; 50% from the intervention group improved their scores at post-test and scored within the non-risk categories compared to 9% in the control group. In the Backwards digit span task though, a higher percentage of participants (86.9%) in the intervention group scored within the at-risk category compared to 81.8% in the control group. 35% of the participants in the intervention group improved their scores and fell within the non-risk categories post-treatment, compared to 0% in the control group. It is important to note that the groups scored similar at both tasks at baseline. The rest of the participants in the intervention group also improved their performance in the backwards digit span task, however their scores did not improve enough to fall in the non-risk category. The findings of the current study are in line with previous studies (Quach et al., 2016) which tested working memory capacity in adolescents and college students after participating in a mindfulness practice and found significant improvements in working memory function.

The results of the current study are also partially in accordance with Zeidan et al. (2010), although they tested a university sample, which reported benefits of a brief mindfulness intervention on cognitive tasks, including verbal fluency and working memory. The current study reported benefits of mindfulness training on both cognitive tasks; namely, in the verbal fluency and the backwards digit span task. In contrast, Zeidan et al. (2010) found significant improvements post-treatment on the verbal fluency task but not on the forward/backwards task that was used in their study. A possible explanation of the relationship between mindfulness and cognitive performance is that a key component of mindfulness is self-regulation, and as discussed earlier, self-regulation improves cognitive function (Moore & Malinowski, 2009). According to Kabat-Zinn (1990), mindfulness has calming effects on the individual, and along with the ability that it offers to focus on the present moment, cognitive function is also improved after training. Another explanation of the relationship between mindfulness and cognition is that mindfulness teaches the individual to be aware of the present moment, while noticing the distracting thoughts and emotions, and trying to bring their awareness back to the present moment; this technique improves attention, which is a core component of cognitive function (Biegel et al., 2009; Brown & Ryan, 2003). As discussed earlier (see section 3.2.3), working memory can be affected under stressful conditions, and therefore it shows impaired performance (Kuhlmann et al., 2005; Klein & Boals, 2001). Based on that, students who practice mindfulness regularly should have lower levels of anxiety, which in turn could enhance their cognitive performance at school. As discussed earlier (see section 7.1), attention and working memory are important skills for optimal academic performance.

The dyslexic and non-dyslexic adolescents in the intervention group differed at baseline on both cognitive tasks, namely in verbal fluency and backwards digit span task. The non-dyslexic group showed significantly better performance on both tasks compared to the dyslexic group, and this result is in line with previous studies (Haydicky et al., 2012) which reported impairments in cognitive function in students with specific learning difficulties. Comparing the dyslexic and non-dyslexic adolescents' performance who participated in mindfulness training, there was no difference between the two groups at post-test on the verbal fluency task, as both groups improved their scores after mindfulness. However, the dyslexic and non-dyslexic adolescents differed on the backwards digit span task at post-test, as the non-dyslexic group improved significantly more compared to the dyslexic group. The backwards digit span test assesses working memory performance and is considered to be a difficult task for dyslexic individuals, in which they usually do not perform well. The results of the mindfulness practice showed that working memory is a cognitive function that probably needs more training, practice, and time in order to show improvements in dyslexic individuals. The present findings are not in line with Haydicky et al. (2012) study, which reported improved working memory in children with dyslexia who practiced mindfulness for 20 weeks. There are two differences between the studies though; first, the participants in Haydicky et al. (2012) study practiced mindfulness for 20 weeks, compared to 8 weeks in the present study, which still showed positive effects in the intervention group; and second, Haydicky et al. (2012) did not include a control group for comparison of performance with the intervention group. Although the dyslexic adolescents did not achieve the same performance as the non-dyslexic adolescents in both cognitive tasks, it is still promising that after mindfulness training the dyslexic group improved their working memory scores and they did not remain at the same level as at baseline.

Hypothesis 5: It was hypothesized that the intervention group would still be significantly better than the control group, on all the aforementioned measures, at follow-up.

Most of the research in mindfulness reported results of a pre-post design intervention; the inclusion of a follow-up time in mindfulness studies was limited in the literature. The last hypothesis of the present study was that the intervention group would outperform the control group at follow-up. The results were mixed in the present study, both for the self-report measures and the cognitive tasks. In particular, the intervention group scored lower on state and trait anxiety, and higher on self-esteem at follow-up compared to the control group. The intervention group also performed better on the verbal fluency and the backwards digit span task at follow-up compared to the control group. Therefore, the final hypothesis was partially supported by the data of the present study. When the data were analysed within the intervention group only, there were mixed results with regards to the benefits of mindfulness lasting for some time. Mindfulness effects sustained at follow-up compared to pre-test in all the self-report measures and cognitive tasks. Medium effect sizes ranging from d= -0.55 to d= -0.72 were also reported in the psychological measures from pre-test to follow-up. However, the mindfulness effects sustained at follow-up compared to post-test on state anxiety and mindfulness scores only.

The findings of the present study are in line with findings from Justo (2009) study, in which significant improvements in fluency and flexibility were sustained at follow-up compared to pre-test, but not compared to post-test. The present findings also suggest that the mindfulness skills were improved for the intervention group, after completing the mindfulness practice, and the positive effects lasted for three months after the completion of the intervention. The findings are in line with previous research (Bogels et al., 2008; Edwards et al., 2014; Diaz-Gonzalez et al., 2019), which reported a significant change in mindfulness skills in adolescents after completing mindfulness training. The results of the present study indicated that the adolescents improved their mindfulness skills in terms of being able to recognize their emotions and experiences happening during the intervention by being present in that moment. The results suggested that the improved mindfulness skills of the intervention group might have contributed to the improved self-esteem, and the reduced levels of anxiety that the adolescents showed post-intervention.

In contrast, Johnson et al. (2017) did not find differences between the mindfulness and the control group in any measure used in their study, including mindfulness, anxiety, and depression. Johnson et al. (2017) suggested that the results may be attributed to the specific age of adolescents, which is probably a young age to learn and practice mindfulness, as it has not yet fully studied what age is best to teach mindfulness. Pepping et al. (2016) reported that low mindfulness skills were associated to maladaptive functioning and behaviour in adolescents, particularly in depression, anxiety, and stress conditions. Pepping et al. suggested that the emotion regulation plays an important role in anxiety and depression, and as such, due to limited emotion regulation in adolescents, they are more likely to experience high levels of internalizing problems. It is interesting to note that there were no significant differences on mindfulness skills at any time point between the dyslexic and non-dyslexic adolescents in the intervention group; the findings showed that both groups equally improved mindfulness skills through time.

Overall, the present study showed that positive psychology interventions are appropriate for schoolchildren and can have positive effects both on their psychological well-being and cognitive function (Seligman et al., 2009; Norrish et al., 2013). Schools are the most appropriate places for the implementation of positive psychology interventions such as mindfulness, as they support students to flourish and develop emotional skills (Bond et al., 2007; Seligman et al., 2009). Positive education programmes promote an education that supports the development of life skills and well-being (Schiavon et al., 2020; Norrish et al., 2013).

7.7 Limitations

There are some limitations in the current study that need to be acknowledged. First, the study included a small sample size of participants, which suggests that the generalizability of the conclusions should be made with caution to the wider population of adolescents. Second, most of the outcome variables were scores on self-report measures. Although self-report measures are commonly used in psychological intervention research, studies that include observations, and physiological or behavioural measures are stronger (Dunning et al., 2019). Third, the lack of an active control group is another limitation in this study; another intervention, other than mindfulness, could have possibly had similar outcomes on the control group. Based on that, another potential limitation is probably the difficulty of deciding whether it was the meditation itself that contributed to significant improvements or the presence of an interested researcher giving students a break from their normal negative school experience. This would have been better tested with an active control group. Another limitation is that the mindfulness courses were implemented by the researcher, who had previously attended mindfulness courses and still practices mindfulness personally and in group sessions, and not by a trained mindfulness instructor with extensive experience in mindfulness. Fourth, the participants were identified by the Learning Support Provider as these participants were considered most likely to gain from the mindfulness intervention and were not participating in any other school support programme.

7.8 Conclusion

Overall, the present study suggested that mindfulness-based interventions with adolescents are feasible in school settings as part of the school curriculum. The results of the present study seem promising in mindfulness-based interventions with adolescents, given the small sample size in the study and the positive effect sizes on most psychological and cognitive measures. The outcomes of the present study suggested that mindfulness training may be effective in improving psychological well-being and increasing cognitive capacity in adolescents, as well as increasing the ability in adolescents to be mindful and aware of the present moment, while things happen. Mindfulness teaching has been proved as a helpful and powerful technique for students, which has the potential to enhance cognitive and academic performance. Furthermore, the results showed that mindfulness activities may alleviate secondary symptoms of dyslexia, such as anxiety symptoms and poor psychological well-being, along with improvements in cognitive function. Following on from this chapter which presented the effects of mindfulness training on psychological well-being and cognitive performance in adolescents, the following chapter (Study 4) presents the association between anxiety and cognitive performance in adolescents at risk of dropping out from school, including dyslexic and non-dyslexic adolescents.

Chapter 8

Study 4: Cognitive function in dyslexic and non-dyslexic adolescents at risk of school failure. The linkage between stress and cognitive function in dyslexia.

8.1 Introduction

The present chapter presents the fourth empirical study, which aimed to a) investigate the performance of adolescents at risk of school failure, including adolescents with dyslexia, on cognitive function tasks, particularly on non-language procedural memory, declarative memory, working memory, and motor tasks, and b) to explore the relationship between stress and performance on these tasks.

8.1.1 Declarative and procedural memory in Dyslexia and the impact of stress

As discussed in the Introduction (see chapter 2, section 2.3.3), the declarative memory system is responsible for the learning of events and facts (Squire, 1987), and due to its flexibility, it can even compensate for some impairments in neurodevelopmental disorders, such as dyslexia, SLI, and autism (Pennington and Bishop, 2009; Ullman & Pullman, 2015). Most research suggests that declarative memory remains intact and functional in developmental dyslexia (Ullman & Pullman, 2015; Hedenius et al., 2013; Jimenez-Fernantez et al., 2011; West et al., 2018), while the procedural system is impaired (Vicari et al., 2003; Vicari et al., 2005; Nicolson et al., 2010; Biotteau et al., 2015). Vicari et al. (2003) conducted a study with dyslexic children and adolescents on the declarative and procedural memory systems. Declarative and procedural learning were tested with two different serial reaction time tasks. The results indicated that the dyslexic group showed a procedural learning deficit compared to the non-dyslexic group, while their performance on the declarative learning task did not differ from the non-dyslexic group. Another study (Kramer et al., 2000) revealed that specific aspects of verbal memory were impaired in dyslexic children. Although the results indicated that the dyslexic group was slower in the encoding and rehearsal phase of the task, as they learned less words than the non-dyslexic group, they showed similar results in retrieving and remembering the information to the non-dyslexic group. In contrast, Messbauer and de Jong (2003) found that children with dyslexia who were tested on a paired associate learning task had a poorer performance on a verbal learning task (words and non-words) compared to typically developing children but had the same performance as the non-dyslexic group on the visual task. Semantic knowledge, which is part of declarative memory, plays an important role in dyslexic children's reading, as they rely more on semantic knowledge (Ullman & Pullman, 2015). Nation and Snowling (1998) reported that children with dyslexia showed better semantic context and improved their reading scores compared to typically developing children. The dyslexic children used semantic context to compensate for their decoding skills, which were poorer than those of the non-dyslexic children. Another study found that enhanced declarative memory is associated with better reading performance in dyslexic children (Hedenious et al., 2013) due to its compensating role in reading in dyslexia.

The procedural learning system, as discussed in the Introduction (see chapter 2, section 2.3.3), is responsible for the learning of rules and sequences (Poldrack et al., 1999). Cognitive development and learning to read rely on the procedural learning system, and therefore a deficit in this system can affect the development of reading and writing skills (Karmiloff-Smith, 1992). Skills are processed automatically in the procedural memory system after some practice and repetition (Lum et al., 2013). Automaticity plays an important role in reading development, so that reading can become accurate and fluent (Logan, 1997; van Daal & van der Leij, 1999), but also in the acquisition of cognitive and motor skills (Nicolson & Fawcett, 1990; Vicari et al., 2005; Savage, 2004). It has been hypothesized that the underlying causes of reading difficulties and dyslexia may be explained by deficits in the procedural learning system and the automatization of skills (Nicolson & Fawcett, 1990; 2007; Vicari et al., 2005); this is supported by the Automatization Deficit Hypothesis (Nicolson & Fawcett, 1990) (see section 2.3.1.1), and the Procedural Learning Deficit Hypothesis (Nicolson & Fawcett, 2007) (see section 2.3.3.1). Furthermore, the cerebellum is involved in the automatization of language and cognitive skills (Fulbright et al., 1999; Leiner et al., 1993), and underlies the procedural learning system. A cerebellar function impairment, as suggested by the Cerebellar Deficit Hypothesis, discussed in the Introduction (see section 2.3.2.1), could lead to skill automatization and procedural learning deficits in dyslexia (Nicolson & Fawcett, 1999).

The procedural learning system is not only involved in language but also in motor skills (Ullman, 2004). The literature suggests that children with dyslexia frequently present with motor skill deficits (Stoodley et al., 2005; Ramus et al., 2003). Procedural skill deficits, and procedural motor sequential learning deficits are reported in dyslexia (Nicolson et al., 2010; Vicari et al., 2005; Lum et al., 2013). A number of studies (Jimenez-Fernandez et al., 2011; Stoodley et al., 2006; Vicari et al., 2003; Nicolson et al., 2010; Lum et al., 2013) that investigated procedural sequential learning deficits in dyslexia used serial reaction time tasks, as these tasks do not include any verbal-related tests, and therefore they are separated from phonological-related difficulties (Vakil et al., 2015). Vicari et al. (2005) investigated procedural learning deficits in dyslexic children using a Serial Reaction Time task, which assessed sequential learning, and a Mirror Drawing task, which assessed speed processing of visuospatial stimuli. The results indicated that the children with dyslexia showed impairments in both tasks, which suggests that the deficits in dyslexia are not confined to verbal skills, but also extend to general learning skills.

In contrast to the aforementioned studies, other studies have not found an impairment in procedural learning in dyslexic individuals (Kelly et al., 2002; Vakil et al., 2015; West et al., 2018; Waber et al., 2003). It has been proposed that the inconsistencies in the results might be attributed to methodological or experimental design problems, such as differences in the characteristics of the sample, including age, gender, or comorbidity of disorders. Hedenius et al. (2013), and Nicolson et al. (2010) investigated procedural learning deficits in dyslexic individuals after an overnight consolidation and after extended practice. It has been suggested that single practice and short exposure to SRT tasks and procedural tasks cannot give valid results for procedural impairments in the disorder (Hauptmann et al., 2005). Needle et al. (2010) reported that the dyslexic adults had a poorer performance in the SRT task after overnight consolidation, both in terms of speed and accuracy, compared to the non-dyslexic adults. Likewise, Hedenius et al. (2013) reported that the dyslexic children in their study showed an impairment in a procedural sequence learning task, after a 24-hr interval and extended practice. The results suggested a deficit in the consolidation of skill learning, which is necessary for the automatization of skills, and provided a further explanation that procedural learning deficits might be better explained after extensive practice and overnight consolidation.

As discussed in the Introduction (see chapter 3, section 3.2.2), stress affects learning, particularly the declarative learning system, which is more affected than the procedural learning system (Kirschbaum et al, 1996; Lupien et al., 1997). Schwabe et al. (2010) suggested that under stressful conditions there is a shift from the declarative to the procedural learning system. This is particularly important for dyslexia, because if stress causes a shift from the declarative to the procedural learning system, then dyslexic individuals may be more affected due to an impaired procedural memory system, as suggested by the Procedural Learning Deficit Hypothesis. This shift can have adverse effects on dyslexic individuals' learning and performance, as under stressful conditions, the dyslexic individuals may be forced to switch from a stronger, cognitive declarative learning system to an impaired, automatic procedural learning system. According to Vogel and Schwabe (2016), the shift between the declarative and procedural memory systems can also be repressing for students, as it can create strong, negative memories and lead to habitual actions, which in turn can affect their ability to obtain new knowledge and use new information. The impact of stress on the declarative and procedural learning systems is discussed in detail in the Introduction (see chapter 3, section 3.2.2).

8.1.2 Working Memory in Dyslexia and the impact of stress

Evidence suggests that specific learning difficulties are characterized by multiple cognitive deficits, including phonological, auditory, and visual processing; rapid naming and processing speed; as well as short-term memory and working memory (Menghini et al., 2006; Weiss et al., 2014; Masoura, 2006; Smythe, 2007). Working memory and retrieval of information are believed to be core skills for successful performance at school, as working memory is the basic component of learning (Holmes et al., 2010). Verbal working memory has been found to predict reading ability and academic performance in childhood and adolescence (Jarvis & Gathercole, 2003). Working memory skills are crucial in classroom activities, particularly for literacy and arithmetic, as children need to store the information that they are given by the teacher, decode words, and do arithmetic activities (Gathercole & Pickering, 2000). Working memory difficulties are also associated with attentional and concentration difficulties (Aronen et al., 2005; Holmes et al., 2010).

Working memory deficits have been associated with difficulties in learning, and they have also been identified as a key deficit in dyslexic individuals (Jeffries & Everatt, 2004; Pickering, 2006a). Previous researchers (Pickering, 2006; Swanson & Siegel, 2001; Swanson-et al., 1996) found that children with learning and reading difficulties showed deficits in their verbal short-term memory, phonological short-term memory, and verbal working memory.

Pickering and Gathercole (2004) reported that children with specific learning difficulties were six times more likely to show verbal working memory deficits compared to children without specific learning difficulties. Jeffries and Everatt (2004) tested a group of children with dyslexia, a group with various Special Educational Needs, and a group without SEN on a range of phonological processing, visuo-spatial working memory, motor coordination, and executive functioning tasks. Although the results showed that both the SEN group and the dyslexic group had a poorer performance on the phonological working memory tasks, only the dyslexic group performed worse on the phonological awareness tasks as well as on the working memory task. However, no differences were reported between the dyslexic group and the group without SEN on the visuo-spatial working memory and motor coordination tasks. Research has also suggested that dyslexic individuals show poor performance on digit span tasks, which indicates working memory deficits (Miles, 1993; Jeffries & Everatt, 2004).

Gathercole and Pickering (2000) tested a group of 7- and 8-year-old children on a range of working memory tasks, including phonological loop tasks, visuo-spatial sketchpad tasks, and central executive tasks. Both the 7- and 8-years old children with SEN showed a poorer performance on all the working memory tasks; in particular, significant deficits were identified in central executive tasks, especially in the backwards digit recall task. Children with SEN also performed poorly on the visuo-spatial sketchpad tasks, but they were less impaired than children without SEN on the phonological loop tasks. Gathercole and Pickering argued that the children with SEN performed particularly poorly on the central executive tasks because such tasks require the child to store the information and process it at the same time, which is a demanding task for a child with SEN. Gathercole and Baddeley (1990) argued that children with Specific Language Impairment (SLI) are characterised by deficits in working memory skills, particularly in central executive, phonological loop, and visuo-spatial tasks. Nine undergraduate male students with dyslexia were tested on a range of executive functioning tasks, including digit span tasks, an inhibition task, a verbal fluency task, a planning task, a sequencing task, and an organisation task (Brosnan et al., 2002). The results indicated that the dyslexic group showed impaired performance on the forward and backward digit span tasks, and on the verbal fluency task compared to the non-dyslexic group, but no deficits were found in the rest of the tasks, which included planning, sequencing, and organisation tasks of executive functioning.

Other studies with adult students with dyslexia (Smith-Spark & Fisk, 2007), and children with dyslexia (Swanson, 2000) have found both verbal and visuospatial working memory deficits. Smith-Spark and Fisk (2007) assessed dyslexic university students on a series of simple verbal span tasks including digit, letter, and word span tasks, as well as a series of complex working memory tasks, including verbal and visuospatial tasks. The results showed that the dyslexic group performed poorer on the verbal span tasks, in both a simple and complex condition, as well as on a spatial span task in the complex condition. Swanson et al. (2006) found that children with specific learning difficulties showed impairments in verbal working memory tasks but not in visuo-spatial working memory tasks.

Some researchers (Snowling, 1981; Jorm, 1983) have attributed the impaired working memory of dyslexic children to phonological processing deficits. Given that working memory is comprised of a phonological store, where verbal phonological information is kept, this could potentially have a negative impact on dyslexic children's learning process. Neuroimaging studies have provided evidence of impairments in frontoparietal function in dyslexic individuals (Paulesu et al., 1996; Richard & Berninger, 2008). Evidence (Ben-Yehudah et al., 2007; Daum et al., 1993) suggests that the cerebellum contributes to verbal working memory function and to the acquisition and execution of learned skills. One fMRI study (Wolf et al., 2010) explored the functional connectivity of different brain regions in a verbal working memory task in dyslexic adolescents and young adults. Wolf et al. (2010) did not find any difference in reaction time between dyslexic and control participants, but as the working memory load increased, the dyslexic participants' performance was less accurate. The fMRI results showed functional connectivity deficits in the dyslexic adolescents within the left prefrontal and parietal cortex, as well lessened functional connectivity in the left gyrus and the left hippocampal cortex.

Similar results were found by Beneventi et al. (2010) who investigated brain correlates of working memory, using fMRI, in dyslexic children. The n-back working memory task was administered in the study, in which children were presented with letters one by one, and they had to decide if the letter being presented was the same as the one presented two trials back. The behavioural results indicated poorer performance in the dyslexic group in terms of both reaction time and of accuracy. The fMRI results revealed decreased functional activation in the dyslexic group in the prefrontal and parietal cortex, as well as in the cerebellum. These results provide evidence to support the notion that there are working memory deficits in dyslexic individuals. The impact of stress on working memory is discussed in the Introduction (see chapter 3, section 3.2.3).

8.1.3 Motor function in dyslexia and the impact of stress on the cerebellum

As discussed in the Introduction (see section 2.3.2.1), the Cerebellar Deficit Hypothesis (Nicolson & Fawcett, 1999) suggests that dyslexic individuals have difficulty in automatizing skills, whether these are cognitive or motor skills, due to cerebellar impairment. A number of studies (Nicolson & Fawcett, 1990; Fawcett et al., 1996; Yap & Van der Leij, 1994; Needle et al., 2006; Legrand et al., 2012) have reported deficits in children with dyslexia in terms of postural stability, balance, motor coordination, and muscle tone. Brookes et al. (2010) found balance impairments in dyslexic children in an eyes-open, as well as in a blindfolded condition task. The same study showed that the dyslexic adults showed balance impairments in the blindfolded condition only. The authors suggested that the eyes-open task might have been a rather simple and easy task for the adults. Nicolson and Fawcett (1995) tested motor skills in three groups of children with dyslexia aged 8, 13 and 17 years, using a bead threading and a peg moving task. According to the Automatization Deficit Hypothesis (Nicolson & Fawcett, 1990), impairments are not only evident in the speed of articulation, but also in simple motor skills when language components are not included, such as in a bead threading test. The results indicated that all three groups of dyslexic children had poorer performance on both the bead threading and the peg moving tasks compared to the typically achieving children of the same age. However, the dyslexic groups performed even worse on the bead threading test compared to the typically achieving children of the same reading age. According to Fawcett and Nicolson, the results show clear evidence of both a cerebellar dysfunction and an automatization deficit, even for a simple motor skill, in dyslexia.

A neuroimaging study (Nicolson et al., 1999) supported the cerebellar deficit theory with further evidence; it showed that dyslexic adults performed worse in a motor sequence task compared to non-dyslexic adults. In particular, the results indicated differences in brain activity (in the right cerebellar cortex) while learning the motor sequence. The results suggest the activation of the cerebellum during the learning of sequences, until learning becomes automatic, and after that stage. The cerebellar deficit theory (Nicolson & Fawcett, 1999) claims that this process is impaired in dyslexia.

Several other studies (Barth et al., 2010; van Oers et al., 2018; Ramus et al., 2003), however, have not found motor or cerebellar deficits in dyslexia. Wimmer et al. (1999) did not find evidence of cerebellar impairment in dyslexic children using a dual balancing task. The authors also controlled for comorbidity between ADHD and dyslexia and found that only the dyslexic children who had comorbidity with ADHD showed poor performance on the balancing task. It has been suggested that motor impairments are likely to be found in dyslexic individuals when controlling for co-occurring ADHD disorder or low IQ (Rochelle & Talcott, 2006; Rochelle et al., 2009; Wimmer et al., 1999). Rochelle et al. (2009) suggested that balance and postural deficits in dyslexia are more strongly related with ADHD symptoms than with reading deficits. The impact of stress on the cerebellar activity is discussed in the Introduction (see chapter 3, section 3.2.4).

8.2 Design of the study

Study 4 investigated the performance of dyslexic and non-dyslexic adolescents on a range of cognitive tasks declarative and procedural memory tasks as well as motor tasks, and the association of stress to cognitive performance. Stress was assessed using behavioural self-report measures to assess personal feelings and current levels of stress.

8.3 Rationale and aim of Study 4

As discussed in the Introduction (see chapter 2, section 2.3.3.1), individuals with dyslexia show impairments in procedural learning (Nicolson et al., 2010, Nicolson & Fawcett, 2018; Brookes et al., 2007), and in motor tasks (Nicolson et al., 1995; Fawcett et al., 1996; Fawcett & Nicolson, 1999; Finch et al., 2002), which are explained by the Procedural Learning Deficit Hypothesis (Nicolson & Fawcett, 2007), while the declarative memory system remains intact and compensates for impairments in the procedural system (Ullman & Pullman, 2015; Lum et al., 2010). However only a few studies have tested declarative and procedural memory concomitantly in dyslexic adolescents. In addition, evidence suggests that individuals tend to shift from using their declarative system to the procedural system under stress (Vogel & Schwabe, 2016; Ness & Calabrese, 2015; Nicolson et al. 2010), and as such cognitive performance is impaired under stressful conditions. Based on these previous findings, Study 4 explored procedural and declarative memory skills, along with cerebellar motor activity in dyslexic and non-dyslexic adolescents, and their relationship to stress.

The first aim of the study was to investigate the performance of dyslexic adolescents on procedural and declarative memory tasks, in addition to motor function tasks. The second aim of the study was to explore the psychological and behavioral effects of stress on cognitive performance in adolescents with dyslexia, depending on which learning system, declarative or procedural, the task needed to engage.

8.4. Hypotheses for Study 4

The hypotheses for this study were based on previous theories and research discussed in the Introduction.

Based on the Cerebellar Deficit Hypothesis (Nicolson and Fawcett, 1999) (see section 2.3.2.1), Hypothesis 1 was:

- Hypothesis 1: Adolescents with dyslexia will show significantly poorer performance on motor function tasks (bead threading and postural stability) compared to non-dyslexic adolescents.

Based on Nicolson and Fawcett's (2007) Procedural Learning Deficit Hypothesis (see section 2.3.3.1), it was predicted that there will be an interaction between declarative and procedural learning system. Hypothesis 2 was:

- Hypothesis 2: Adolescents with dyslexia will show significantly poorer performance on procedural learning tasks (MST and WIT) compared to non-dyslexic adolescents.

Based on Smith-Spark's and Fisk's (2007) study, discussed in section 8.1.2, hypothesis 3 was:

- Hypothesis 3: Adolescents with dyslexia will show significantly poorer performance on the verbal working memory task compared to non-dyslexic adolescents.

Based on the theories and research discussed in the Introduction (see chapter 3., section 3.2., and sections 8.1.1, 8.1.2 and 8.1.3) in regard to the impact of stress on cognitive and motor function, hypothesis 4 was:

- Hypothesis 4: A significant association will be found between anxiety and performance on declarative, procedural, and motor tasks for both groups, but the association will be stronger for the dyslexic group.

Although there was no specific hypothesis in the present study about declarative learning, based on previous research (see section 8.1.1), it was of interest to test the performance of the dyslexic and non-dyslexic group on declarative learning tasks, namely on the Visual Declarative Memory test, and the Picture Memory Recall test.

8.5 Methodology

8.5.1 Ethical considerations

Study 4 received ethical approval from the Department of Psychology Research Ethics committee in accordance with the University of Sheffield's Research Ethics Approval Procedure. Permission to conduct this study in the school premises was obtained from the School Head and the Learning Provider. After approval from the School Head, an Invitation Letter, a Participant Information Sheet, and an Informed Consent Form were sent to parents via the school. If the parent consent and the child wished to participate, they were invited to sign a consent form and return it to school.

There was liaison with relevant staff to ensure that none of the participants felt particularly emotionally vulnerable regarding their dyslexia in line with Singer's (2005) suggestion that dyslexic children are at an increased risk of intense emotional reaction. The participants were told the aims of the study at the onset and again after completion of the study and were encouraged to ask as many questions as they wanted. The participants were informed that they could withdraw from the study at any time without giving any reason. None of the participants withdrew from the study.

8.5.2 Participants

Similar to Study 2, Study 4 was also conducted in collaboration with the Sheffield Futures Organization (www.sheffieldfutures.org.uk) which assisted with the recruitment of participants and access to the school. A sample of 40 students participated in Study 4. The students were invited to take part in the study by the Learning Provider (there was no overlap between the participants in Study 2 and 3 with Study 4 and 5). Eighteen students with dyslexia, and 22 students without dyslexia participated in the study, aged 14 and 15 years old, from Year 10 with a mean age of 14.7 years. Nineteen students were females, and 21 students were males.

None of the students with dyslexia were known to have other developmental or neurological disorders (e.g., ADHD, SLI, autistic spectrum disorder). The dyslexic adolescents, who participated in the study, had a formal diagnosis of dyslexia either from the educational psychologist within the school or from a diagnostic Centre outside the school. The non-dyslexic adolescents were not known to have a previous history or diagnosis of learning or other developmental difficulties.

8.5.3 Materials and Apparatus

A battery of tasks covering a wide range of skills was administered in Study 4 to assess cognitive, physical, and affective skills. Most of the tests in Study 4 were derived from the Dyslexia Screening Test (DST-S) (Fawcett & Nicolson, 2004). In particular, the DST-S was comprised of 9 subtests which assessed literacy skills (reading, writing, and spelling), executive function/memory retrieval, naming speed, balance, working memory, and non-verbal reasoning. Four additional tasks were administered in Study 4 derived from the Learning Assessment Battery LAB (Nicolson, 2010) and the South Yorkshire Ageing study (SEAS) (Tarmey, 2012) to assess procedural and declarative memory. For the affect suite, the State – Trait Anxiety Inventory (STAI) (Spielberger et al., 1970) was administered; the State anxiety Inventory assessed the current state of anxiety just before the participants were tested, and the Trait Anxiety Inventory assessed dispositional anxiety. Details of the tests are presented below.

This basket of tasks was chosen to allow 'whole person' measures to be derived, including not only measures of literacy attainment, but also the underlying executive capacity in terms of mental coordination, declarative learning, physical coordination, procedural learning, and affect. Six key tasks were used as 'probes' for these capabilities, namely the Declarative Memory task as a probe for the ability to extract and remember detail from a complex presentation; the Delayed Picture Recall task as a probe for the ability to recall information over a 20 minute period of interfering activities; the Motor Sequence Learning task as an index of physical procedural learning; the Postural Stability task as an index of proprioceptive learning (ability to adjust to an unexpected stimulus disturbing balance); and the Trait Anxiety measure as an enduring index of affect. The composite DST-S At Risk Quotient gives an index of risk of dyslexia.

Dyslexia Screening Test-Secondary (DST-S)

The DST-S was designed to assess secondary school students between 11.6 and 16.5 years of age, and to distinguish students who are at risk of reading failure (Fawcett & Nicolson, 2004). The DST-S has been used for research purposes demonstrating that it is a valid tool for assessing students (Fawcett et al., 2001; Reynolds & Nicolson, 2007; Reynolds et al., 2003). The DST-S is comprised of twelve tests which cover different areas shown to be affected in reading disorders; namely, they cover literacy skills, phonological awareness, verbal memory, motor skills and balance, and memory retrieval fluency (Fawcett & Nicolson, 2004; Reynolds et al., 2003). The DST-S was chosen for this study because it portrays an assessment on a multi-level approach. The DST-S also considers the cerebellar contribution to dyslexia deficits and the phonological deficit theory (Kirk & Reid, 2001). The DST-S test reports a test-retest reliability of 0.76 (Fawcett & Nicolson, 2004). Test-retest reliability is also reported for each subtest separately; in particular, the reliability for the tests of reading, spelling, and writing is 0.9; reliability for bead threading, postural stability, and semantic fluency is above 0.7; and reliability for rapid naming, backwards digit span, and verbal fluency is 0.8 to 0.88. DST-S includes the following tests: Rapid naming, Bead threading, One-minute reading, Postural stability, Phonemic segmentation, Spoonerisms, Two-minute spelling, Backwards digit span, Nonsense passage reading, One-minute writing, Verbal fluency, Semantic fluency, and Non-verbal reasoning.

The DST-S was not used as a diagnostic tool in the present study, but as a tool to present the general profile of dyslexic adolescents in areas relating to literacy skills, motor skills and balance, as well as executive function and working memory. Therefore, for the purpose of the current study, the following nine tests were administered:

i) Literacy skills

1. The One Minute Reading test is a composite test of single word reading accuracy and fluency and it tests speed as well as accurate performance. The participant had to read aloud a page of 60 words in total, graded in difficulty, in one minute. The participant started with a practice and then moved on to the main test.

Example of words used in the practice.

cat	boat
ball	fox
hit	ship

2. The Two Minute spelling test assessed speed, accuracy of spelling, and speed of writing. The test was comprised of two sets of spelling: an easy one, and a harder one. The participant first had a practice and then moved on to the main test. The scoring for this test emerged by noting 1 point for each word spelt correctly.

Example of words used in the practice.

train	children	Monday

3.The One Minute Writing Test examined the speed and accuracy of copying a short passage. The participant started first with a practice and then moved on to the main test. The raw score was the number of words completed correctly.

Example of writing used in the practice.

Can you copy?

ii) Motor tests

1. The Postural Stability test was based on clinical procedures for establishing cerebellar abnormalities. Postural stability was measured using a balance tester plastic device which had a collar that slid from one side to the pommel. The participants were required to stand upright, to look ahead, and to keep their arms by the sides while they were blindfolded. The experimenter stood behind the participant (see Fig. 8.1) while holding the balance tester horizontally and then pushed the collar along the shaft at the participant's back, while the participant had to stay as still as possible. Pressure was applied for 1.5 seconds, and the collar was pushed with 2.5 kg pressure. The test was performed six times; three times with the arms at the side, and three times with the arms straight in front. The raw score was the sum of the six trials.

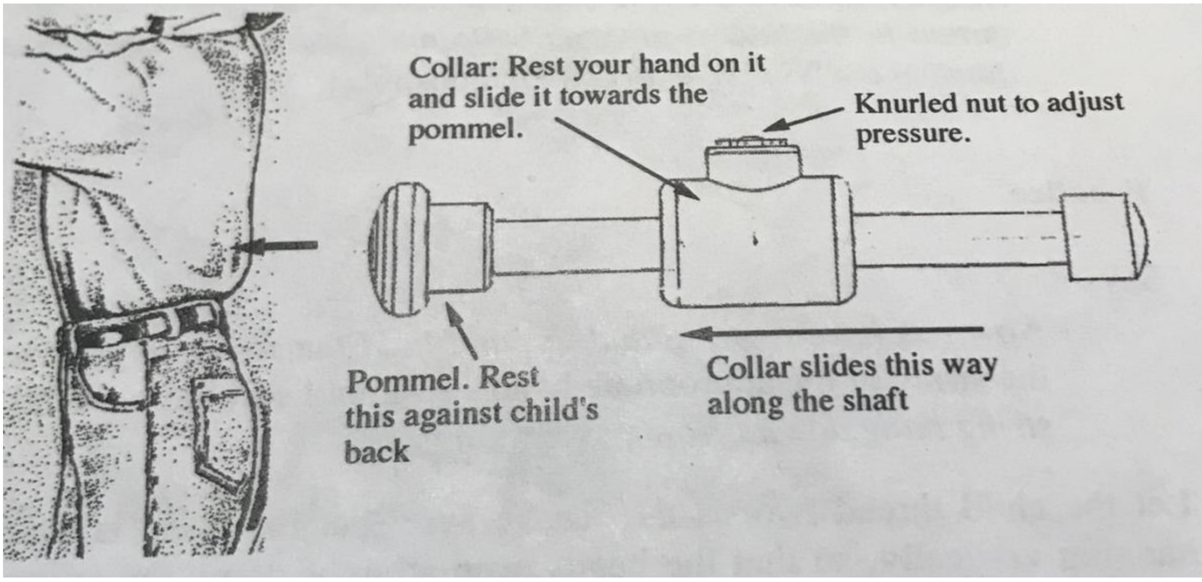


Figure 8.1 Balance tester of the postural stability test

2. The Bead Threading test (see Fig. 8.2) assessed a fine motor skill, particularly a hand-eye coordination and manipulative skill. The participants were given 15 wooded beads and a string, and they had to hold the string in their writing hand and bead as many beads as possible onto

the string in 30 sec. First, there was a practice with three beads and then the participant moved on to the main test. The raw score was the number of beads threaded minus the first three beads threaded in the practice.

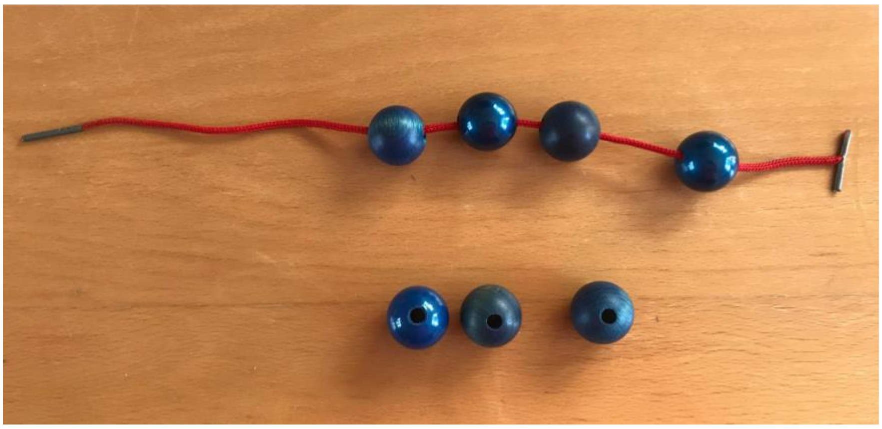


Figure 8.2 The bead threading test

iii) Verbal Working Memory

The Backwards Digit Span was a test that measured the number of digits the participant could remember in the correct order. The digits were read aloud by the Researcher one per second.

The participant first started with a practice, and then moved on to the main test. The score emerged from the total number correct in the main test. In order to score one mark, the whole list should have been correct, otherwise no score was given for a list if the digits were in the wrong order.

Example of digits used in the practice.

Stimuli	Correct answer
92	29
134	431
1567	7651

iv) Executive Function/Memory Retrieval Fluency

1.The Rapid Automatized Naming task (RAN) required the participants to name a series of outline pictures on a card as fast as they could (see Fig. 8.3). The participant first started with a practice, and then moved on to the main test.

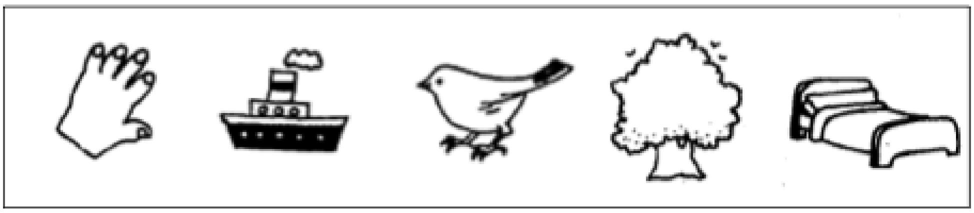


Figure 8.3 Example of the Rapid Automatized Naming test

2. The Verbal fluency test assessed how many words beginning with S the participant could think of in a minute. The participant first started with a practice, saying words starting with g, and then continued to the main test for one minute. The scoring for this test emerged by noting 1 point for each different valid word.

3. The Semantic Fluency assessed how many words, which were names of animals, the participant could think of in a minute. The participant first started with a practice, by saying as many names of foods, as possible. The scoring for this test emerged by noting 1 point for each different animal. The verbal and semantic fluency tests assessed speed of retrieval from long term memory.

DST-S Interpretation

The DST-S has age-based norms for each sub-test, and these norms were used to convert raw scores into decile scores (1-10), with a decile score of 1 indicating the lowest 10% on the norms (Fawcett & Nicolson, 2004). Decile scores ranging from 1-3 correspond to risk categories (1 = high risk, 2 = moderate risk, 3 = mild risk), and deciles scores above 4 correspond to normal, non-risk, category for having reading disorders (Fawcett & Nicolson, 1998). Higher scores in the DST-S indicate better performance.

The DST-S provides a method for deriving an overall ‘At Risk Quotient’ (ARQ) which calculates the weighted mean of the at-risk scores on the individual tasks. An ARQ of 0.9 or greater is considered a ‘strong risk’ indicator, an ARQ of 0.6-0.8 is considered a mild risk indicator, and an ARQ from 0-0.5 are classified as ‘not at risk’. In Study 4, the ARQ was divided by 8 (the total numbers of tests used in this study, except for the semantic fluency test which is not an index of dyslexia). The composite DST-S at Risk Quotient gave an index of risk of dyslexia. A profile chart was also completed using the set of tests administered. The chart provided an ‘at a glance’ indication of the areas of relative strength and relative weakness. Internal consistency of the Dyslexia Screening Test for study 4 was .68 which indicated good reliability for the DST-S.

Declarative Memory Tests (Learning Assessment Battery; unpublished Nicolson, 2010)

1.Visual Declarative Memory test

For this test, the participants were given a card illustrating 14 pictures depicting images, such as a dice (see Fig. 8.4). Participants were given one minute to memorize as many details as they could about the pictures and were then asked 13 subsequent questions verbally to test their memory. The participant was scored based on number of correct answers. Both the pictures and questions were controlled for equal difficulty.

Figure 8.4 Pictures displayed on Visual Declarative Memory test

2. Picture Memory Recall test

This test assessed recall for a set of 18 pictures of common, everyday household, objects (see Fig. 8.5) presented sequentially for 1 second, including both immediate recall and delayed recall after 20 minutes. However, the pictures were not shown again to the participants for the delayed version of the test.


£10

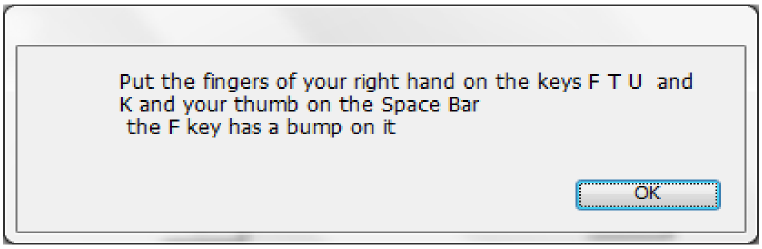

More

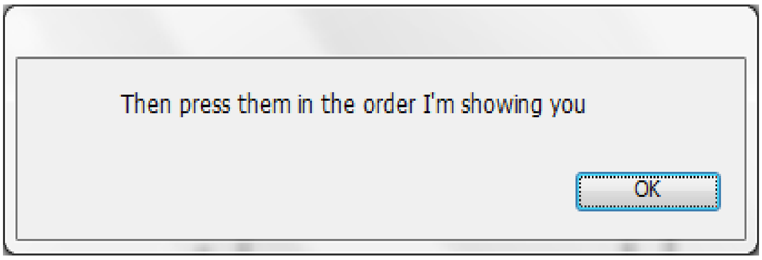
Figure 8.5 Pictures displayed on Picture Memory Recall test

Procedural Memory tests (Learning Assessment Battery; Nicolson, 2010)

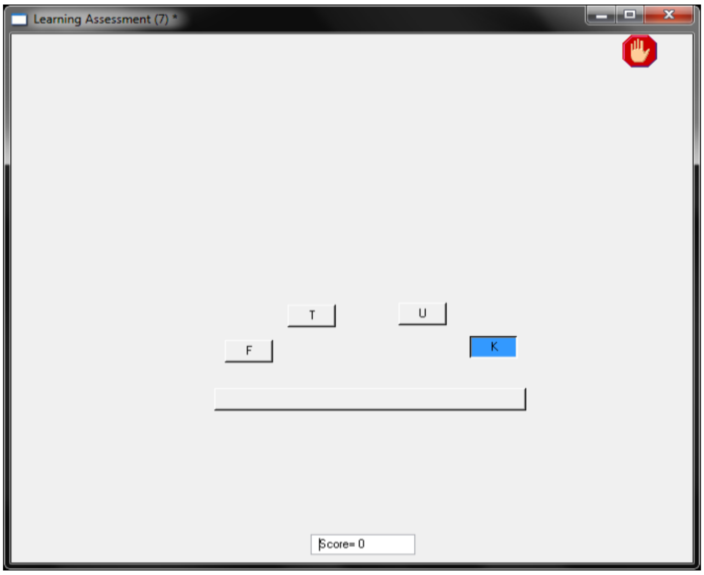
2. Motor Sequence Task (MST)

Procedural learning was assessed using the LAB Motor Sequence Learning task. This task was modelled on Korman et al. (2003) task, and the participants had to learn and repeat a sequence of 4 key presses on a keyboard (e.g., FKUT FKUT FKUT) (see Fig. 8.6) 18 times. These 4 keys were different during the main task, in which the programme highlighted the sequence but only for the first trial, and then the participant had to complete the task by memory. All sequences were achievable using one hand on the keyboard. Before the task began, the computer software asked which hand was being used, right or left, and automatically chose the sequence accordingly. The MST programme generated two scores: first, the participant was scored for the number of correct sequences, and second, for speed (time taken to learn the set of keys in seconds). The maximum number of correct sequences in the task was 18.





The experimenter read the instructions aloud to the participant.

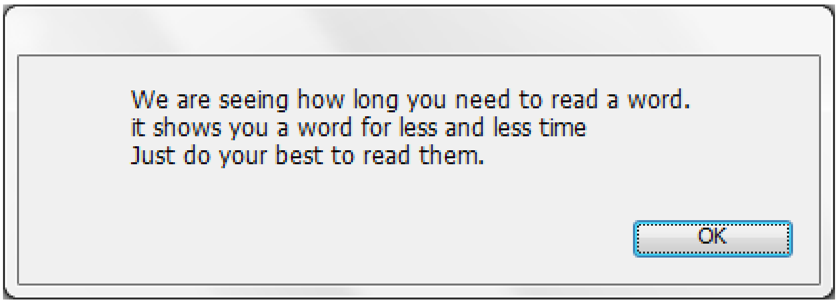


The letter that the participant needed to press flashed up blue. Letters flashed in a sequence and this sequence gradually got faster.

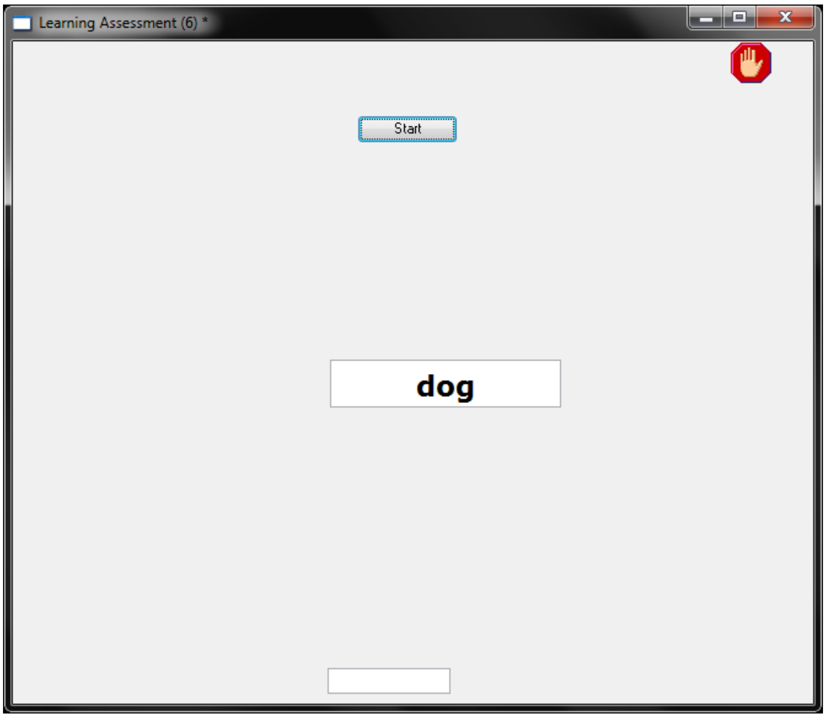
Figure 8.6 MST as it appeared on laptop screen

2. Word Identification Task (WIT)

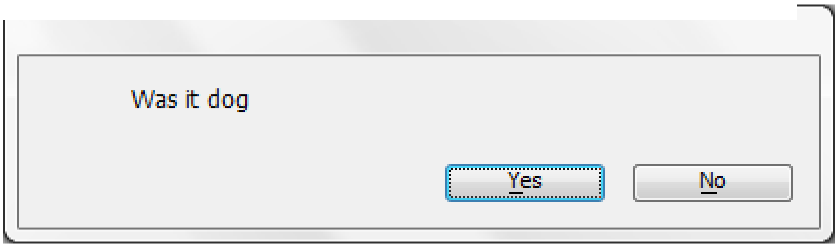
The WIT was designed to measure the participant's reading capabilities. During the task, the participant was shown a series of words (see Fig. 8.7). Two sets of word were administered in the study: a set of real words and a set of pseudowords. Seven words were displayed at five-word lengths (from 3 letter words to 7 letter words) at increasing speeds. With each successive word in a series, the presentation time got shorter, starting with 1000ms, and decreasing to 50ms. During the WIT, words flashed up on the screen followed by an interval in which the participant had to say each word aloud after it was presented, and their answer was recorded by the programme. The task began with a short practice trial of five words. Participants were allowed to pass if they were unsure of any words. Each word identified correctly scored 1 point. Two scores were generated from the task: first, for accuracy, which corresponded to the number of correct words, and second, for speed (time taken to read aloud the word in seconds). The maximum number of correct words the participant could read was 35.



The experimenter read aloud the instructions displayed.



The word flashed up quickly for the participant to identify.



The experimenter asked the participant what the word they had read was and pressed ‘Yes’ or ‘No’ accordingly.

Figure 8.7 WIT task as it appeared on the laptop screen

To control for anxiety effects during the experiment, behavioral measures of anxiety were used in Study 4, which measured participants’ subjective feelings of stress before. The State and Trait Anxiety Inventory was administered to assess levels of stress before the assessment. The Researcher was also presented as rather distant and non-reinforcing to the students, which could potentially be considered as stress-provoking behavior for some children.

State – Trait Anxiety Inventory (STAI)

The State – Trait Anxiety Inventory (STAI) (Spielberger et al., 1970) used in the current study is the same as reported in Study 2 (chapter 6).

8.5.4 Procedure

All tests were administered on an individual basis during school time, in a quiet classroom in the school. The assessment was completed in one session and lasted approximately for an hour. The children were escorted in the classroom by the Learning Provider, who was outside the classroom during the assessment, but in close proximity. The participants completed the tasks in the following order: they first completed the State and Trait anxiety Inventory, to assess present levels of anxiety prior to completing the tasks, then they were tested on the Dyslexia Screening Tasks, followed by the Declarative and Procedural memory tasks.

8.6 Results

8.6.1 Descriptive statistics

Table 8.1 reports the mean scores and standard deviations for each group, along with effect sizes for the Dyslexia Screening Tests. The Median scores are also reported as the data was not normally distributed.

Table 8.1 Means, standard deviations, and median scores by group, along with effect sizes for the DST-S tasks

Task	Dyslexia (N=18)		Non-dyslexia (N=22)		
	Mean (SD)	Median	Mean (SD)	Median	Effect size
Literacy					
One-minute reading	2.28 (.96)	2.00	3.50 (1.44)	3.50	0.85
Two-minute spelling	2.22 (1.00)	2.00	3.95 (1.91)	4.00	0.90
One-minute writing	2.11 (.96)	2.00	3.14 (1.17)	3.00	0.88
Motor					
Bead threading	2.06 (1.83)	1.00	3.82 (2.11)	3.00	0.83
Postural stability	2.67 (.91)	3.00	3.73 (1.24)	4.00	0.85
Verbal working memory					
Backwards digit span	1.94 (.87)	2.00	3.36 (1.53)	4.00	0.93
Executive Function/Memory retrieval fluency					
Rapid automatized naming	1.67 (.91)	1.00	3.77 (1.54)	4.00	1.36
Verbal fluency	2.17 (1.72)	1.50	3.50 (1.60)	3.00	0.83
Semantic fluency	2.72 (.75)	3.00	3.36 (1.26)	4.00	0.51

Table 8.2 Means and standard deviations by group, for declarative and procedural memory tests and for the STAI

Test	Dyslexia (N=18) Mean (SD)	Non-dyslexia (N=22) Mean (SD)	Effect size
Declarative memory			
Visual declarative memory	11.00 (2.47)	13.18 (2.67)	0.82
Picture memory recall	9.06 (2.15)	10.45 (1.71)	0.81
Picture memory recall delayed	8.06 (3.21)	10.00 (2.64)	0.74
Procedural memory			
MST number sequences – 1st trial	10.67 (2.02)	12.77 (2.58)	0.81
MST speed (secs) / sequence – 1st trial	3.83 (.44)	3.43 (.47)	0.85
MST number sequences – 2nd trial	11.44 (2.09)	14.05 (1.64)	1.60
MST speed (secs) /sequence – 2nd trial	3.75 (.42)	3.32 (.42)	1.02
WIT real words accuracy	28.67 (3.18)	30.64 (2.36)	0.83
WIT speed (secs) for real words	3.41 (.48)	2.10 (.45)	2.91
WIT pseudowords accuracy	17.44 (3.51)	20.82 (.42)	16.9
WIT speed (secs) for pseudowords	3.85 (.29)	3.51 (27.3)	0.01
STAI			
State anxiety	43.22 (5.34)	38.73 (4.41)	1.02
Trait anxiety	44.44 (5.46)	39.82 (5.13)	0.90

8.6.1.2 Distribution of categorical scores

Graphs 8.8 and 8.9 present the distribution of categorical scores, within each group, for the total score of the DST-S, and the State-Trait anxiety Inventory. The distribution of scores in the DST-S were analysed with crosstabs. According to the 'At Risk Quotient' scores, within the dyslexic group, most dyslexic adolescents had high frequency of scores in the 'strongly at risk' category, 77.8% came out with ARQ > 1.0; and 22.2% were in the 'mildly at risk' category. Of the non-dyslexic group, 32% of students had scores in the 'strongly at risk' category of dyslexia, 59% had scores in the 'mildly at risk' category of presenting dyslexia symptoms, and 9% had scores falling into the 'not at risk' category of dyslexia. As mentioned in section 8.5.3, an ARQ of > 0.9 is a 'strong risk' indicator, an ARQ of 0.6-0.8 is 'mild risk', and 0-0.5 is a 'not at risk' indicator.

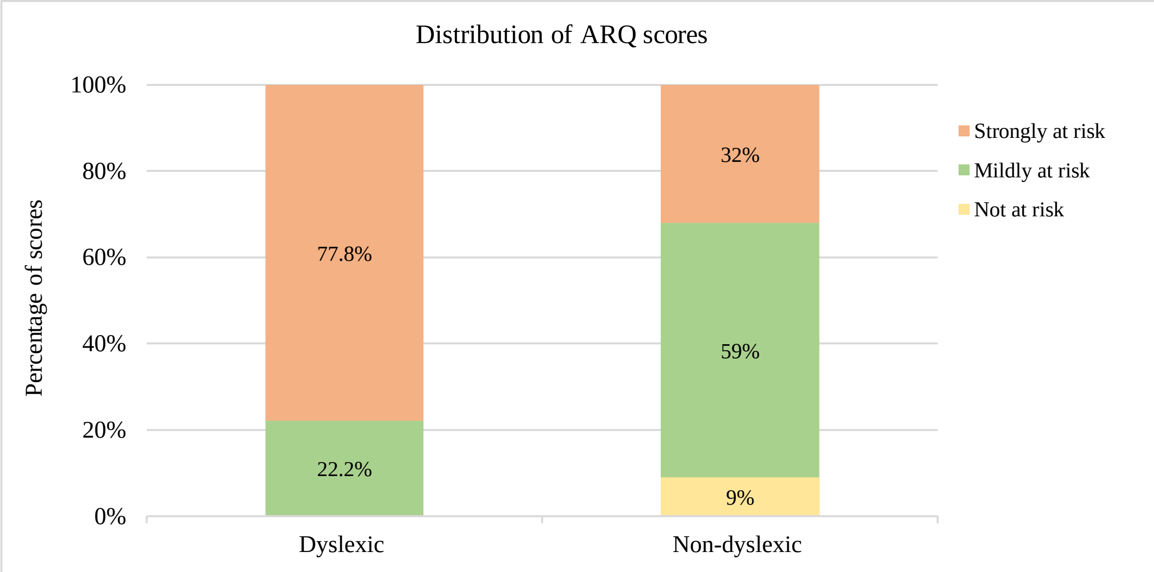


Figure 8.8 Distribution of ARQ categorical scores for the dyslexic and non-dyslexic adolescents

According to the STAI scores, most students in the dyslexic group (66.7%) had scores falling into the 'high anxiety' category (scores > 40), and 33.3% were in the 'low anxiety' category (scores < 40). In contrast, more than half of students (60%) in the non-dyslexic group showed low levels of anxiety, while 40% reported high levels of state anxiety.

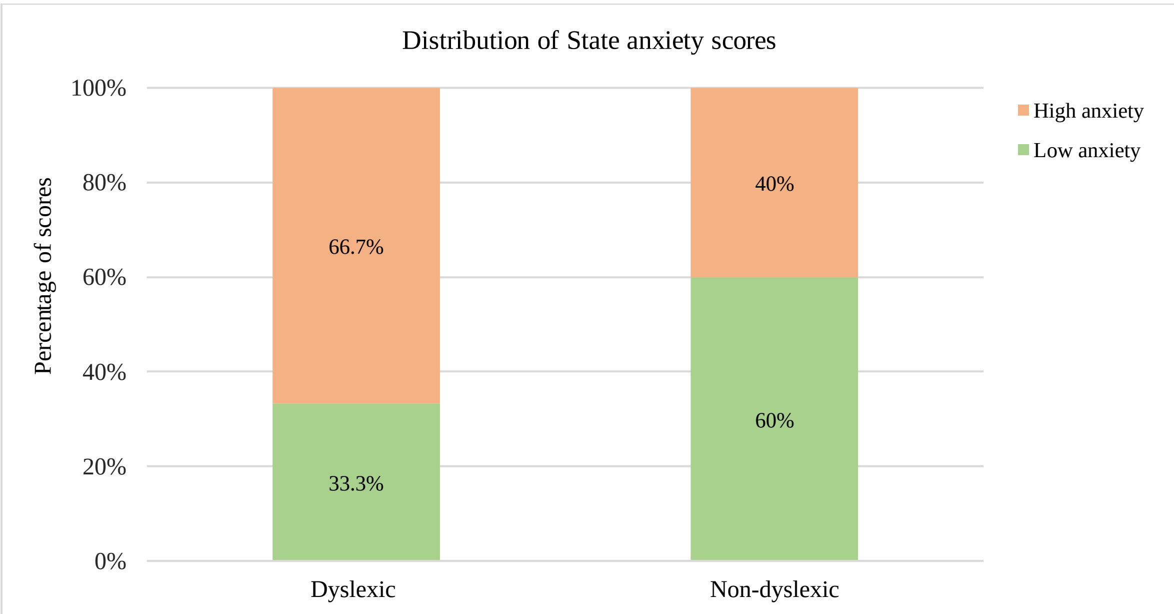


Figure 8.9 Distribution of State anxiety categorical scores for the dyslexic and non-dyslexic adolescents

Similar results were obtained for the distribution of Trait anxiety scores (see Fig. 8.10). Within the dyslexic group, most students (72.2%) had scores in the 'high anxiety category' (scores > 40), and 27.8% had scores in the 'low anxiety category' (scores < 40). In the non-dyslexic group, 45.5% had scores in the high levels of anxiety and 54.5% had scores in the low levels of anxiety. As mentioned in Section 6.4.3, scores for both scales range from 20-80, with higher scores representing higher levels of anxiety; scores below 40 are within the normal, non-clinical, range, while scores above 40 show clinical symptoms of anxiety.

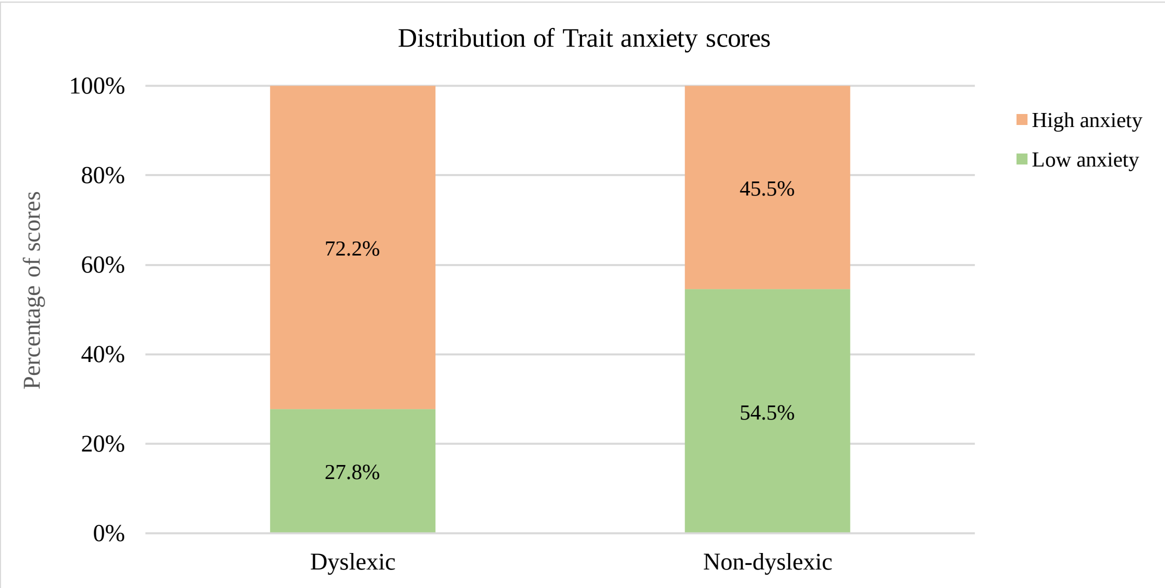


Figure 8.10 Distribution of Trait anxiety categorical scores for the dyslexic and non-dyslexic adolescents

8.6.2 Statistical analysis

The normality of data was checked using the Shapiro-Wilk test, along with the inspection of histograms. Some data were not normally distributed (Shapiro-Wilk test < .05); therefore, a non-parametric test was used to analyse the data. The examination of boxplots indicated that there were a few outliers in the data, however, they were not significant outliers, and hence, it was not necessary to remove them from the analysis.

An Independent Samples t-test was conducted for the normally distributed data with 95% confidence interval (CI) for the mean difference to compare the scores between the two groups (dyslexic and non-dyslexic). The Levene's test showed that the assumption of equality of error variances was met for all the variables ($p > .05$). A non-parametric Mann-Whitney U Test was conducted for the non-normally distributed data. Due to the small sample size, and comparisons being significant in the same direction, p-values were not adjusted. This method was also suggested by previous research (Gallant & Nicolson, 2017; Moran, 2003; Moore et al., 2017), for cases where all changes are in the predicted direction. Figure 8.11 shows the performance of dyslexic and non-dyslexic adolescents on the Dyslexia Screening subtests. Higher mean scores on DST tasks indicate better performance.

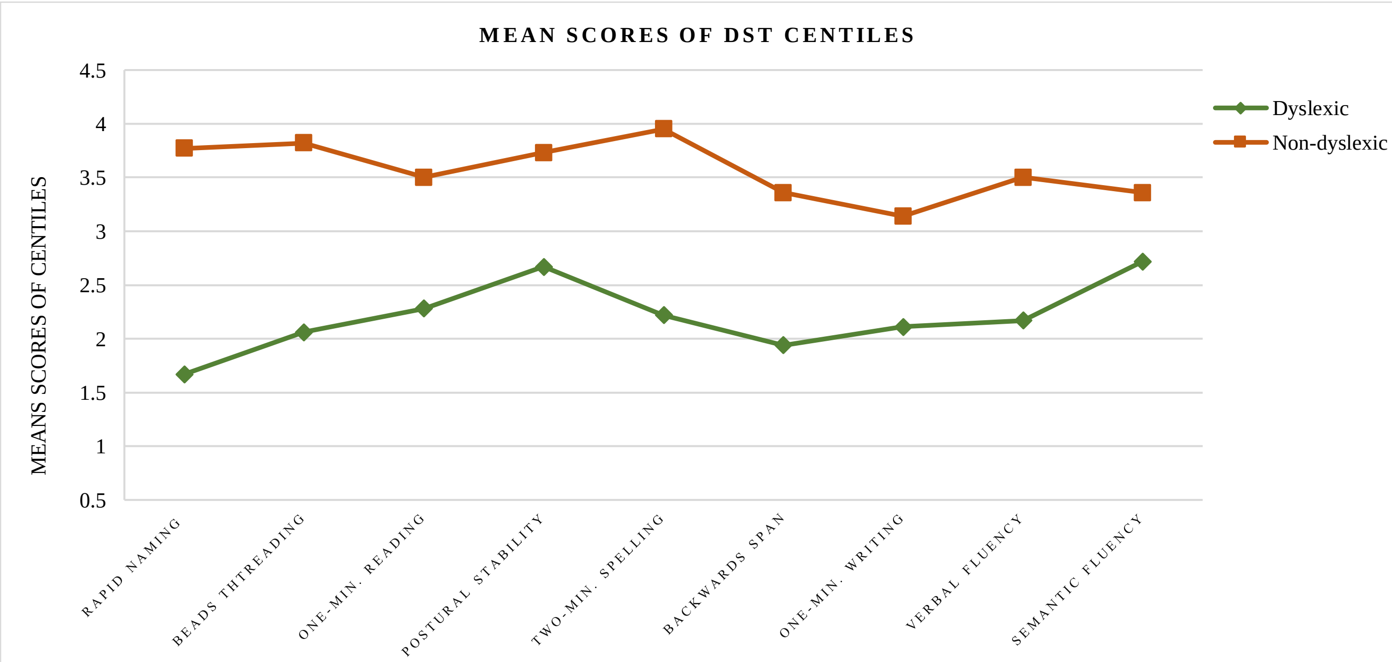


Figure 8.11 Mean scores of performance of dyslexic and non-dyslexic adolescents in the DST subtests

The DST-S subtests were analyzed separately using the risk index. The students in the dyslexia group obtained from five up to nine risk scores in the DST-S subtests, with a mean of 2.19, compared with a mean of 3.30 of the control group. A Chi square analysis showed that the students with dyslexia were more likely to fall into the risk categories in the One-minute Reading task, χ^2 (1) = 4.268, p = .039; in the Rapid Automatized Naming task, χ^2 (1) = 6.599, p = .010; in the Beads Threading task, χ^2 (1) = 5.560, p = .018; and in the Backwards Digit Span task, χ^2 (1) = 6.825, p = .009.

8.6.2.1 Between group statistical tests.

Literacy skills

A Mann-Whitney U Test indicated significant differences between the dyslexic and non-dyslexic group scores in the one-minute reading test (U = 100.5, Z = -2.71, p = .007 2-tailed), the two-minute spelling test (U = 86.00, Z = -3.10, p = .002 2-tailed), and the one-minute writing test (U = 102.0, Z = -2.70, p = .007 2-tailed). The direction of the differences found between the two groups was the same for all the literacy tests, with the dyslexic group indicating lower scores (i.e., worse performance) than the non-dyslexic group (see Table 8.1). Inspection of individual data, on a case-by-case basis, indicated a high incidence of signs in the dyslexic group, with 16 of 18 students (88.9%) who scored low (i.e., within the ‘at risk’ category) in the one-minute reading test, the two-minute spelling test, as well as in the one-minute writing test. The non-dyslexic group also showed low performance in most of the literacy tasks. Particularly, 50% of the non-dyslexic group scored within the ‘at risk’ category in the one-minute reading task, 36.3% in the two-minute spelling task, and 59% in the one-minute writing task.

Executive function

A Mann-Whitney U test indicated significant differences in the RAN task (U = 57.50, Z = -3.92, p = .001 2-tailed), and in the verbal fluency task (U = 99.00, Z = -2.75, p = .006 2-tailed) with the dyslexic group performing worse in both tasks compared with the non-dyslexic group (see Table 8.1). There was no difference between the groups in the semantic fluency task (U = 135.0, Z = -1.79, p = .09 2-tailed). Individual differences revealed that more than half (88.9%) of the dyslexic adolescents scored within the ‘at risk’ category in the RAN test, compared to 50% in the non-dyslexic group. Fifteen of the 18 adolescents (83.4%) in the dyslexic group were within the ‘at risk’ category in the verbal fluency task, compared to 11 of 22 (50%) in the non-dyslexic group. The same pattern was identified in the semantic fluency task, with 83.4% of the dyslexic adolescents scoring low, while 45.4% of the non-dyslexic adolescents scored low in the task.

Motor function tests

Two motor function tasks were administered in the present study: the bead-threading test and the postural stability test. A Mann-Whitney U Test revealed a significant difference in the bead threading scores (U = 102.5, Z = -2.72, p = .006 2-tailed) between the groups, with the dyslexic group scoring lower (i.e., poorer performance) compared to the non-dyslexic group (see Table 8.1). Individual scores indicated that 14 of the 18 dyslexic adolescents (77.8%) scored within the ‘at risk’ category in the postural stability task, compared to 10 of the 22 students (45.5%) in the non-dyslexic group. Significant differences were also found in the postural stability scores (U = 100.5, Z = -2.75, p = .006 2-tailed) with the dyslexic group showing poorer performance compared to the non-dyslexic group. Inspection of individual data indicated a high incidence of signs in the dyslexic group, with 16 of the 18 students tested (88.9%) scoring within the ‘at risk’ category in the bead threading task, while 11 of the 22 students (50%) in the control group scored in that category.

Verbal working memory test

A Mann-Whitney U Test indicated a significant difference in the backwards digit span test scores between dyslexic and non-dyslexic adolescents, U = 89, Z = -3.05, p = .002 (two tailed). The dyslexic adolescents performed significantly poorer as compared to the non-dyslexic adolescents (see Table 8.1). Inspection of individual data indicated that all but one of the dyslexic adolescents scored within the "at risk" category (94.4%), compared to 7 of 22 in the non-dyslexic group (31.8%). Table 8.3 shows a summary of the Mann-Whitney U test for the DST tasks.

Table 8.3 Summary of the Mann-Whitney U test for the DST-S tasks

Tasks	Mann-Whitney U	Z	Sig. (2-tailed)
One-min. Reading	100.5	-2.71	.007
Two-min. Spelling	86.00	-3.10	.002
One-min. Writing	102.0	-2.70	.007
RAN	57.50	-3.92	.001
Verbal Fluency	99.00	-2.75	.006
Semantic Fluency	135.0	-1.79	.09
Bead threading	102.5	-2.72	.006
Postural stability	100.5	-2.75	.006
Backwards Digit Span	89	-3.05	.002

Declarative memory tests

Two declarative memory tests were administered in the present study: the visual declarative test and the memory recall test. An independent-samples t-test revealed that the difference between the groups in visual declarative test scores was significant, t (38) = 2.65, p = .01. Significant differences between the dyslexic and non-dyslexic group were also found in the picture memory recall test scores, t (38) = 2.29, p = .03, and in the delayed picture memory recall test, t (38) = 2.10, p = .05 (see Table 8.2).

Procedural memory tests

Two procedural memory tests were administered in the present study: the Motor Sequence Task (MST) and the Word Identification Task (WIT). The MST was comprised of two trials, and it was analysed based on two scores: a) on the number of sequences in each trial, and b) on speed, which was the average time taken for each sequence. The WIT comprised two sets of words: a) real words, and b) pseudowords. There was also a variable assessing speed reading. An Independent-samples t-test was carried out to compare the differences between the two groups (dyslexic & non-dyslexic) on each score.

1.Motor Sequence Learning Task

There was a significant difference in the mean scores of the dyslexic and non-dyslexic students on the number of sequences in the 1st trial, t (38) = 2.82, p = .008. The dyslexic group scored lower (i.e., poorer performance) compared to the non-dyslexic group. Significant differences between the groups were also found for speed (meantime per sequence) in the 1st trial, t (38) = -2.77, p = .009. The dyslexic group reported higher mean time (i.e., poorer performance) in completing the task than the non-dyslexic group (see Table 8.2).

A significant difference was found between the groups in the number of sequences in the 2nd trial of the test, with the dyslexic group scoring lower compared to the non-dyslexic group, t (38) = 4.40, p = .001. A significant difference was also found between the groups in speed, in the 2nd trial of the test, t (38) = -3.18, p = .003, with the dyslexic group reporting higher meantime in relation to the non-dyslexic group (see Table 8.2).

A within-group analysis was conducted for each group to test whether automaticity of the procedural tasks was achieved by each group. Based on a previous study (Biotteau, Chaix & Albaret, 2015), it was suggested that skill automatization cannot be measured by differences between the dyslexic and the control group, but it should be measured by differences within the group. A Repeated Measures analysis (Dependent variables: correct sequences and reaction time, Independent variables: trial 1 & 2) showed that the dyslexic group improved in the number of correct sequences, from the first ($M= 10.67$, $SD = 2.03$) to the second trial of the task ($M= 11.44$, $SD = 2.09$), $F(1, 17) = 4.99$, $p = .04$. The same pattern was also identified in speed; the dyslexic group was improved in speed from the first ($M= 3.83$, $SD = .44$) to the second trial ($M= 3.74$, $SD = .42$), $F(1, 17) = 6.41$, $p = .02$.

The non-dyslexic group also performed better in the second trial, both in the sequence learning of the task, as well as on speed. In particular, the results showed that the number of correct sequences achieved by the non-dyslexic group was improved from the first ($M= 12.77$, $SD = 2.58$) to the second trial ($M= 14.05$, $SD = 1.64$), $F(1, 21) = 10.34$, $p = .004$. Speed was also improved between the first and the second trial ($M= 3.42$, $SD = .47$ & $M= 3.32$, $SD = .42$, respectively), $F(1, 21) = 8.15$, $p = .009$.

2.Word Identification Task

The results indicated significant differences between the dyslexic and non-dyslexic group in terms of speed and accuracy. Significant differences were found in real words accuracy, $t(38) = 2.24$, $p = .01$, and in reading speed of real words, $t(38) = -2.84$, $p = .007$, with the dyslexic group showing slower speed compared to the non-dyslexic group. Significant differences between the groups were also found in pseudowords reading accuracy, $t(38) = 3.00$, $p = .005$; the dyslexic group performed worse than the non-dyslexic group. A significant difference was also found in reading speed of pseudowords, with the dyslexic group having lower speed compared to the non-dyslexic group, $t(38) = -2.90$, $p = .006$ (see Table 8.2).

State and Trait anxiety

The STAI was administered a few minutes before the students were tested on the other tasks, to assess how anxious they felt immediately before they were tested (State Anxiety measure), and to assess their general feelings of anxiety (Trait Anxiety measure).

An independent-samples t-test showed a significant difference in state anxiety scores for the dyslexic and non-dyslexic group, $t\ (38) = -2.91$, $p = .006$ (see Table 8.2 for mean scores). According to the State -Trait Anxiety manual, 11 of the 18 dyslexic adolescents (66.7%) scored in state anxiety above the cut-off point (39-40), which is clinically used to identify clinical symptoms of anxiety, compared to 10 out of 22 non-dyslexic adolescents (45.4%) who scored above the cut-off point. Although the scores for some students were above the cut-off point, the levels of stress were not very high, as the maximum score in the study was 54, and the maximum score in the scale is 90.

A significant difference was found in trait anxiety scores, $t\ (38) = -2.75$, $p = .009$. The direction of the difference found both in state and trait anxiety variables indicated higher scores for the dyslexic group compared to the non-dyslexic group (see Table 8.2). Individual data indicated that 13 of the 18 dyslexic adolescents (72.2%) scored above the cut-off point (39-40) in trait anxiety, compared to 10 of the 22 students in the control group (46%). The scores of both groups in trait anxiety were close to 50, which indicates that the anxiety levels could potentially be considered as clinical symptoms of anxiety. Table 8.4 shows a summary of the Independent-Samples t-test for the Declarative and Procedural tasks and the STAI.

Table 8.4 Summary of the ANOVA tests for the Declarative and Procedural tasks and the STAI

Tasks	t	df	Sig. (2-tailed)
Visual Declarative test	2.65	38	.01
Memory recall test	2.29	38	.03
Delayed Picture Memory recall test	2.10	38	.05
MST Number of sequences/1st trial	2.82	38	.008
MST Speed 1st trial	-2.77	38	.009
MST Number of sequences/2nd trial	4.40	38	.001
MST Speed 2nd trial	-3.18	38	.003
WIT Real words accuracy	2.24	38	.01
WIT Real words speed	-2.84	38	.007
WIT Pseudowords accuracy	3.00	38	.005
WIT Pseudowords speed	-2.90	38	.006
State anxiety	-2.91	38	.006
Trait anxiety	-2.75	38	.009

8.6.2.2 Correlation analysis by group.

A Spearman’s rank-order correlation test (the DST-S literacy tasks were non-parametric) by group was conducted to assess the relationship between declarative, procedural, literacy tasks and anxiety measures (see results in Table 8.5 and Table 8.6). In general, performance on declarative and procedural tasks did not significantly relate to literacy tasks in either group. Most of declarative learning tasks were associated to procedural learning tasks in the dyslexic group, whereas no such association was found in the non-dyslexic group. State and trait anxiety did not correlate with any other measure in the dyslexic group, except for moderate positive correlations with the writing, the reading, and the declarative task; however, significant negative as well as positive correlations were found between trait anxiety and procedural learning tasks in the non-dyslexic group.

Table 8.5 Correlations between declarative tasks, procedural tasks, literacy tasks, and anxiety measures for the dyslexic group (n = 18)

Measures	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DST-Literacy															
1.One-min. Reading	.07	-.32	.52*	.21	.16	-.24	-.13	-.27	.04	-.01	.22	.10	.16	.42	.05
2.One-min. Writing		.26	-.06	.07	.19	.05	-.01	-.07	-.09	-.23	.25	-.44	.36	-.32	.14
3.Two-min. Spelling			-.23	.283	.41	.30	-.36	.12	-.49*	-.25	.11	-.42	-.07	.07	-.14
Declarative tasks															
4.Visual declarative				.095	.28	.13	-.32	.30	-.27	-.31	-.02	-.31	-.21	.37	-.13
5.Picture Memory Recall					.74**	-.27	-.39	.26	-.54*	-.21	.16	-.06	.09	.08	.27
6.Delayed Pic. Memory recall						-.22	-.41	.47	-.43	-.55*	.36	-.43	.09	.16	.26
Procedural tasks															
7.WIT Word Accuracy							-.48*	-.13	-.32	-.11	-.59**	-.17	-.41	.05	-.37
8.WIT Speed								.01	.80**						
9.WIT Pseudowords Accuracy									-.23	-.42	.20	-.19	-.01	-.01	-.19
10.WIT Pseudowords Speed										.51*	.05	.57*	-.02	-.28	-.04
11.MST Reaction time 1st trial											-.03	.77**	-.03	-.13	-.06
12.MST Correct sequences 1st trial												-.14	.66**	.07	.02
13.MST Reaction time 2nd trial													-.07	-.14	-.13
14.MST Correct sequences 2nd trial														-.12	-.10
STAI															
15.State anxiety															.14
16.Trait anxiety															

Note. *p < .05, **p < .01

Table 8.6 Correlations between declarative tasks, procedural tasks, literacy tasks, and anxiety measures for the non-dyslexic group (n = 22)

Measures	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DST															
1.One-min. Reading	.07	.18	-.13	.05	-.17	-.18	.03	-.03	.47*	.10	-.45*	.16	-.19	-.30	.34
2.One-min. Writing		.12	-.08	-.16	.02	-.34	.02	.07	.33	.09	.06	-.09	-.35	.11	-.16
3.Two-min. Spelling			.01	-.27	-.27	.15	-.23	-.30	.03	.16	-.08	.20	.06	-.20	.43*
Declarative tasks															
4.Visual declarative				-.05	.02	.19	-.34	.06	.09	.14	.19	.23	.30	-.37	.09
5.Picture Memory Recall					.59**	-.01	.14	.24	.14	-.13	-.15	-.02	-.07	.19	.04
6.Delayed Pic. Memory recall						-.13	.19	.25	-.24	-.31	-.22	-.12	-.16	.01	-.22
Procedural tasks															
7.WIT Word Accuracy							-.23	-.03	-.07	-.02	-.26	-.06	-.17	.13	.19
8.WIT Speed								.10	.42	-.62**	-.19	-.60**	-.34	.13	-.56**
9.WIT Pseudowords Accuracy									.42	-.40	-.18	-.48*	-.33	-.13	-.58**
10.WIT Pseudowords Speed										-.01	-.08	-.19	-.23	-.10	-.11
11.MST Reaction time 1st trial											.33	.88**	.47*	-.18	.61**
12.MST Correct sequences 1st trial												.22	.71**	-.01	-.12
13.MST Reaction time 2nd trial													.50*	-.22	.73**
14.MST Correct sequences 2nd trial														-.16	.29
STAI															
15.State anxiety															.01
16.Trait anxiety															

Note. *p < .05, **p < .01

8.6.2.3 Correlation analysis between motor function tasks, literacy tasks, and anxiety measures by group.

A Spearman's rank-order correlation test was conducted (the DST-S tasks were non-parametric) to assess the relationship between motor function tasks (postural stability and bead threading), literacy tasks, and anxiety measures (see results in Tables 8.5 and 8.6). Performance on the motor tasks did not relate to measures of literacy skills in either group, except for the One-min. Writing task which was significantly positively correlated to postural stability (r = .52, p = .027) in the dyslexic group. State and trait anxiety was not statistically related to motor function or literacy tasks in either group, except for moderate positive correlations between reading and state anxiety, and between the bead threading and state anxiety measures in both groups.

Table 8.7 Correlations between motor tasks, literacy tasks, and anxiety measures for the dyslexic group (n = 18)

Measures	1	2	3	4	5	6	7
DST-Literacy							
1.One-min. Reading		.07	-.32	-.10	.16	.42	.05
2.One-min. Writing			.26	.52*	.25	-.32	.14
3.Two-min. Spelling				.22	.04	.07	-.14
Motor function tasks							
4.Postural stability					.20	.02	.25
5.Bead threading						.30	.30
STAI							
6.State anxiety							.14
7.Trait anxiety							

Note. *p < .05

Table 8.8 Correlations between motor function tasks, literacy tasks, and anxiety measures for the non-dyslexic group (n = 22)

Measures	1	2	3	4	5	6	7
DST							
1.One-min. Reading		.07	.18	.14	-.24	-.30	.34
2.One-min. Writing			.12	.25	.01	.11	-.16
3.Two-min. Spelling				.22	-.35	-.20	.43*
Motor function tasks							
4.Postural stability					-.13	.10	.11
5.Bead threading						.45*	.02
STAI							
6.State anxiety							.01
7.Trait anxiety							

Note. *p < .05

8.7 Discussion

Study 4 investigated the differences between dyslexic and non-dyslexic adolescents on a number of tasks, including literacy and verbal working memory tasks. The first aim of the study was to test declarative and procedural memory, in particular the learning and automatization of motor sequences of dyslexic and non-dyslexic adolescents, based on the Procedural Learning Deficit theory. The second aim of the study was to examine the association between stress and task performance.

First, significant differences were revealed between the groups in literacy tasks, as well as in executive function tasks, with the dyslexic group showing poorer performance compared to the non-dyslexic group, as expected. However, it should be noted that the non-dyslexic group also displayed poor performance on many tasks, where in some cases their performance was below average. Therefore, the non-dyslexic group is characterized by an overall below average performance in some literacy and cognitive tasks, but still better than the dyslexic group. Second, the motor function and the procedural memory performance of the dyslexic group were slower and less accurate compared to the non-dyslexic group. Third, the declarative memory skills of the dyslexic group were not at the same level as the non-dyslexic group, and the performance of the dyslexic group on the verbal working memory task was poorer than the non-dyslexic group. Fourth, there was no association between stress and performance on most of the tasks, which could suggest that performance was not affected by stress. However, the results suggested that the levels of stress in the dyslexic group were significantly higher than the non-dyslexic group.

Hypothesis 1: Adolescents with dyslexia will show significantly poorer performance on motor function tasks (bead threading and postural stability) compared to non-dyslexic adolescents.

The findings of the present study supported the first hypothesis that the dyslexic students would show poorer performance on the motor function tasks of bead threading and postural stability. The individual analyses indicated that nearly 90% of the dyslexic adolescents showed significant impairments in the bead threading task. However, half of the non-dyslexic participants also showed poor performance on the bead threading task. Most of the adolescents in the dyslexic group also scored low in the postural stability task, and showed more difficulty in maintaining their balance, suggesting a high risk of balance deficit. However, almost half of the non-dyslexic students also showed poor performance on the balance task. The results of Study 4 are in line with a number of previous studies (Fawcett & Nicolson, 1994; Nicolson & Fawcett, 1999; Ramus et al., 2003; Fawcett et al., 1996), in which the dyslexic group showed differences in motor ability compared to the non- dyslexic group, particularly in the balance and bead threading task.

The fact that almost half of the non-dyslexic students performed poorly on the literacy and motor function tasks could be due to the characteristics of the sample per se in the study. As mentioned above, the participants of the study were students who were at risk of dropping out of education; therefore, even if the students were not identified with specific learning difficulties, they still may have had other educational needs.

In Study 4, the participants undertook a balance task while blindfolded, whereas in some previous studies (Stoodley et al., 2005; Moe-Nilssen, et al., 2003) participants undertook a balance task under two conditions; blindfolded, and with eyes open. The results of these previous studies showed that the dyslexic participants performed worse on the eyes open condition compared to the control group, but still wobbled more in the blindfold condition, although they did not show any significant differences from the control group. In contrast to these results (Stoodley et al., 2005; Moe-Nilssen et al., 2003), Study 4 found impairments in a blindfold condition, in line with Fawcett et al., (1996), and Nicolson and Fawcett (1999). An explanation of balance impairments while eyes are closed is that balance depends on and functions through different sensorimotor control systems which include sensory information input from visual, proprioceptive, and vestibular systems. The three sensorimotor systems function in combination for optimum balance stability; however, vision is the principal system on which individuals depend for postural stability (Gaerlan et al., 2012). It has been demonstrated that when vision does not function properly, individuals use compensatory strategies to help them balance (Brookes et al., 2010). Previous research (Stoodley et al., 2005; Moe-Nilssen et al., 2003) has shown that when individuals are blindfolded, balance is impaired since individuals need to associate the head and body in relation to the space where they are, and vision plays a key role to achieve that.

The individual analyses showed the heterogeneity of symptoms of dyslexia. Of the 18 adolescents with dyslexia, 89% showed reading deficits, 94% naming speed deficits, and 83% motor deficits. According to Nicolson and Fawcett (2006), the cerebellar deficit hypothesis can explain the phonological, naming speed, and sensorimotor difficulties. More than half of the adolescents with dyslexia in the present study showed problems in reading, speed, and balance, which according to Nicolson and Fawcett (2006) are indicators of cerebellar deficit. These deficits could be attributed to skill automatization problems that are often covered by the conscious compensation process (Nicolson & Fawcett, 1990).

In summary, the results of Study 4 provide evidence for motor and balance deficits in dyslexia, which indicate a developmental disorder in motor skills (Nicolson & Fawcett, 1995; Needle et al., 2006; Legrand et al., 2012). The results also suggest an automatization skill deficit in dyslexia, even for the simplest motor task, such as the bead threading task. However, due to small correlations between literacy and motor function tasks in the dyslexic group, the cerebellar deficit theory should not be considered as a causal theory of dyslexia, but rather that motor deficits are co-occurring symptoms of phonological deficits in dyslexia, that can explain the range of impairments identified in the disorder. According to Fawcett et al. (1996), mild cerebellar motor impairments could account for the underlying causes of phonological deficits in dyslexia, and therefore could suggest a causal relationship with dyslexia.

Hypothesis 2: Adolescents with dyslexia will show significantly poorer performance on procedural learning tasks (MST and WIT) compared to non-dyslexic adolescents.

Study 4 investigated the procedural learning in dyslexic and non-dyslexic adolescents, using a Motor Sequence Learning task and a Word Identification task, based on the Procedural Learning Deficit theory by Nicolson & Fawcett (2007). The results from the present study partially supported the second hypothesis that the adolescents with dyslexia would show poorer performance on procedural learning tasks (MST and WIT) compared to the non-dyslexic adolescents. The results demonstrated that the dyslexic adolescents performed poorly on the motor sequence task, both on response accuracy and on speed. The dyslexic group made more errors and needed more time to learn the sequences compared to the non-dyslexic group. The same pattern was identified in the Word Identification task, in which the dyslexic adolescents showed poorer performance than the non-dyslexic adolescents, in terms of word accuracy and word processing speed. The dyslexic group was much slower in the MST in both trials and needed more time to learn the sequences than the non-dyslexic group; the response accuracy was also much lower for the dyslexic group in both trials compared to the non-dyslexic group. Speed of both groups improved in the second trial; however, the improvement was very small for the dyslexic group, and it did not reach at the same level as the non-dyslexic group, therefore it was not a significant change. The response accuracy of the dyslexic group in both trials was still worse compared to the non-dyslexic group. Even after practice, the dyslexic adolescents still had difficulties with procedural memory and the automatization of the task. These results suggest an impairment in sequence learning and automaticity in dyslexic individuals, even for a task that does not require verbal or language competency.

The results of Study 4 provide support for the Procedural Learning Deficit Hypothesis, which states that the procedural memory and the procedural learning are impaired in dyslexia. The results are consistent with previous research on motor sequence learning and reaction time tasks (Fawcett & Nicolson, 1995; Frith, 1986; Menghini et al., 2006; Vicari et al., 2005; Ullman, 2004). In particular, the results are in line with Nicolson and Fawcett study (2000), which reported procedural learning and automatization deficits in the dyslexic group, on long-term training on a keyboard task. Although the training on the keyboard task was shorter in the present study, compared to Nicolson and Fawcett's study (2000), the results indicated that the 'quality of automatization', as discussed in the Introduction (see section 2.4.3.1), was not as good as the non-dyslexic group, as it was impaired both in terms of errors and speed.

The Automatization Deficit theory supports the results of Study 4, as the dyslexic adolescents did not automatize the procedural tasks as quickly as the non-dyslexic adolescents. When the groups were compared to each other, the dyslexic group had lower speed and poorer performance on the Motor Sequence Learning task. However, when the performance of the dyslexic group was analysed from the first to the second trial of the task, the results suggested that after a brief practice, the dyslexic participants improved their performance both in terms of speed and accuracy. However, it cannot be concluded from these results that the dyslexic group automatized the motor task, which is in accordance with previous research (Biotteau et al., 2015; Lang & Bastian, 2002) which suggests that improved performance on a task after some practice does not necessarily result in automaticity. Automaticity occurs after extensive practice and a consolidation period (Hedenius et al., 2013; Needle et al., 2010). The results suggested that although the dyslexic students did not perform as well and as fast as the non-dyslexic students on the motor learning tasks, after some practice they had the ability to improve their performance.

Based on Biotteau et al. (2015), skill automatization should be measured by differences within the group. In that case, the dyslexic group in the present study showed an improved performance in the second trial of the task compared to the first trial; however, this happened only after a short practice and at a lower speed compared to the non-dyslexic group. According to Crossman (1959), practice facilitates learning, and helps skills become automatic quickly through practice. The improved performance of the dyslexic group in the second trial of the task could be attributed to the learning of the task in the first trial, in which they had proceduralised the skills needed by practicing them.

Vakil et al. (2015) found that the results of the study were not in accordance with the Procedural Learning Deficit theory, as there was no difference in the learning rate (speed) between the dyslexic and non-dyslexic group, but there was a slower performance for the dyslexic group. The authors attributed the slow performance of the dyslexic group on the information processing speed deficit, rather than on the Procedural Deficit theory. In contrast, the results of the present study identified differences in the learning rate between the dyslexic and non-dyslexic group, as well as considerably slower performance for the dyslexic group. This could potentially provide evidence of a relationship between procedural learning deficits and dyslexia.

The Word Identification task tested word reading and speed (how long it takes to read a word), tasks that assess automaticity and procedural learning in dyslexia. Participants were tested on real words, as well as on pseudowords. The results revealed that the dyslexic group showed impaired performance on reading both pseudowords and real words. However, speed was impaired in both reading real words and pseudowords, and they were considerably slower than the non-dyslexic group. Although both groups took longer to read the pseudowords, and both groups read less pseudowords than real words, the dyslexic group was still considerably slower compared to the non-dyslexic group and read a considerably smaller number of pseudowords than the non-dyslexic group. Although reading speed for the dyslexic group was slower than the non-dyslexic group on real words reading, they read a similar number of words as the non-dyslexic group. This finding suggested that even though the dyslexic group needed more time to read real words, they achieved to score similarly to the non-dyslexic group. According to Frey and Fisher (2010), automaticity is not about speed; it is about creating the appropriate mechanisms needed to automatize a task. The results of the current study are in line with previous results (Nicolson et al., 2010; van Daal & van der Leij, 1999), which indicated speed limitations in word reading, both in real words and pseudowords (Nicolson et al., 2010). The results suggest the absence of fast automatic word reading in dyslexic students.

Furthermore, associations between literacy tasks and procedural tasks were identified. In particular, the One-minute Writing task was correlated with the MST correct sequences task. In addition, the Two-minute spelling task was correlated with the WIT speed task, and the MST correct sequences task.

The findings of the present study provide evidence for procedural deficits in dyslexia and may support the Procedural Learning Deficit and Automatization theories. The current study showed that the dyslexic adolescents do not only show difficulties in relation to literacy and reading skills, but the difficulties extend to memory and motor skills. The results reflect an automaticity deficit, shown by both procedural learning tasks used in the study. The theories of mild cerebellar dysfunction and procedural memory deficit offer a multilevel approach to dyslexia.

Hypothesis 3: Adolescents with dyslexia will show significantly poorer performance on the verbal working memory task compared to non-dyslexic adolescents.

The results indicated a difference between the dyslexic and non-dyslexic group on the backwards digit span task, supporting the relevant hypothesis in the present study. Individual analyses, of the dyslexic group, showed that a high proportion (77.8%) showed an impairment in working memory. The results are in line with previous studies (Smith-Spark & Fisk, 2007; Pickering & Gathercole, 2001; 2004; Brosnan et al., 2002) which showed verbal working memory deficits in dyslexic participants, particularly in the backwards digit span task. A deficit in central executive is due to the difficulty of storing previous information and processing the information at the same time; a skill which, as discussed earlier in section 3.2.3, is particularly difficult for individuals with specific learning difficulties because of working memory problems (Pickering & Gathercole, 2001; Smith-Spark, & Fisk, 2007).

The results of Study 4 could potentially provide a broader explanation of dyslexia which does not solely depend on the phonological deficits of dyslexia (Snowling, 1995; Vellutino, 1979). The dyslexic group showed problems in storing and processing the digits required in the task, and it also seemed that they had problems in learning the sequence of the digits. The results could possibly account for the cerebellar deficit hypothesis (Nicolson, et al., 2001) which states that individuals with dyslexia might suffer from mild cerebellar dysfunction. In support of that, previous researchers (Ben-Yehudah et al., 2007) have suggested that the cerebellum affects the verbal working memory function, as well as the acquisition and execution of learned skills (Daum et al., 1993). The findings suggest that the dyslexic participants did not only show difficulties in the literacy domain, but also the difficulties extended to executive function. As discussed in section 8.1.2 (Holmes et al., 2010), working memory is a core skill for school performance, and therefore a working memory deficit could result in failing in those tasks in which working memory is involved, which is the case for most classroom activities and tasks, particularly in reading and mathematics. Smith-Spark and Fisk (2007) suggested that an impairment in the central executive component of working memory might be the most core deficit of working memory problems in dyslexia in relation to less documented problems in phonological loop and visuo-spatial sketchpad. Moreover, previous research has shown that working memory difficulties, in general and in dyslexia, also extended to other executive functioning skills, such as in problem solving, organization, attention and inhibition (Jeffries & Everatt, 2004; Brosnan et al., 2002; Schmahmann, 2001).

Performance of dyslexic and non-dyslexic adolescents in visual declarative memory tasks

Study 4 investigated declarative memory in dyslexic and non-dyslexic adolescents using two different tasks; a visual declarative memory test, and a memory recall (and delayed memory recall) test. Previous studies suggest that the declarative memory remains intact in dyslexia, while the procedural memory is impaired (Nicolson & Fawcett, 2007; Vicari et al., 2003; Lum et al., 2013). The results of the present study, however, are mixed, depending on the task. Differences between the groups were observed on the visual declarative memory as well as on the memory recall and the delayed memory recall test. However, significant associations were observed between the declarative and procedural memory tests in the dyslexic group, which could suggest that the two memory systems are not as independent as expected. The declarative memory test was significantly related to the reading task in the dyslexic group, whereas such an association was not found in the non-dyslexic group. The compensatory role of declarative memory in dyslexia, which was suggested in previous studies (Ullman & Pullman, 2015; Hedenius et al., 2013; Vicari et al., 2003; Lum et al., 2013) was not evident in the present study, as the two groups did not have comparable performance in declarative memory tests. The results of the present study could suggest that there is an interaction between the two systems during a cognitive task, and that the two systems do not work separately from each other (Ullman, 2004; Poldrack et al., 2001). Therefore, the impaired performance on the one system could possibly lead to impaired performance on the other system.

Hypothesis 4: A significant association will be found between anxiety and performance on all tasks for both groups, but the association will be stronger for the dyslexic group.

Study 4 aimed at exploring the effects of state and trait anxiety on cognitive performance in dyslexic and non-dyslexic adolescents. Psychological self-report measures were used to identify high levels of state and trait anxiety before completing the cognitive tests. Although the results indicated that the dyslexic group showed higher anxiety levels than the non-dyslexic group, the prediction that there will be an association between anxiety and cognitive performance was not fully supported by the results from the present study. In contrast to previous studies (Schwabe et al, 2010; 2012; Kirschbaum et al., 1996) in which the declarative and procedural memory was impaired under stress, the present study did not find significant associations between stress and performance in the dyslexic group. The lack of association between state anxiety and performance could possibly be explained by the lack of stressors in the present z` study, which could have provoked state anxiety related responses to the participants. However, moderate associations were found between the bead threading task and state anxiety in both groups.

There is longstanding evidence of cerebellar involvement in affective state, with the 'Cerebellar Cognitive Affective Syndrome' (Schmahmann & Sherman, 1998) being highly influential, which was partially evident in the present study. Trait anxiety was found to be significantly related to most procedural memory tasks in the non-dyslexic group, whereas such a relationship was not found in the dyslexic group. Despite this association, the non-dyslexic group still performed better in the procedural memory tasks compared to the dyslexic group. It should also be noted that almost half of the non-dyslexic adolescents in this study scored high in both state and trait anxiety. As mentioned before, an important characteristic of the sample of this study is that the students were at risk of dropping out from school, and although the non-dyslexic group was not identified as having specific learning difficulties, they may have had other non-specific educational needs. This could possibly explain their below average performance in some tasks and the relatively high levels of anxiety. According to Schwabe et al. (2012), although stress have damaging effects on memory systems, it was found that the procedural system is not affected by stress. Therefore, the lack of association between stress and procedural memory in the dyslexic group is supported by previous research. However, as procedural memory was associated to trait anxiety in the non-dyslexic group, this could probably be attributed to the characteristics of the group that were mentioned before.

Inspection of individual data indicated that almost all the dyslexic adolescents, apart from four, (approximately 80%) showed high levels of state and trait anxiety (above 39-40 which is the cut-off point), and their performance on the tasks used in the study was falling within the “at risk” category in almost all the tasks. Although almost half of the non-dyslexic adolescents presented high levels of anxiety (both state and trait), their performance on the tasks did not seem to be affected by anxiety, as most of the adolescents were in the “mildly at risk” category in most tasks.

A possible explanation for the results in the present study suggested that the stressors imposed in the study were not significant enough to cause actual stress to the participants. The impact of anxiety on performance is better understood under the appropriate stressful conditions, and with the appropriate physiological measures of anxiety (McLeod et al., 1986; Kantor et al., 2001; Leckman et al., 1982), which were not included in the present study. The participants were purposefully not exposed to stress before the tasks, except that the researcher was presented as distant and non-committing during the assessment, which can be regarded as stress-provoking for some individuals. Therefore, the anxiety levels (state and trait) were only measured based on the adolescents’ personal self-reports. Another explanation suggests that, according to Lepine et al. (2005), stress in some cases can facilitate and enhance some specific areas of cognitive performance if the stressor is perceived as a challenge rather than a hindrance. This is in accordance with the Yerkes-Dodson Law (1908, as cited in Reber 1995) which states that the level of difficulty of a task and the level of anxiety are related and should be considered together. This means that difficult tasks demand relatively higher levels of anxiety, whereas easier tasks demand lower levels of anxiety. Although some of the cognitive and motor tasks used in the present study are considered as quite difficult, particularly for dyslexic students, they may not have been perceived as too difficult by the students of the present study, and therefore their performance may have not been affected by stress. Research into positive dyslexia (Eide & Eide, 2011) suggests that because people with dyslexia are more frequently exposed to stressful situations, they are able to develop more coping strategies which help them overcome stressful situations.

8.8 Limitations

There are some limitations in the present study that need to be acknowledged. First, similar to studies 2 and 3, the sample of study 4 was not random as the participants were not chosen by the researcher, but they were chosen by the learning provider who worked in the school. Second, the lack of stressors and physiological measures in the study did not enable to test the association between stress and performance. Third, due to the small sample size, the results of the present study cannot be generalised to other populations and should be interpreted with caution.

8.9 Conclusion

In conclusion, the results of the present study suggested that multiple memory systems are impaired in dyslexia, including verbal working memory, and declarative and procedural memory systems. It was indicated that the dyslexic adolescents were weaker in literacy tasks and showed poorer performance in a range of motor function tasks, as well as in declarative and procedural learning tasks. The Procedural Deficit Hypothesis, along with the Automatization Deficit Hypothesis were supported by the current data and provided a potential explanation of the underlying causes of phonological deficits in dyslexia. Furthermore, although the findings indicated that the dyslexic group showed higher state and trait anxiety levels than the non-dyslexic group, anxiety was not significantly associated to cognitive performance; a finding which suggests that performance was not affected by anxiety levels in the present study. Following on from this chapter, the next chapter investigated the effectiveness of an online cerebellar-based intervention, the Zing intervention, which was not used as a remediation exercise particularly for dyslexia related symptoms, but rather as an exercise to improve cognitive and motor function in adolescents at risk of school failure.

Chapter 9

Study 5: Evaluation of a 'cerebellar challenge' intervention in dyslexic and non-dyslexic adolescents at risk of school failure

9.1 Introduction

The present chapter presents the fifth empirical study that aimed to evaluate an online cerebellar based 'whole person' intervention in dyslexic and non-dyslexic adolescents at risk of school failure.

The current generation of adolescents is important for the future needs of the society (Patton et al., 2018). However, there is increasing concern regarding the three major dimensions of human wellbeing - physical wellbeing, affective wellbeing, and cognitive wellbeing - of current adolescents. Recent surveys indicate that physical activity declines in adolescence (Farooq et al., 2018), with a WHO survey of 1.6 million adolescents in 48 countries concluding that 81% undertook insufficient physical activity (Guthold et al., 2020). Around one in five of British or US adolescents suffer from significant mental health issues (Government Statistical Service, 2018; Merikangas et al., 2010), with a higher recent estimate of nearly 40% in deprived areas of the UK (Deighton et al., 2019). The PISA international survey of reading (OECD, 2019) estimates that nearly 20% of UK and US 15-year-olds have not reached level 2 (able to identify the main idea in a piece of text of moderate length) reading ability.

Cognitive wellbeing refers to the function of the 'central executive' (Baddeley & Hitch, 1974), the brain functions regulating the brain's information processing requirements, including working memory, memory retrieval, speed of processing, task switching and maintenance of attention. Recent developments (Diamond, 2013; Prencipe et al., 2011) highlight the importance of 'hot' executive function, including control of impulsiveness, anger and risk taking. There is emerging evidence of the intrinsic interconnectedness of these functional dimensions, with theoretical developments in terms of embodied cognition (Barsalou, 2008) and embodied emotion (Koole, 2009; Niedenthal, 2007; Niedenthal et al., 2005) highlighting the interdependence of cognitive, physical, and emotional wellbeing. Neuroscience approaches highlight the importance of brain circuits combining specialist processing capabilities (Buckner et al., 2011; Koziol et al., 2012).

Educationally there is growing evidence of this inter-dependence, with exercise benefitting physical and mental wellbeing (Chen et al., 2017; Cotman et al., 2007; Hillman et al., 2008), stress adversely affecting all three (Dupere et al., 2015; Engert et al., 2019; Joos et al., 2019; McEwen, 2013; Schwabe, 2017), and the 'growth mindset' intervention having beneficial effects on resilience to social stress (Yeager et al., 2016).

There is converging evidence suggesting that the cerebellar function (Nicolson & Fawcett, 1999; Frank & Levinson, 1973; Nicolson et al., 2002; Mariën et al., 2014) as well as the cognitive functions, particularly the working memory, are impaired in dyslexic individuals (Baddeley & Wilson, 1993; Smith-Spark & Fisk, 2007). The Cerebellar Deficit Theory (Nicolson & Fawcett, 1999) proposed that the cerebellum is the key feature for the automatization of motor skills, and it might be important for cognitive skills too. The Cerebellar Deficit Hypothesis (Nicolson & Fawcett, 1999) stated that dyslexic individuals might suffer from cerebellar abnormalities that can lead to problems in automatizing language skills, which in turn can lead to problems in mastering reading, writing, and spelling skills. Further studies concluded that working memory capacity was lower in dyslexic individuals as compared to non-dyslexics (Palmer, 2000; Smith-Spark et al., 2003; Ackerman & Dykman, 1993). Such limitations might benefit from remedial interventions which are particularly important for dyslexic children.

Previous research investigated computer-based interventions for dyslexia difficulties in phonological, reading, and writing tasks (Lynch et al., 2000; van der Leij, 2013; Torgesen et al., 2010; Lyytinen et al., 2007). But research into computer-based programmes for cognitive and executive function difficulties has received less attention in dyslexic and non-dyslexic populations. In a meta-analysis of studies about the effectiveness of working memory computer programmes, Melby-Lervag and Hulme (2013) found that working memory was improved in most studies, but the improvements only lasted for a short time after using the computer programme. A number of previous studies have investigated the brain's plasticity and its ability to change the activity of some regions after training (Korman et al., 2003; Doyon et al., 2003; Ungerleider et al., 2002).

Horowitz-Kraus and Breznitz (2009) investigated the change of capacity of working memory after training, as well as the relationship between working memory and error detection in dyslexic university students. Horowitz-Kraus and Breznitz (2009) used the CogniFit Personal Coach training programme. Their results indicated that not only the dyslexic participants, but also the non-dyslexic participants, improved working memory capacity, as well as the brain activity, after training; however, the dyslexic participants improved significantly more. The results indicated that there was a transfer effect in reading tasks and in brain activity. Horowitz-Kraus and Breznitz (2009) concluded that brain training programmes are beneficial, not only for dyslexic individuals but also for the general population, as the programmes do not only improve working memory and executive function skills, but also error detection skills. Further studies (Shouli, Lotfi & Arbabi 2014; Shokoohi-Yekta et al., 2014) explored the effectiveness of a computerised cognitive training programme, designed by BrainWare Safari, on cognitive function skills in children with dyslexia. The programme trained cognitive skills such as working memory, visual and auditory processing, and sensory integration. An experimental group was tested on a range of visual spatial working memory tests, and in visual attention tests. The results showed that the dyslexic group improved after training in visual-spatial working memory tasks, as well as in attention tasks as compared to the non-dyslexic group.

An approach of attested general utility for adolescents with specific learning difficulties derives from the growth mindset framework (Dweck & Leggett, 1988) in which children are encouraged "*to see intellectual abilities not as fixed but as capable of growth in response to dedicated effort, trying new strategies and seeking help when appropriate*" (Yeager et al., 2019). The 'National Study of Learning Mindsets' involved 12,500 children from 134 US schools and concluded that "*A short (less than one hour), online growth mindset intervention ... improved grades among lower-achieving students"* (Yeager et al., 2019). These are extraordinary results, indicating the power of positive interventions to overcome a history of stress and shame. Furthermore, given that the brain is indeed changing significantly around puberty, adolescence does provide a major opportunity for new learning and neural change.

Physical and coordinative exercise can improve brain and cognitive function, as well as enhance brain plasticity (Kirk-Sanchez & McGough, 2014; Gonzalez-Palau et al., 2014). A neuroimaging study (Burciu et al., 2013) which investigated the effectiveness of sensorimotor postural training in brain changes, particularly in the cerebellum, found that patients with cerebellar degeneration improved balance after training. Burciu et al. (2013) also found that both patients and controls increased gray matter volume in the dorsal premotor cortex as well as in the cerebellum.

A coordinative exercise improved attention and coordination skills in adolescents (Buddea et al., 2008). Rogge et al. (2017) investigated the effectiveness of a balance training programme on cognitive performance, specifically on memory and spatial cognition in participants aged 19-65 years. The intervention lasted for 12 weeks, and the participants exercised twice a week.

Rogge et al. (2017) found that only the intervention group had improved performance on balance, memory, and spatial cognition, but there was no change in executive function test. Moreover, Rogge et al. (2017) found that the intervention group improved on a learning task associated with the hippocampal, declarative, memory system. There is also evidence for the benefits of balance and motor training, as well as of physical activities on cognitive performance in adults (Li et al., 2018; Chang et al., 2012).

It was pointed out earlier (see chapter 2, section 2.3.3.1) that the cortico-cerebellar brain system corresponds to the procedural memory system (Doyon et al., 2003), and the cerebellum may be involved in the procedural memory system (Ullman, 2001; 2004). Previous research suggests that motor skills, and training on motor tasks, enhance procedural memory performance, and therefore enhance procedural learning (Muller et al., 2016).

One major cause of anxiety and depression is stress, and there is strong survey evidence of high stress levels in schools. A US study revealed that 27% of 1019 teenagers reported experiencing a level of stress that was an 8, 9 or 10 on a 10-point scale during the school year (American Psychological Association, 2014) and over 70% of 920 13-17 respondents rated anxiety and depression as a major problem among their peers (Pew Research Center, 2019). The impact of heightened stress on behaviour is potentially highly significant, with studies revealing impaired ability for ‘declarative’ information processing (Schwabe & Wolf, 2013; Wirkner et al., 2019), and decision-making processes that are more risk taking, more reward seeking and more disadvantageous under conditions of uncertainty (Starcke & Brand, 2016). Of particular interest, a recent study (Zhang et al., 2020) established a clear link between trait anxiety and neural circuitry linking the right cerebellum with the right hippocampus and right parietal lobe in terms of impulsivity.

There is strong evidence that natural activities, such as exercise, can improve not only physical fitness but also cognitive fitness, and even stimulate the growth of new brain neurons and connections (Hillman et al., 2008; Hoetting & Roeder, 2013). There is also strong evidence (Niemann et al., 2014) that exercise can potentiate the brain for new learning, with "coordinative balance" exercises, such as balance training or tai-chi, leading to neural growth in the hippocampus – a core structure for explicit learning and memory – and in the cerebellar-cortical loop (Burciu et al., 2013; Ben-Soussan et al., 2015) - a core network for implicit learning and coordination.

The evidence suggests that the cerebellum is involved in motor function, balance, cognitive function, and associative learning (Fulbright et al., 1991; Leainer et al., 1991; Nicolson et al., 1999). Evidence also suggests that the cerebellum is involved in emotional processing (Schmahmann & Caplan, 2006; Turner et al., 2007) and in anxiety related disorders (Caulfield & Servatius, 2013; Moreno-Rius, 2018). As discussed previously (see chapter 3, section 3.3.2 and chapter 6, section 6.1) adolescents with dyslexia suffer with heightened levels of stress and anxiety. It was also discussed in Chapter 6 (section 6.1) that a high proportion of adolescents drop out of school due to a number of factors that contribute to disengagement among which are low school performance and behavioural problems. The research presented in Chapter 8 highlighted the interconnection between the three axes of mental health, physical health, and academic health.

9.2 Rationale and aim of Study 5

In Study 4, the adolescents with dyslexia had poorer performance on motor function tasks (bead threading and postural stability), on procedural learning tasks (Motor Sequence Tasks & Word Identification Task), and on cognitive function tasks (verbal working memory). As discussed in the introduction (see section 9.1), physical exercise and coordination improved cognitive and cerebellar function (Kirk-Sanchez & McGough, 2014; Gonzalez-Palau et al., 2014; Burciu et al., 2013, Kwok et al., 2011). Gallant and Nicolson (2017) evaluated the effectiveness of a novel internet-based "cerebellar / vestibular stimulation" intervention, called Zing intervention, on older adults. The intervention was designed to enhance performance in sensorimotor coordination, dual tasking, and eye movement. The intervention was personalised for each participant who used it, after taking an initial assessment to assess the needs and areas for improvement of each participant. Participants were tested on a battery of 18 tests, including the Dyslexia Adult Screening Test (DAST) balance test; two pegboard tests; the DAST writing test; two working memory tests; the DAST Backwards Digit Span test; a Spatial Memory test; a declarative memory test; a Picture Memory test (including immediate recall and delayed recall after 20 minutes); the DAST Rapid Naming; Reading; Nonsense Passage Reading; Phonological Processing; and Spelling tests; the DAST Nonverbal Reasoning; Semantic fluency; and Verbal fluency. Two affect tests were also used to assess depression and happiness. Gallant and Nicolson (2017) found improvements for the intervention group in the following tests: in balance (Balance test & Pegboard tests), in Hippocampal, Declarative Memory tests (Declarative memory, Immediate Picture Memory Recall, and Delayed Picture Memory Recall tests), in Verbal Working Memory (Backwards Digit Span test), and in executive function (Verbal fluency test).

Reynolds et al. (2003) evaluated the effectiveness of an exercise-based treatment similar to the Zing intervention, the DDAT exercise programme aimed at remediating reading difficulties in a sample of junior school students. The DDAT is a programme consisting of exercises on sensory stimulation, including visuomotor and vestibular exercises. The DDAT is comprised of the following: a balance board exercise, throwing and catching of bean bags exercise, a dual tasking exercise, and stretching and coordination exercises. The DDAT exercise programme was used by the intervention group daily at home for ten minutes, for six months. The participants were assessed on a range of the Dyslexia Screening Test-Junior (DST-J) tests. In particular they were assessed before and after the intervention on literacy skills, including the One Minute Reading, the Nonsense Passage Reading, the Two Minute Spelling, and the One Minute Writing test; on Phonological awareness and Verbal Working Memory skills, including the Phonemic Segmentation test and the Backwards Digit Span test; on cerebellar/vestibular tests, including the Bead Threading test and the Postural Stability test; and on Memory Retrieval Fluency skills, including the Rapid Automatized Naming task, the Verbal fluency task, and the Semantic fluency task, along with school tests based on standardized attainment tests (SATS). A series of Dynamic Posturography tests were applied in both the intervention and control group, including the Sensory Organization test, the Motor Control test, and the Adaptation test. A range of eye tracking tests were also administered. The intervention group showed significant changes in the cerebellar/vestibular tests, while the control group did not show any changes. For the intervention group, substantial improvements were observed on a range of tests such as on reading, semantic fluency, phonemic segmentation, nonsense passage reading, phonological skills, bead threading, and postural stability tests, whereas there were no such improvements for the control group. Moreover, significant improvements were observed in the intervention group on the national SATS.

Based on the results of Study 4, and following previous intervention studies by Reynolds et al. (2003), and Gallant and Nicolson (2017), Study 5 evaluated the effectiveness of an internet-based 'cerebellar challenge' intervention, called Zing intervention (www.zingperformance.com) on dyslexic and non-dyslexic adolescents. The Zing intervention includes exercises focusing on balance, and as discussed in Chapter 8, balance and motor skills are thought to be impaired in dyslexic individuals (Stoodley et al., 2005; 2006; Nicolson et al., 1999), and therefore such an intervention might improve motor skills in dyslexic adolescents. The Zing intervention was not used in Study 5 as a remediation exercise for dyslexia related symptoms, but rather as an exercise to improve cognitive and cerebellar function in a group of adolescents at risk of school failure. The aim of the Zing intervention in Study 5 was to stimulate and activate the cerebellum by engaging the whole body in a series of exercises that stimulated the balance systems and enhanced general well-being including emotional and affective processing.

9.3 Hypotheses for Study 5

The hypotheses of Study 5 were developed based on Gallant and Nicolson (2017) study which evaluated the effectiveness of the Zing intervention in a group of older adult individuals on a number of cognitive tests, declarative tests, and motor tests.

It was hypothesized that the intervention group would show improvements in balance and sensorimotor coordination.

- Hypothesis 1: The intervention group would improve significantly more in sensorimotor coordination tasks, especially in balance, at posttest, compared with the control, no intervention, group.

It was hypothesized that the intervention group would show improvements in declarative memory.

- Hypothesis 2: The intervention group would improve significantly more in declarative memory tasks, at posttest, compared with the control, no intervention, group.

It was hypothesized that the intervention group would show improvements in procedural memory.

- Hypothesis 3: The intervention group would improve significantly more in procedural memory tasks, at posttest, compared with the control, no intervention, group.

It was hypothesized that the intervention group would show improvements in verbal working memory.

- Hypothesis 4: The intervention group would improve significantly more in the verbal working memory task, at posttest, compared with the control, no intervention, group.

It was hypothesized that the intervention group would show improvements in general well-being and emotional affect.

- Hypothesis 5: The intervention group would improve significantly more in state and trait anxiety, at posttest, compared with the control, no intervention, group.

9.4 Methodology

9.4.1 Ethical considerations

The ethical approval received for this study was the same as for Study 4 (see section 8.5.1).

9.4.2 Participants

The sample of Study 5 was identical to that described in Study 4, as the present study was a follow-up design to Study 4. A sample of 40 students (19 females, 21 males), from Year 10 (mean age 14.7 years) participated in Study 5; of those students, 18 had dyslexia and 22 did not have dyslexia or other specific learning difficulties. Participants were randomly assigned to the Zing intervention group or the control group; 20 students were assigned to the intervention group and 20 students to the control group. The control group did not have any intervention. Participation was voluntary and there was no drop out of the study.

9.4.3 Zing intervention

The Zing intervention (https://www.zingperformance.com) was developed to stimulate and activate the cerebellum through engaging the whole body in a series of exercises that stimulate the balance systems. Zing was designed with the idea that when the cerebellum becomes fully functional, learning becomes simpler, cognitive skills improve, and emotional wellbeing increases. This intervention was originally developed to tune up the coordination abilities of top sporting performers, using a series of graded exercises designed specifically to improve three performance dimensions: sensorimotor coordination, eye movement control and dual tasking. However, extensive feedback had suggested that the programme was valuable for many average performers. Consequently, the system was embedded in an internet-based 'game' format designed to challenge and stimulate the user to keep improving their performance. Zing Performance offers a number of courses specifically tailored to each individual user, with applications in education, sporting areas, and organizational development.

The Zing system involves a series of graded activities on three dimensions - dynamic activity (patterned movement sequences), focus activity (developing the ability both to concentrate and to 'dual task') and stability activity (coordinative balance). Underpinning the approach is the technique of vestibular stimulation. Rather than cardiovascular exercise, which is designed to have energetic use of highly practiced routines, or even coordinative balance such as tai chi, which involves learning new actions, vestibular activities are designed to cause abnormal input for the vestibular system, for example by requiring the user to put their head on one side while undertaking tasks. This presents the vestibular system, and the cerebellum, with an immediate challenge, requiring activation of many circuits to cope with the ensuing proprioceptive feedback.

Participants in the Zing intervention start with brain assessments which last for about 30 minutes and look like computer games. Then a chart generates showing the start point and the targets suggested for each brain skill. The system creates a customized program based on those measures to suit the participant. At the end of each session the participant reports how easy or hard the exercises are, and the program calculates the optimum set of exercises for the next session. These exercises continue for 30 days, until the participant goes through the assessment again. As the participant makes progress for the duration of the program, the exercises increase in intensity as they progressively drive the development and maturing of different parts of the cerebellum. A typical course lasts 6 months and is composed of daily physical activities and digital video games.

9.4.4 Experimental design and procedure

The aim of Study 5 was to test the effectiveness of a 'cerebellar-challenge' intervention on cognitive and cerebellar function. The study was designed as a pretest – posttest experiment, thus, a repeated measures design was used. Participants were asked to complete a battery of tests before taking part in an 8-week Zing intervention, and then participants were asked to repeat the same battery of tests immediately after completing the intervention. The pre-assessment tests were done one to two weeks before the intervention (the pre-intervention set of data was from Study 4 as the baseline); the intervention lasted for 8 weeks, and the post-assessment tests were done one to two weeks immediately after the intervention was completed.

The full Zing 360 session programme was designed for 6 months with two sessions per day for 10 minutes. However, in Study 5, the intervention was shorter than recommended by the Zing Performance team and was applied for 8 weeks, as the school gave permission for two months to implement the intervention in the school. The Zing intervention was also previously applied for eight weeks in Gallant and Nicolson (2017) study, which examined the effectiveness of the intervention in a group of older adults, and the results showed greater improvement for the intervention group, compared to the control group, on measures of balance, coordination, and declarative memory.

The Zing intervention could potentially fulfil the criteria of user autonomy, user engagement, and growth mindset (in that it was designed to highlight the opportunities for enhanced neuroplasticity and performance). Furthermore, being activity based could address the three axes of physical health, mental health, and academic health.

The intervention in Study 5 took place in a computer room in a school, three times a week, for 30 minutes per session. All the students assigned to the intervention group did the Zing exercises at the same time. The Researcher was present in the computer room in all the sessions to answer any questions and to supervise the students during the exercises. The Learning Provider was also present in all the sessions.

9.4.5 Intervention training

The participants in the current study were required to undertake a minimum of 8 weeks ‘cerebellar challenge’ training, as well as balance and sensorimotor coordination training using an online set of activities. These were provided by Zing Performance Ltd. and were designed to stimulate brain regions involved in coordinative balance. Initially, participants had to undergo an assessment to determine their strengths and weaknesses. After this, a four-week long programme was set for them, specifically designed to target their greatest needs. Participants were required to do the activities three times a week for 30 minutes per session. Each week, three exercises were assigned, with two of the three appearing at each session.

After four weeks, the participants were reassessed before continuing onto unit two. A screenshot from one of the Zing sessions is shown in Figure 9.1.

Figure 9.1 A screenshot from a session of the Zing programme

9.4.6 Materials and Apparatus

The battery of tests used to assess dyslexia and anxiety symptoms in the current study were the same as reported in Study 4 (chapter 8).

9.5 Results

9.5.1 Descriptive statistics

Means and standard deviations for the DST tasks, across the two time periods, are shown in Table 9.1.

Table 9.1 Pre-intervention and post-intervention means and standard deviations for the DST tasks

	Measures	Group	Pre-intervention Mean (SD)	Post-intervention Mean (SD)
Literacy skills	One-minute reading	Intervention	2.95 (1.31)	3.90 (1.29)
		Control	2.95 (1.46)	3.35 (1.49)
	Two-minute spelling	Intervention	3.55 (2.04)	3.65 (1.49)
		Control	2.80 (1.43)	2.75 (1.41)
	One-minute writing	Intervention	2.65 (.93)	2.90 (1.02)
		Control	2.70 (1.41)	2.80 (1.05)
Motor tasks	Bead threading	Intervention	2.95 (2.35)	3.80 (1.67)
		Control	3.10 (2.12)	3.15 (1.38)
	Postural stability	Intervention	3.05 (1.27)	4.60 (1.04)
		Control	3.45 (1.14)	3.35 (1.42)
Verbal working memory test	Backwards digit span	Intervention	3.05 (1.35)	4.05 (1.27)
		Control	2.40 (1.50)	2.60 (.82)
Executive function /Memory retrieval fluency	Rapid Automatized Naming	Intervention	3.10 (1.65)	3.60 (1.46)
		Control	2.55 (1.67)	2.65 (1.98)
	Verbal fluency	Intervention	2.40 (1.60)	3.15 (.99)
		Control	3.40 (1.81)	3.70 (1.38)
	Semantic fluency	Intervention	3.05 (.99)	3.90 (.97)
		Control	3.10 (1.12)	3.35 (.99)

The means and standard deviations for the declarative and procedural memory tasks, across the two time periods, are shown in Table 9.2.

Table 9.2 Pre-intervention and post-intervention means and standard deviations for the declarative and procedural memory tasks and for the STAI

	Measures	Group	Pre-intervention Mean (SD)	Post-intervention Mean (SD)
Declarative Memory tasks	Declarative memory	Intervention	11.95 (3.18)	13.90 (3.21)
		Control	12.45 (2.35)	12.20 (3.13)
	Picture memory recall	Intervention	9.45 (2.19)	10.55 (2.16)
		Control	10.20 (1.82)	10.40 (1.72)
	Delayed picture memory recall	Intervention	7.65 (2.06)	10.70 (2.39)
		Control	10.60 (3.17)	9.50 (2.44)
Procedural Memory tasks	WIT Real words accuracy	Intervention	29.40 (3.73)	30.70 (2.84)
		Control	29.45 (2.66)	29.50 (3.34)
	WIT Real words speed	Intervention	3.14 (.54)	3.08 (.52)
		Control	3.23 (.48)	3.20 (.47)
	WIT Pseudowords accuracy	Intervention	19.05 (3.86)	19.25 (3.43)
		Control	19.55 (3.99)	19.60 (3.64)
	WIT Pseudowords speed	Intervention	3.76 (.41)	3.71 (.40)
		Control	3.57 (.38)	3.54 (.36)
	MST reaction time-1st trial	Intervention	1.74 (.34)	1.66 (.31)
		Control	2.10 (.46)	2.08 (.45)
	MST Correct sequences-1st trial	Intervention	12.15 (2.54)	13.00 (2.12)
		Control	11.50 (2.58)	11.60 (2.13)
	MST reaction time- 2nd trial	Intervention	1.65 (.26)	1.55 (.22)
		Control	1.81 (.32)	1.75 (.29)
	MST Correct sequences- 2nd trial	Intervention	13.20 (1.85)	14.40 (2.01)
		Control	13.00 (2.38)	13.10 (3.02)
STAI	State anxiety	Intervention	40.00 (4.95)	37.15 (5.18)
		Control	41.50 (5.64)	40.25 (6.54)
	Trait anxiety	Intervention	42.30 (4.23)	39.80 (3.60)
		Control	41.50 (6.97)	41.80 (5.76)

9.5.2 Statistical analysis

A 2 (Time) x 2 (Group) mixed-design analysis of variance (ANOVA) was carried out to assess the impact of the proposed Zing intervention on adolescents, across two time periods (pre-intervention and post-intervention), on a battery of tests including motor tasks, declarative and procedural learning tasks as well as cognitive and literacy tasks. The between-subjects variable was Group (two levels: Intervention and Control) and the within-subjects variable was Time (two levels: pretest and posttest). The data was checked for normality using the Shapiro-Wilk test, along with the inspection of histograms. The examination of boxplots indicated that there were a few outliers in the data, however, they were not significant outliers, and therefore they were not removed from the analysis. The Levene's test showed that the assumption of equality of error variance was met for all the variables ($p > .05$). The assumption of homogeneity of intercorrelations was checked for all the variables, using Box's M statistic and it was met. Following the method of Gallant and Nicolson (2017), and Moran (2003), a Bonferroni correction for multiple comparisons was not applied in the data because all the comparisons were significant in the same direction, and thus, uncorrected probabilities were reported.

9.5.2.1 Between group statistical tests.

An increase in the mean scores of all the DST-S subtests, and the declarative and procedural tests indicated an improvement from pre-test to post-test. Whereas a reduction in the mean scores of the State and Trait anxiety measures indicated an improvement from pre-test to post-test. Means and standard deviations for all tests are presented in Tables 9.1 and 9.2.

Literacy tests

Three literacy tests were administered in Study 5; namely, the one-minute reading test, the two-minute spelling test, and the one-minute writing test. A significant result was only found for the one-minute reading task, with a main effect of time, $F(1, 38) = 10.86$, $p = .002$, $\eta^2 = .222$ (see Fig. 9.2), but no main effect of group, $F(1, 38) = .494$, $p = .48$, $\eta^2 = .013$, and no interaction effect, $F(1, 38) = 1.803$, $p = .18$, $\eta^2 = .045$.

For the two-minute spelling test, there was no difference for time, $F(1, 38) = .012$, $p = .91$, $\eta^2 = .000$, or for group $F(1, 38) = 3.231$, $p = .08$, $\eta^2 = .078$, and no interaction effect between time and group, $F(1, 38) = .111$, $p = .74$, $\eta^2 = .003$.

For the one-minute writing task, there was no difference for time, $F(1, 38) = .903$, $p = .348$, $\eta^2 = .023$, or for group, $F(1, 38) = .007$, $p = .93$, $\eta^2 = .000$, and no interaction between time and group, $F(1, 38) = .166$, $p = .68$, $\eta^2 = .004$

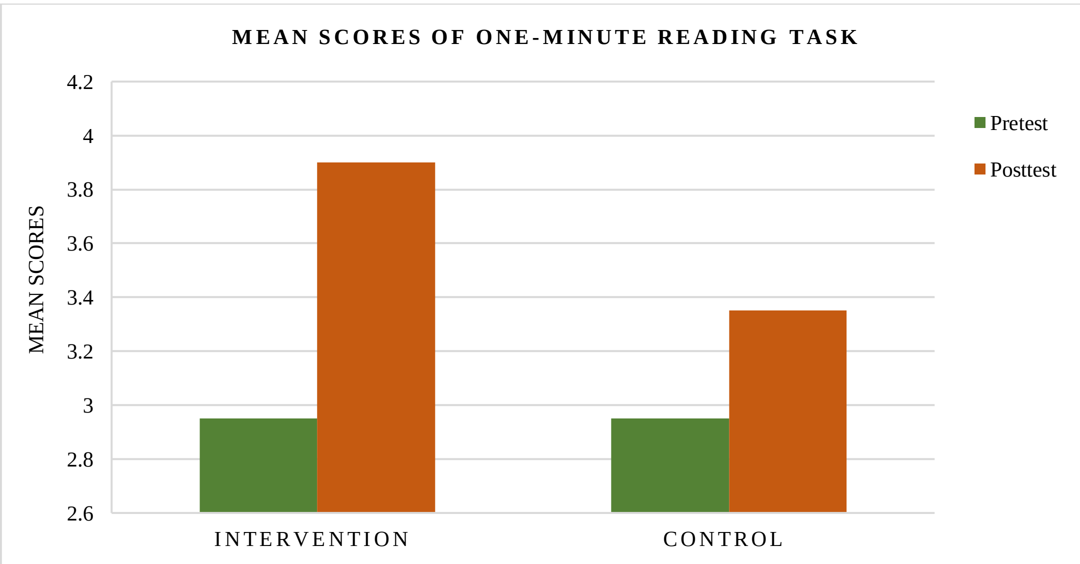


Figure 9.2 Time effect on the one-minute reading task

Executive Function / Memory retrieval tasks

Three executive function tests were administered in Study 5; the Rapid Automatized Naming test, the Verbal fluency test and the Semantic fluency test. The results did not show a significant difference for time for the RAN test, $F(1, 38) = 1.235$, $p = .27$, $\eta^2 = .031$, or for group, F (1, 38) = 2.596, p = .11, η^2 = .064, and there was no interaction between time and group, F (1, 38) = .549, p = .46, η^2 = .014.

There was a significant main effect for time in the verbal fluency test, F (1, 38) = 5.665, p = .02, η^2 = .130, but no main effect for group, F (1, 38) = 3.528, p = .06, η^2 = .085, and no significant interaction between time and group, F (1, 38) = 1.041, p = .31, η^2 = .027.

There was a significant difference for time in the semantic fluency test, F (1, 38) = 7.380, p = .010, η^2 = .163 (see Fig. 9.3), but no difference for group, F (1, 38) = .914, p = .34, η^2 = .023, and no interaction between time and group, F (1, 38) = 2.196, p = .14, η^2 = .055.

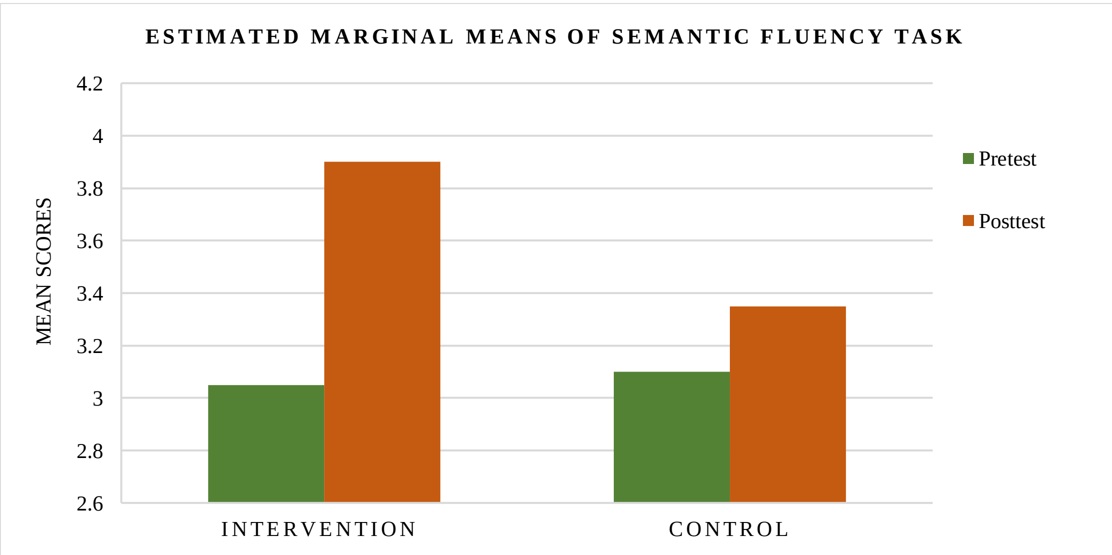


Figure 9.3 Time effect on the semantic fluency task

Motor tasks

Two motor tests were administered in Study 5: the beads threading test, and the postural stability test. The results showed that there was an effect of time for the beads threading test, $F (1, 38) = 4.847$, $p = .03$, $\eta^2 = .113$, but no effect for group, $F (1, 38) = .199$, $p = .658$, $\eta^2 = .005$; and no interaction between time and group, $F (1, 38) = 3.830$, $p = .058$, $\eta^2 = .092$.

A significant effect of time was found for the postural stability test, $F (1, 38) = 11.62$, $p = .002$, $\eta^2 = .234$, but there was no main effect for group, $F (1, 38) = 1.697$, $p = .20$, $\eta^2 = .043$. There was an interaction between time and group (see Fig. 9.4), $F (1, 38) = 15.04$, $p < .001$, $\eta^2 = .284$, which showed that while the intervention group improved at post-test, the control group got worse.

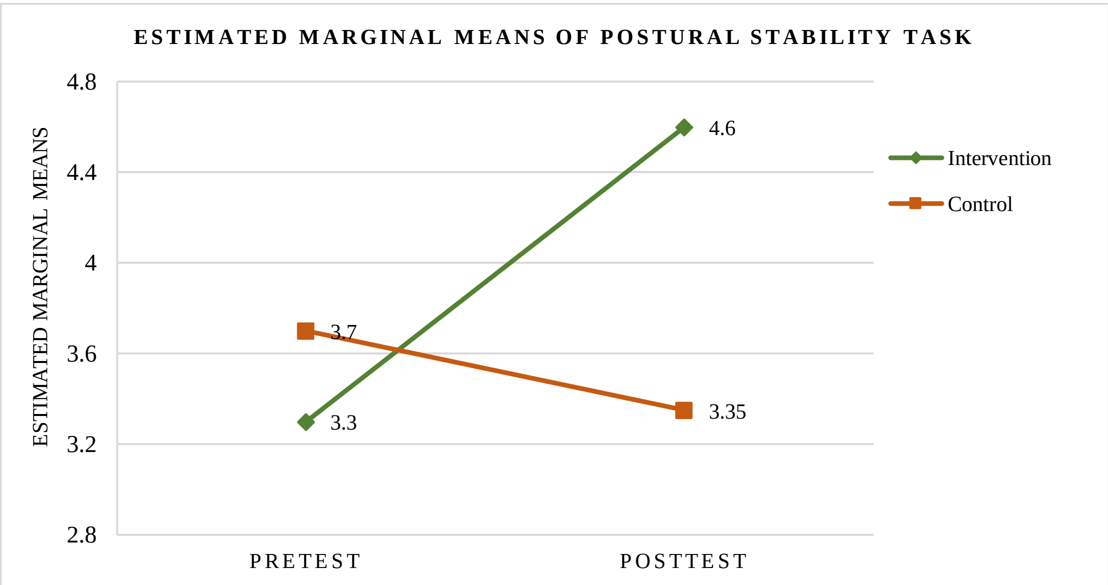


Figure 9.4 Interaction effect for postural stability between time and group

Verbal working memory test

There was a main effect of time for the backwards digit span test, $F(1, 38) = 8.393$, $p = .006$, $\eta^2 = .181$, and a main effect of group, $F(1, 38) = 9.425$, $p = .004$, $\eta^2 = .199$. The two groups differed at post-test, with the intervention group scoring significantly higher compared to the control group (see Fig. 9.5). There was no interaction between time and group, $F(1, 38) = 3.730$, $p = .06$, $\eta^2 = .089$.

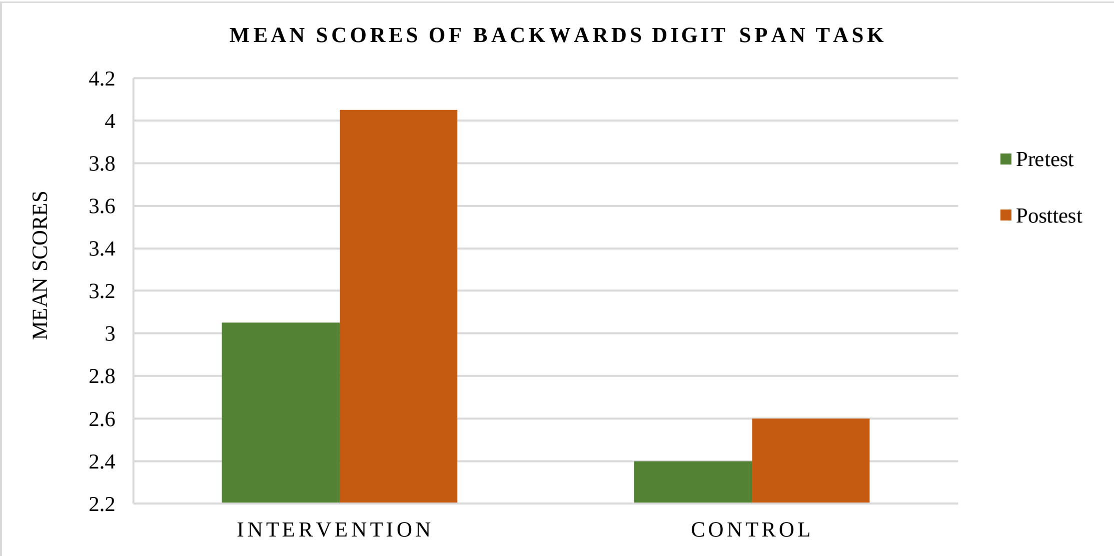


Figure 9.5 Time effect on backwards digit span task

Declarative memory tests

An increase in the mean scores of declarative memory tests indicated an improvement in performance on the tests. Two declarative memory tests were administered in Study 5; the declarative memory test, and the picture memory recall test, along with the delayed memory test, which took place 20 minutes after the memory recall test. A significant effect of time was found for the declarative memory test, $F(1, 38) = 7.918$, $p = .008$, $\eta^2 = .172$, but no main effect for group, $F(1, 38) = .447$, $p = .50$, $\eta^2 = .508$. There was a significant interaction (see Fig. 9.6) between time and group, $F(1, 38) = 13.260$, $p = .001$, $\eta^2 = .259$, which showed that the intervention group improved their performance, while the control group remained almost the same.

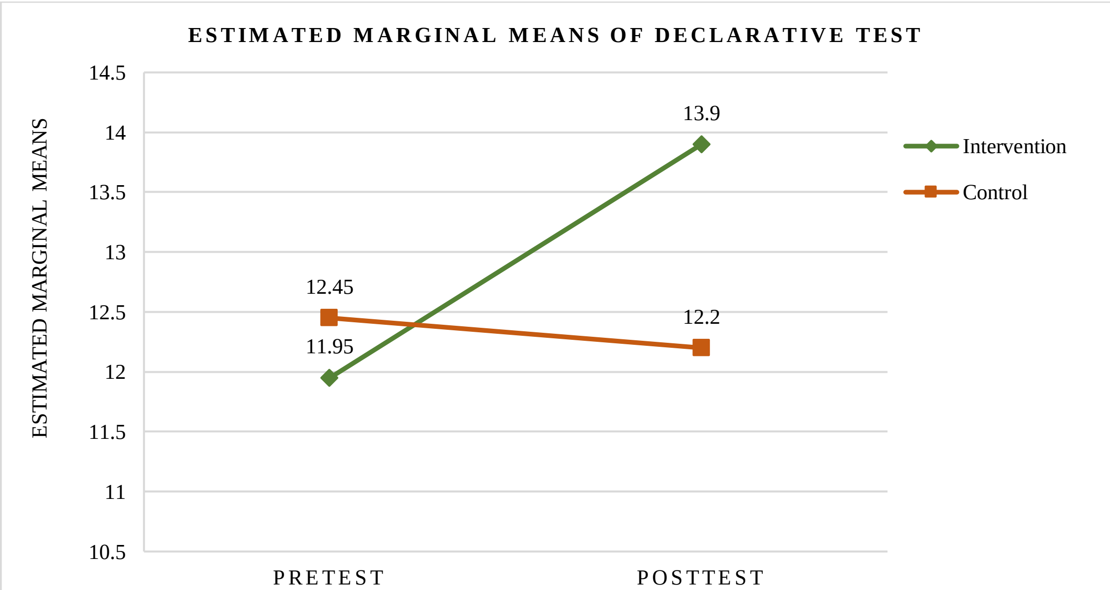


Figure 9.6 Interaction effect on declarative memory test between time and group

The results indicated a significant difference between pre- and post-test on the picture memory recall test, $F (1, 38) = 7.216$, $p = .011$, $\eta^2 = .160$. There was no difference between the groups, $F (1, 38) = .268$, $p = .60$, $\eta^2 = .007$, and no interaction between time and group, $F (1, 38) = 3.458$, $p = .07$, $\eta^2 = .212$.

For the delayed memory recall test, there was a significant difference for time, $F (1, 38) = 6.429$, $p = .015$, $\eta^2 = .145$, and for group, $F (1, 38) = 1.531$, $p = .22$, $\eta^2 = .039$, and there was an interaction between time and group (see Fig. 9.7), $F (1, 38) = 29.12$, $p < .001$, $\eta^2 = .434$, which showed that the performance of the intervention group improved, while the control's group performance decreased at post-test. These results may suggest that the original groups were not well matched, with poorer performance in the intervention group at pre-test.

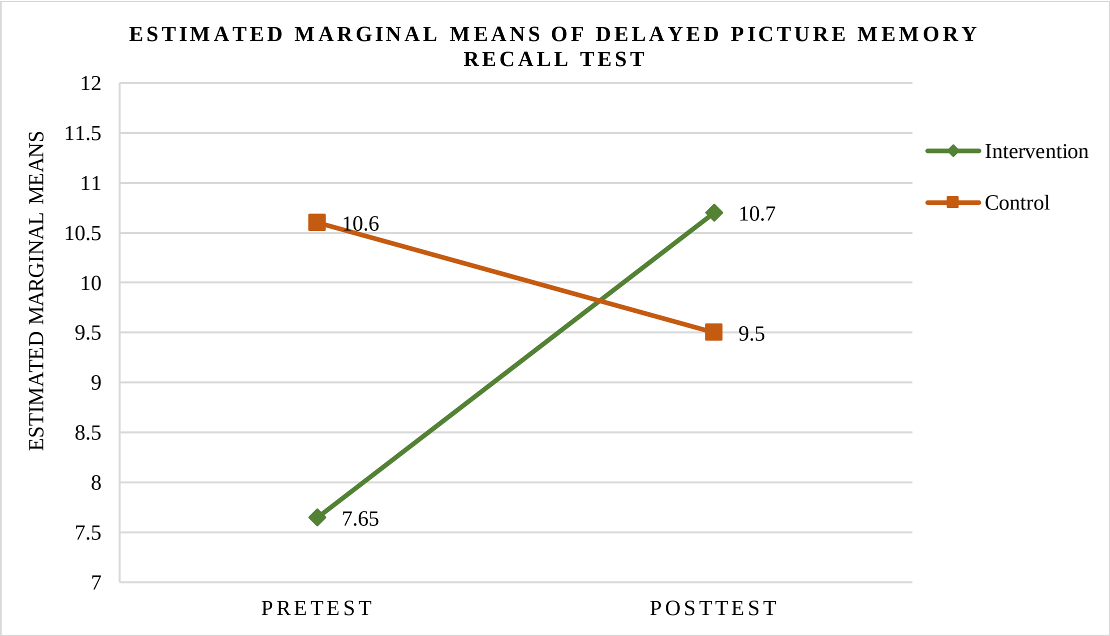


Figure 9.7 Interaction effect on delayed picture memory recall delayed test between time and group

Procedural memory tests

Two procedural memory tests were administered in Study 5: the Motor sequence task (MST) and the Word identification task (WIT). The MST included two trials, and it was analysed for two different scores: a) for the number of correct sequences in each trial, and b) for speed. The WIT included two sets/conditions; the number of words read aloud, and the number of pseudowords read aloud; and the results were analysed for two scores: a) for the number of correct words / pseudowords, and b) for speed.

For the MST, there was a separate analysis for each trial. For the 1st trial of the task, there was no difference between pre-test and post-test for the number of sequences, $F(1, 38) = 3.418$, $p = .07$, $\eta^2 = .083$, or for group, $F(1, 38) = 2.145$, $p = .15$, $\eta^2 = .053$. However, there was an interaction between time and group, $F(1, 38) = 9.947$, $p = .003$, $\eta^2 = .207$, which showed that while the intervention group scored higher at post-test, the control group scored the same (see Fig. 9.8).

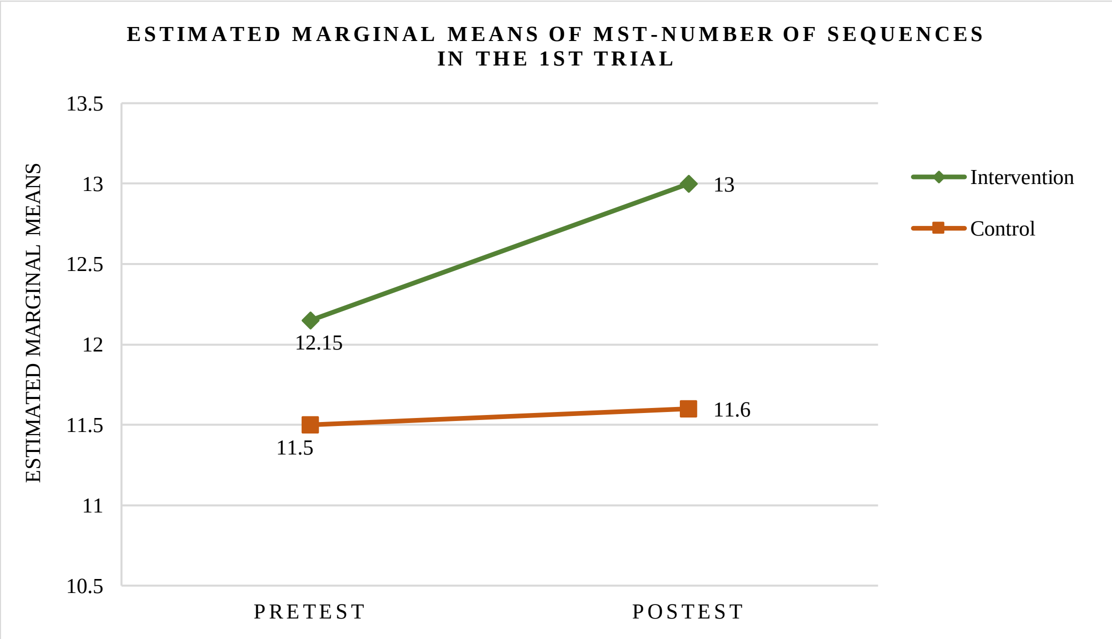


Figure 9.8 Interaction effect on MST-Correct sequences in the 1st trial between time and group

For the speed in the 1st trial of the task, there was a main effect for time, $F(1, 38) = 7.876$, $p = .008$, $\eta^2 = .172$, and a main effect for group, $F(1, 38) = 9.882$, $p = .003$, $\eta^2 = .206$. The two groups differed both at pre-test and post-test, with the control group having significantly lower speed both at pre-test and post-test (see Fig. 9.9). There was no interaction between time and group, $F(1, 38) = 2.912$, $p = .09$, $\eta^2 = .071$.

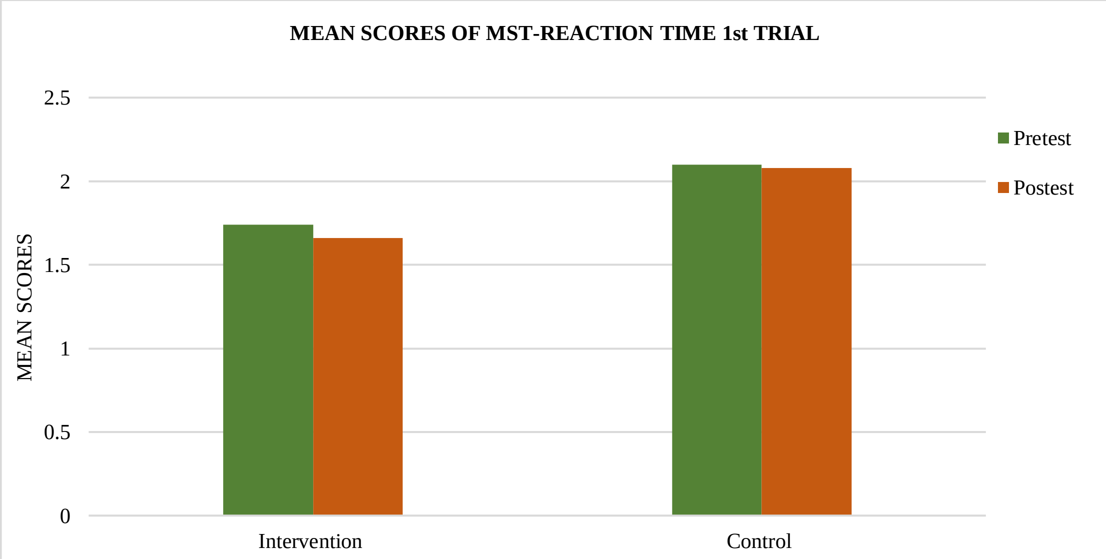


Figure 9.9 Main effect of time for MST-reaction time in the 1st trial

In the 2nd trial of the task, there was a difference between pre-test and post-test in the number of sequences, $F (1, 38) = 7.216$, $p = .011$, $\eta^2 = .160$. There was no difference between the groups, $F (1, 38) = 1.127$, $p = .29$, $\eta^2 = .029$. However, there was a significant interaction between time and group, $F (1, 38) = 5.166$, $p = .029$, $\eta^2 = .120$ (see Fig. 9.10).

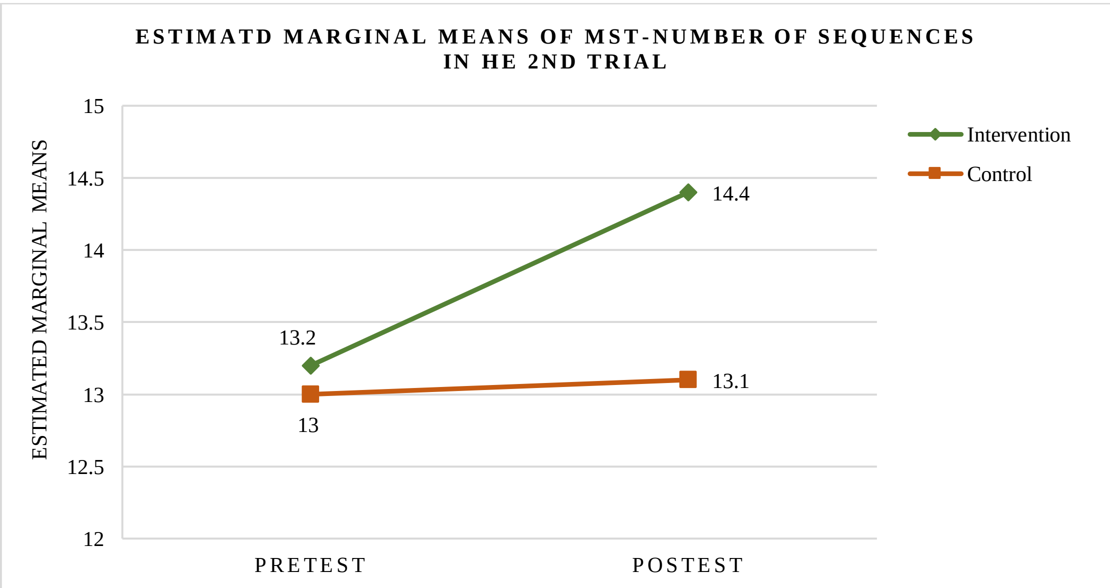


Figure 9.10 Interaction effect on MST-Correct sequences in the 2nd trial between time and group

For the speed in the 2nd trial of the task, there was a difference between pre-test and post-test, F (1, 38) = 8.050, p = .007, η^2 = .175, and a significant difference between the groups at post-test, F (1, 38) = 4.849, p = .034, η^2 = .113, with the intervention group having significantly higher speed than the control group (see Fig. 9.11). There was no interaction between time and group, F (1, 38) = .268, p = .60, η^2 = .007.

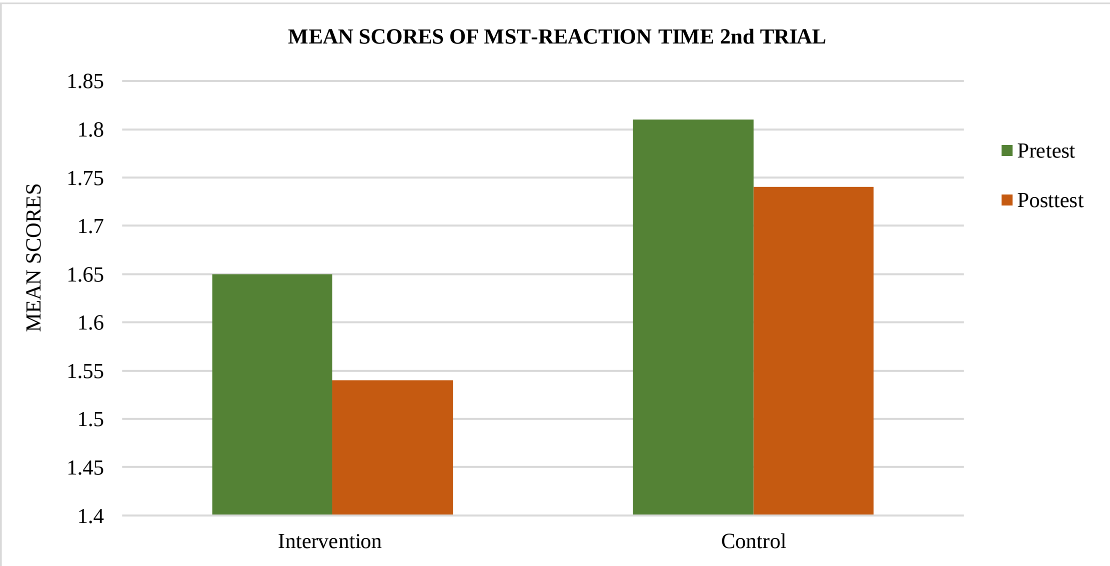


Figure 9.11 Main effect of time on MST reaction time in the 2nd trial

For the WIT real words accuracy set, there was a difference between pre-test and post-test scores, F (1, 38) = 5.812, p = .021, η^2 = .133. There was no difference between group scores, F (1, 38) = .355, p = .55, η^2 = .009. There was an interaction between time and group, F (1, 38) = 4.983, p = .03, η^2 = .116, which showed that while the intervention group showed better performance at post-test, the control group did not show such a change (see Fig. 9.12).

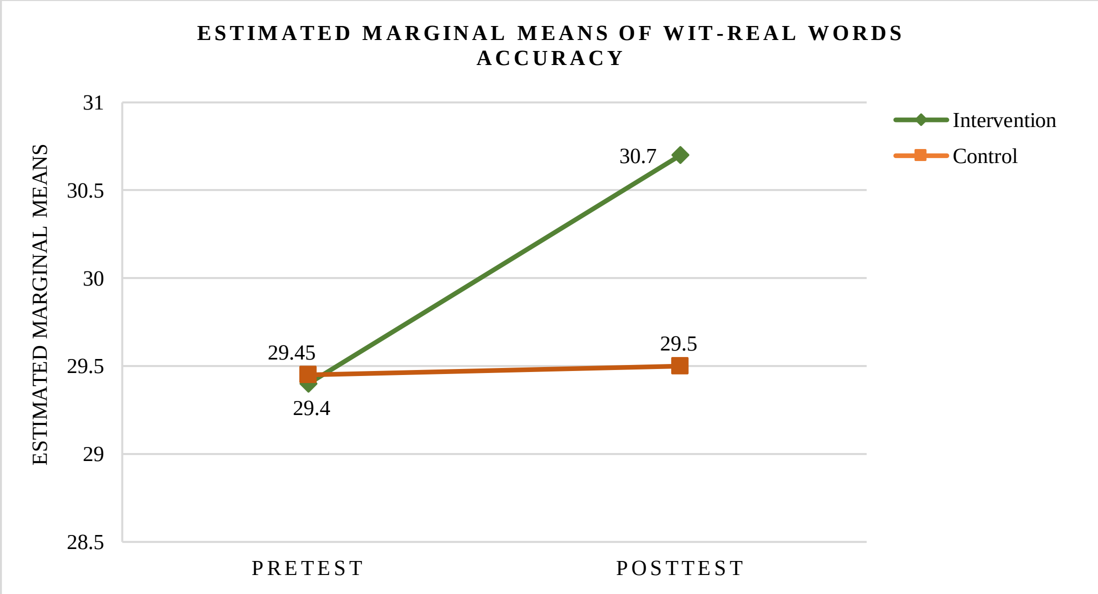


Figure 9.12 Interaction effect on WIT real words accuracy between time and group

For the real words speed scores, there was a difference between pre-test and post-test scores for speed (see Fig. 9.13), $F\ (1, 38) = 7.142$, $p = .011$, $\eta^2 = .158$. There was no difference between the groups, $F\ (1, 38) = .453$, $p = .50$, $\eta^2 = .012$, or an interaction effect between time and group, $F\ (1, 38) = .696$, $p = .40$, $\eta^2 = .018$.

Figure 9.13 Main effect of time for WIT real words speed

There was no difference between pre-test and post-test scores in the WIT pseudowords accuracy set, $F (1, 38) = .216$, $p = .64$, $\eta^2 = .006$, and no difference in group scores, $F (1, 38) = .136$, $p = .71$, $\eta^2 = .004$; and no interaction between time and group, $F (1, 38) = .078$, $p = .78$, $\eta^2 = .002$.

There was an effect for time on pseudowords speed scores, $F (1, 38) = 7.190$, $p = .011$, $\eta^2 = .159$. There was no effect for group, $F (1, 38) = 2.065$, $p = .15$, $\eta^2 = .052$; and no interaction between time and group, $F (1, 38) = .779$, $p = .38$, $\eta^2 = .020$.

State and Trait anxiety

There was a significant difference in time for state anxiety scores, $F (1, 38) = 7.27$, $p = .01$, $\eta^2 = .161$, but no significant difference between the groups, $F (1, 38) = 2.05$, $p =.16$, $\eta^2 = .051$, and no interaction effect between time and group, $F (1, 38) = 1.108$, $p =.29$, $\eta^2 = .028$.

For trait anxiety scores, there was difference in time from pre- to post- test, $F (1, 38) = 5.267$, $p = .027$, $\eta^2 = .122$, but no significant difference between the groups, $F (1, 38) = .139$, $p = .71$, $\eta^2 = .004$. There was a significant interaction between time and group (see Fig. 9.14), $F (1, 38) = 8.532$, $p = .006$, $\eta^2 = .183$, which showed that the intervention group had lower anxiety scores after the intervention, while the control group hardly changed their scores at post-test.

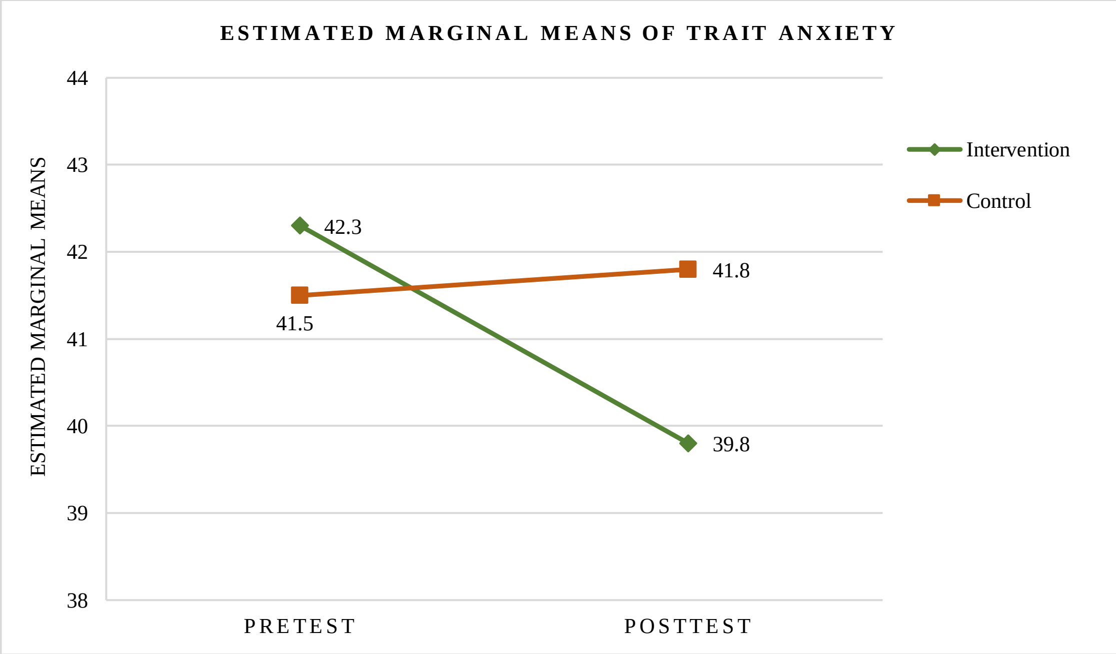


Figure 9.14 Interaction effect on trait anxiety scores between time and group

9.5.2.2 Individual changes within the intervention and control group.

The individual changes in performance on tasks (11 in total) with significant Group differences, and interaction effects are shown in Table 9.3. The significant Group differences and interactions between Group (intervention vs control) and Time are also shown at the individual level, with more than half of the intervention individuals improving for each task, whereas almost the same numbers improved and deteriorated for the control group. In addition, all 20 adolescents of the intervention group improved on at least four of the eleven tasks, 18 (90%) improved on at least 5, 15 (75%) improved on at least 7, 10 (50%) improved on 8 or more, and 3 (15%) improved on all 11 tasks. In the control group, the maximum number of tasks in which the adolescents were improved at was 8 out of the 11 tasks. All 20 adolescents improved on at least two of the 11 tasks, 11 improved on 3 or more, and 8 improved on 6 or more.

In terms of changes in state and trait anxiety scores, the number of adolescents classified as having high state anxiety dropped from 11 (55%) to 6 (30%) for the intervention group, and from 14 (70%) to 8 (40%) for the control group. The number of adolescents with high trait anxiety in the intervention group dropped from 10 (50%) to 6 (30%), and in the control group it remained at 8.

Table 9.3 Individual changes from pre- to post-test on tasks with Group (Intervention vs Control) differences

	Intervention			Control		
	Better	Same	Worse	Better	Same	Worse
Postural stability	17	1	2	8	3	9
	85%	5%	10%	40%	15%	45%
Backwards Digit Span	13	3	4	10	3	7
	65%	15%	20%	50%	15%	35%
Declarative Memory	16	0	4	9	1	10
	80%	0%	20%	45%	5%	50%
Delayed picture memory recall	10	2	8	10	3	7
	50%	10%	40%	50%	15%	35%
MST-Number of sequences 1st trial	13	1	6	12	2	6
	65%	5%	30%	60%	10%	30%
MST-Number of sequences 2nd trial	16	0	4	9	3	8
	80%	0%	20%	45%	15%	40%
MST-speed 1st trial	14	0	6	12	0	8
	70%	0%	30%	60%	0%	40%
MST-speed 2nd trial	17	0	3	11	0	9
	85%	0%	15%	55%	0%	45%
WIT-real words accuracy	16	0	4	10	1	9
	80%	0%	20%	50%	5%	45%
Trait anxiety	15	1	4	11	0	9
	75%	5%	20%	55%	0%	45%

9.5.2.3 Within group statistical tests.

To facilitate comparison of the improvements in performance, from pre-test to post-test, and to measure the magnitude of the observed effect, effect sizes were calculated separately for the control and the intervention group (see Fig. 9.15 & Fig. 9.16). The effect sizes were calculated by extracting the mean difference of two time points divided by the standard deviation of the control group, which is a form of Cohen (1988), applied to change analysis. No change would result in an effect size of 0, whereas a score of + 1.0 would indicate a change of one standard deviation unit. Cohen (1988) suggests that the categories of 0.2 be labelled as small, of 0.5 be labelled as medium, and 0.8 be labelled as large. The formula used to calculate the effect sizes is presented below:

$$ES = \frac{T2control - T1control}{SDcontrolT1}$$

$$ES = \frac{T2intervention - T1intervention}{SDcontrolT1}$$

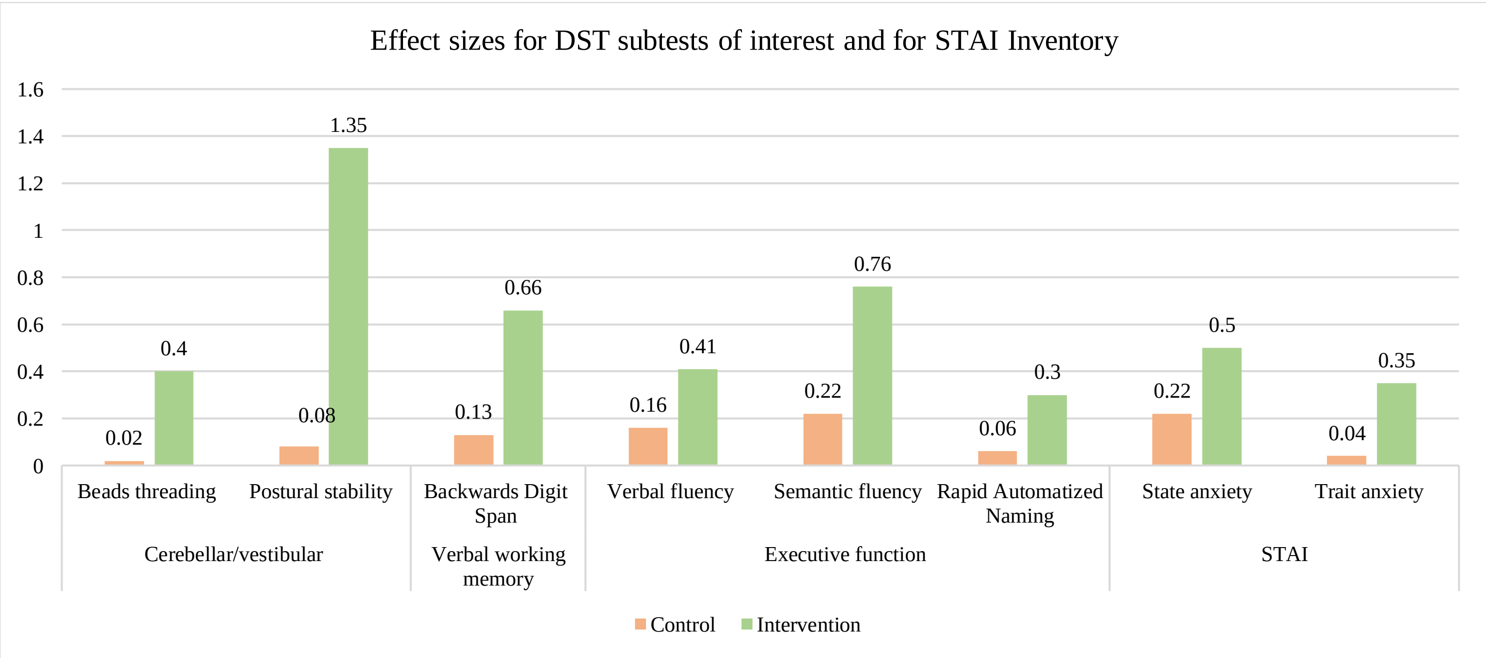


Figure 9.15 Effect sizes by group for DST subtests of interest and STAI Inventory

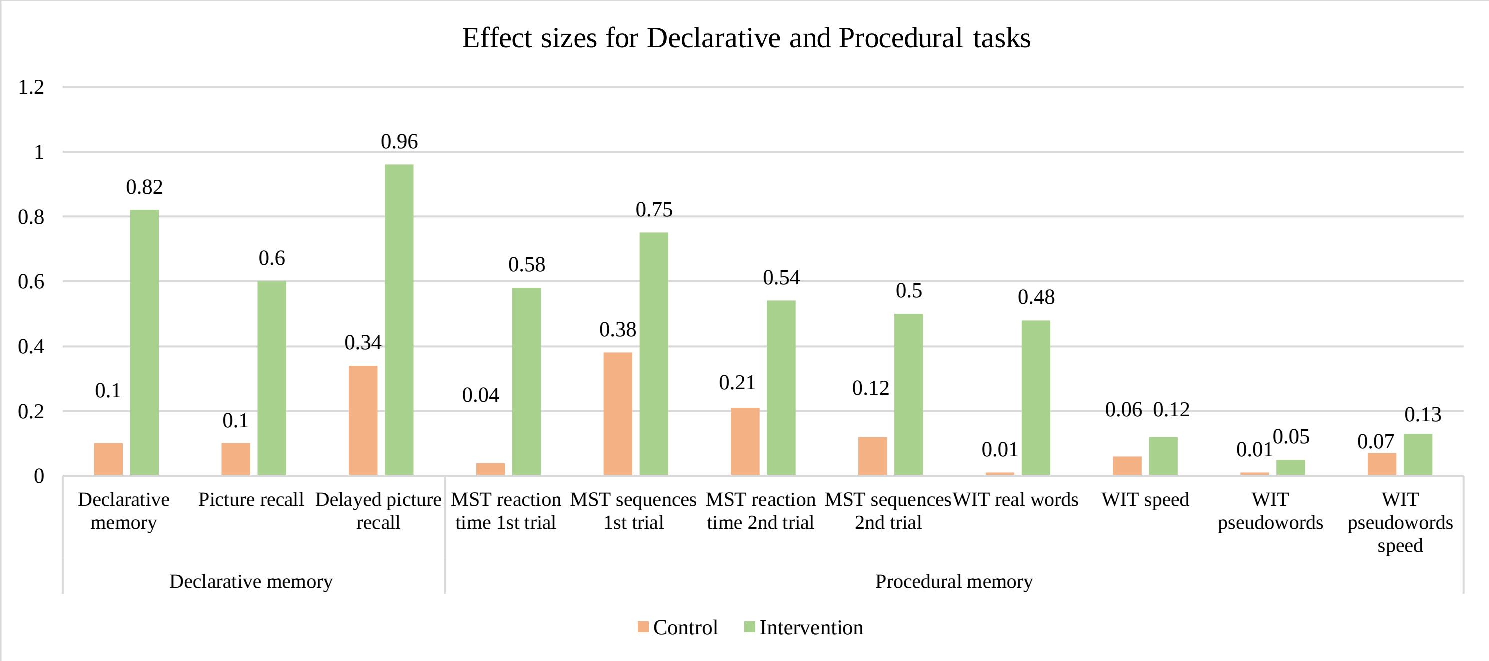


Figure 9.16 Effect sizes by group for Declarative and Procedural Memory tasks

A within-group analysis was also undertaken for each task, for the intervention and the control group separately, to facilitate the comparison of the improvement from pre-test to post-test. This analysis is in accordance with Gallant and Nicolson (2017) study. A repeated measures ANOVA showed that for the control group none of the results approached significance. Based on a previous study (Biotteau et al., 2015), it was suggested that skill automatization should not only be measured by differences between the intervention and the control group, but also by differences within each group.

For the Zing group, the repeated measures ANOVA analysis of the improvement from pre- to post-test was highly significant for the beads threading task ($F(1,19) = 9.61$, $p = .006$); however, there was a small effect size (ES = 0.4); postural stability ($F(1,19) = 26.12$, $p < .001$), with a large effect size (ES = 1.35) (see Fig. 9.15); one-minute reading ($F(1,19) = 11.08$, $p = .004$), with a moderate effect size (ES = 0.65); backwards digit span ($F(1,19) = 9.50$, $p = .006$), with a medium effect size (ES = 0.66); and for semantic fluency $F(1,19) = 16.58$, $p = .001$), with a moderate effect size (ES = 0.76).

A significant improvement from pre-test to post-test was found for the declarative and procedural memory tasks. The changes for declarative memory ($F(1,19) = 17.85$, $p < .001$), picture memory recall ($F(1,19) = 9.23$, $p = .007$), and delayed picture memory recall ($F(1,19) = 33.05$, $p < .001$) were significant. There was a large effect size for the declarative memory task (ES = 0.82), and the delayed picture memory recall task (ES = 0.96); and a medium effect size for the picture memory recall task (ES = 0.6).

A significant improvement from pre-test to post-test was found for the MST correct sequences task, in the 1st trial, $F(1,19) = 4.85$, $p = .04$ as well as in the 2nd trial, $F(1,19) = 16.48$, $p = .001$. Significant improvements were also found for speed in the MST task in the 1st trial, $F(1,19) = 7.95$, $p = .01$ as well as in the 2nd trial, $F(1,19) = 15.21$, $p < .001$. Although there was statistical difference from pre-test to post-test in the 1st and 2nd trial of the MST task, there was no practical improvement as indicated by the medium effect sizes (see Fig. 9.16).

For the WIT task, significant improvement from pre-test to post-test was found for the real words accuracy task, $F(1,19) = 12.30$, $p = .002$; however, there was no practical improvement due to a small effect size (ES = 0.48). An approximately significant improvement was also found for speed of the real words accuracy task, $F(1,19) = 4.88$, $p = .04$, however there was no practical improvement due to a small effect size (ES = 0.12).

Significant improvement was found for the intervention group in trait anxiety scores, $F(1, 19) = 13.73$, $p = .002$, but there was no practical improvement due to a small effect size (ES = 0.35).

9.5.2.4 Group (dyslexic vs non-dyslexic) statistical test for the intervention group.

Although there were consistent differences between the groups at pre-test (see Study 4, section 8.6.2.1), the effects of the Zing intervention were almost similar for both groups. A two-way Repeated Measures ANOVA, with Time being the within factor, and Group (dyslexic vs non-dyslexic) the between factor, was undertaken separately on the relative improvement for the intervention group only. It should be noted that the Bonferroni correction for multiple comparison was not applied in the data because all the comparisons were significant in the same direction, and thus, uncorrected probabilities were reported.

The results showed that there was a significant difference between the dyslexic and non-dyslexic group at post-test on the One Minute Reading task ($p < .001$), Two Minute Spelling task ($p = .014$), Beads threading task ($p = .009$), and Backwards Digit Span task ($p = .02$), with the non-dyslexic group showing a better performance compared to the dyslexic group. No differences between the groups were found on the rest of the tests. In terms of the interactions between Time and Group, 3 tasks showed an interaction, namely State anxiety, $F(1, 18) = 4.443$, $p = .05$; Rapid Naming, $F(1, 18) = 6.902$, $p = .02$; and Verbal Fluency, $F(1, 18) = 9.519$, $p = .006$; in all three of them the dyslexic group showed greater improvement. The rest of the 13 tasks did not show any effect. Means and standard deviations are presented in Tables 9.4 and 9.5.

Table 9.4 Pre- and post-test means and standard deviations for the DST tasks for the intervention group (separate for the dyslexic and non-dyslexic group)

	Measures	Group	Pre-intervention Mean (SD)	Post-intervention Mean (SD)
Literacy skills	One-minute reading	Dyslexic	2.22 (.97)	2.78 (.67)
		Non-dyslexic	3.55 (1.30)	4.82 (.87)
	Two-minute spelling	Dyslexic	2.22 (1.01)	2.78 (.98)
		Non-dyslexic	4.64 (2.01)	4.36 (1.50)
	One-minute writing	Dyslexic	2.11 (.60)	2.44 (.88)
		Non-dyslexic	3.09 (.94)	3.27 (1.01)
Motor tasks	Bead threading	Dyslexic	1.89 (2.03)	2.78 (1.20)
		Non-dyslexic	3.82 (2.09)	4.64 (1.57)
	Postural stability	Dyslexic	2.33 (.71)	4.11 (.93)
		Non-dyslexic	3.64 (1.36)	5.00 (1.00)
Verbal working memory task	Backwards digit span	Dyslexic	2.22 (.44)	3.33 (1.22)
		Non-dyslexic	3.73 (1.50)	4.64 (1.03)
Executive function /Memory retrieval fluency	Rapid Automatized Naming	Dyslexic	1.89 (1.17)	3.22 (1.30)
		Non-dyslexic	4.09 (1.30)	3.91 (1.58)
	Verbal fluency	Dyslexic	1.33 (.50)	3.00 (.71)
		Non-dyslexic	3.27 (1.68)	3.27 (1.19)
	Semantic fluency	Dyslexic	2.78 (.83)	3.56 (.88)
		Non-dyslexic	3.27 (1.10)	4.18 (.98)

Table 9.5 Pre- and post-test means and standard deviations for non-DST tasks for the intervention group (separate for the dyslexic and non-dyslexic group)

	Measures	Group	Pre-intervention Mean (SD)	Post-intervention Mean (SD)
Declarative Memory tasks	Declarative memory	Dyslexic	10.89 (2.62)	12.89 (2.80)
		Non-dyslexic	12.82 (3.46)	14.73 (3.41)
	Picture memory recall	Dyslexic	8.44 (2.07)	10.11 (1.76)
		Non-dyslexic	10.27 (2.00)	10.91 (2.47)
	Delayed picture memory recall	Dyslexic	6.89 (1.90)	9.78 (3.11)
		Non-dyslexic	8.27 (2.05)	11.45 (1.30)
Procedural Memory tasks	WIT Real words accuracy	Dyslexic	27.44 (4.22)	29.22 (3.11)
		Non-dyslexic	31.00 (2.45)	31.91 (2.02)
	WIT Real words speed	Dyslexic	3.59 (.36)	3.52 (.32)
		Non-dyslexic	2.77 (.34)	2.73 (.36)
	WIT Pseudowords accuracy	Dyslexic	17.33 (3.50)	18.00 (2.83)
		Non-dyslexic	20.45 (3.70)	20.27 (3.66)
	WIT Pseudowords speed	Dyslexic	3.94 (.22)	3.87 (.20)
		Non-dyslexic	3.61 (.47)	3.58 (.47)
	MST speed-1st trial	Dyslexic	1.93 (.15)	1.78 (.23)
		Non-dyslexic	1.60 (.38)	1.57 (.34)
	MST Number of sequences-1st trial	Dyslexic	10.67 (1.66)	11.67 (1.66)
		Non-dyslexic	13.36 (2.54)	14.09 (1.87)
	MST speed- 2nd trial	Dyslexic	1.78 (.16)	1.61 (.18)
		Non-dyslexic	1.54 (.28)	1.50 (.25)
	MST Number of sequences- 2nd trial	Dyslexic	11.78 (1.40)	13.22 (1.99)
		Non-dyslexic	14.36 (1.29)	15.36 (1.50)
STAI	State anxiety	Dyslexic	41.55 (4.06)	35.78 (6.62)
		Non-dyslexic	38.73 (5.43)	37.28 (3.58)
	Trait anxiety	Dyslexic	42.55 (4.53)	39.11 (3.69)
		Non-dyslexic	42.10 (4.18)	40.36 (3.61)

9.5.2.5 Inspection of individual data in the dyslexic group which participated in the Zing intervention.

Inspection of individual data showed that before the intervention, 14 of the 20 students in the intervention group fell within the ‘at risk’ category (0-3) in the Beads Threading test, 8 of whom were dyslexic. A small number of students performed better after the intervention; in particular, 4 students showed better performance and fell within the ‘not-at risk’ (above 3) category; of those students, only one student was dyslexic. In the second motor task, the Postural Stability task, there were 12 out of the 20 students who scored within the ‘at risk’ category before the intervention; more than half of those (8) students were dyslexic. After the intervention, 10 out of 12 students showed better performance and scored within the “not at risk’ category; and of those students more than half (6) were dyslexic.

In the Verbal Working Memory task, 12 out of 20 students scored within the ‘at risk’ category before the intervention in the backwards digit span test, 8 of those students were dyslexic. Three students showed better performance after participating in Zing and scored within the “not at risk” category; of those students two were dyslexic.

Little improvement was shown by the dyslexic participants in the executive function tests. Ten of the 20 students in the intervention group scored within the ‘at risk’ category in the Rapid Naming task at pretest. Of those students 8 were dyslexic. After training, 3 dyslexic students improved performance and were not in the ‘at risk’ category. In Verbal fluency, 17 of the 20 students in the intervention group were ‘at risk’ at pretest, of whom 9 were dyslexic. At posttest, only 4 students showed better performance; 2 students were dyslexic and 2 were not dyslexic. In Semantic fluency, 12 of the 20 students in the intervention group scored within the ‘at risk’ category before training; 7 of those students were dyslexic. After training, 7 students showed better performance and were not within the ‘at risk’ category, of whom 4 were dyslexics.

9.6 Discussion

The aim of Study 5 was to evaluate the effectiveness of the Zing intervention on motor and cognitive function in adolescents with and without dyslexia. A battery of tests was applied before and after the intervention. The tests were derived from the DST-S, including literacy tests, executive and motor function tests, and verbal working memory tests. A set of declarative and procedural memory tests were also administered.

In the introduction, it was stressed the importance and interdependence of three functional dimensions - physical wellbeing, cognitive wellbeing, and affective wellbeing – in human performance, and outlined the evidence that adolescents at risk of school dropout might be at risk on all three dimensions in addition to their overt risk of academic failure. It was further noted that some interventions might have benefits on at least two dimensions, and that the 'cerebellar challenge' exercises might have benefits on all three. Study 5 investigated these three functional dimensions for adolescents at risk of school failure by administering a wide-ranging set of measures, before and after a short cerebellar challenge intervention. The initial tasks revealed that in addition to their difficulties with academic performance, the participating adolescents did show abnormally high levels of anxiety, with those with dyslexia showing still higher overall levels. Their performance on measures of declarative memory and working memory (critical for school performance) were also well below average levels than their peers – again with the dyslexic group performing less well than the non-dyslexic group, indicating weak cognitive wellbeing. Third, their performance on measures of balance and bead threading were again below normal levels.

Although the effects of the Zing intervention were significant for some of the tasks, not all the predictions of the current study were supported. Hypothesis 1 which stated that the intervention group would improve on balance and sensorimotor coordination was partially supported, as the intervention group performed significantly better post-intervention on the balance task (postural stability) compared to the control group, however, no such improvement was found for the sensorimotor coordination task (beads threading). Significant changes were also found for the intervention group on the declarative memory tests (declarative test and delayed picture recall test), which supported Hypothesis 2. However, no such changes were reported for the immediate picture recall test. Hypothesis 3 stated that the intervention group would improve significantly more on the procedural memory tasks, which was partially supported by the current data, as the intervention group improved on one of the two tasks assessing procedural memory. In particular, the intervention group improved on the MST task, both on accuracy and speed post-intervention compared to the control group. However, the intervention group did not show such great improvements on the WIT task, except for the real words accuracy test.

In terms of Hypothesis 4, which stated that the intervention group would improve significantly more on verbal working memory, the intervention group improved their performance significantly more in the backwards digit span task than the control group, and thus hypothesis 4 was supported by the data of the present study. The results of Study 5 are in line with Horowitz-Kraus and Breznitz (2009), in which the experimental group showed better performance after training than the control group, in a digit span test. The results are also partly similar to Yang et al. (2017), and Shokoohi-Yekta (2013), in which the intervention groups improved compared to the control group in visual spatial working memory tests, and in visual attention tests, after working memory training. The difference between Study 5 and the previous studies (Horowitz-Kraus and Breznitz, 2009; Yang et al., 2017; Shokoohi-Yekta, 2013) is that Study 5 tested a different component of working memory, the verbal working memory, whereas the previous studies (Horowitz-Kraus and Breznitz, 2009; Yang et al., 2017; Shokoohi-Yekta, 2013) tested visual spatial working memory. However, Morey and Cowan

(2005) suggest that there are cases when the two components of working memory interfere with each other, depending on the task, and therefore both can be impaired.

Hypothesis 5 stated that the intervention group would improve their emotional affect and well-being compared to the control group, which was partially supported as the intervention group showed greater changes in trait anxiety scores compared to the control group. It was not expected that Zing training would directly reduce anxiety scores, as it is not one of the core characteristics of Zing training. However, it was expected that if cognitive and cerebellar performance could be enhanced by Zing training, then an individual would feel less stressed and there would be more mental resources available in the brain to perform other more demanding tasks. The reduction of trait anxiety of the intervention group could be attributed to generic benefits of greater engagement and hope, as discussed above. It is worth noting, however, that there is longstanding evidence of cerebellar involvement in affective state, with the 'Cerebellar Cognitive Affective Syndrome' (Schmahmann & Sherman, 1998) being highly influential. Zhang et al. (2020) established an association between trait anxiety and neural circuitry, which links the right cerebellum with the right hippocampus. Furthermore, the recent discoveries of intrinsic connectivity neural circuits (Buckner et al., 2011) highlight the role of the cerebellum in most. Finally, the establishment of clear anatomical linkage between cerebellum and hippocampus (Watson et al., 2019), added to the anatomical linkage between cerebellum and basal ganglia (Bostan & Strick, 2018), reinforcing the claim that unexpected vestibular input can activate the whole brain and body.

The results of the present study are in accordance with Reynolds et al. (2003) study, which found that the benefits of DDAT training on children with dyslexia were not limited to cerebellar and motor improvements, such as in postural stability, but extended to cognitive and fluency skills, as well as to phonological and literacy skills, including reading. The present findings are also in line with Gallant and Nicolson's (2017) study, which reported the benefits of the Zing intervention in older adults in a range of skills, including balance, coordination, and declarative memory.

Comparing after-intervention with before-intervention performance for the Zing group, the participants – as a group and as individuals – improved their performance on most measures except Writing, Spelling, and RAN. Their performance improved significantly on all 5 key tasks chosen to cover the 'whole person' range of academic, cognitive, physical, and affective status. By contrast there were no such benefits for the control group. There was also evidence of a progressive effect, with the dyslexic group improving more than the non-dyslexic group on three measures, namely Rapid Naming, Verbal Fluency, and State anxiety.

It is important to consider more specific possible benefits attributable to the type of the intervention. As noted earlier, the Zing intervention is a variant of coordinative activity involving a distinctive 'cerebellar challenge' component via vestibular exercises. The coordinative challenge literature highlights the benefits to the hippocampus and hippocampal circuitry. These circuits underpin declarative learning and memory, and therefore the improvements in the school-critical ability to retain information over 20 minutes (Delayed Picture Recall) and the ability to extract detail from complex information (Declarative Memory) are therefore as predicted. It was also predicted the balance exercises would lead to improved balance performance, as reflected by the great improvement in Postural Stability. However, it is also important to note that the postural stability test is completely different from the Zing activities, requiring the participant to adjust rapidly to a push in the back, and good performance therefore requires rapid adjustment to proprioceptive feedback, a specific function of the cerebellum (Doyon et al., 2003).

9.7 Limitations

The following limitations should be acknowledged in the present study. First, the number of participants was not large, and therefore the study was not able to address the underlying causes with certainty. Second, there were no follow up evaluations to assess the continuing effectiveness of the intervention. Third, the control group did not participate in any active intervention, which would allow more direct interpretation of the intervention group results, however it should be stressed that the current 'quasi experimental design' gave a direct assessment of the benefits that the Zing intervention gave compared to the control group. These concerns highlight the need for further research to fully investigate the effectiveness of this type of intervention. Nonetheless, there were mitigating factors, such as assignment to the intervention group was random, and there was no participant drop out during the study period, and therefore no possibility of selective withdrawal. Although the intervention itself was considerably shorter and less intense (30 minutes on three days per week for 8 weeks) than recommended by the Zing Performance team (10 minutes, twice daily for 6 months), it was quite practicable within the school environment.

9.8 Conclusion

In summary, it can be concluded that the results of the present study suggest that a cerebellar based intervention was proved effective for motor and cognitive performance in adolescents. The intervention group did not only improve on motor tasks, including balance, but also on hippocampal, declarative learning tasks. The intervention group was benefited from the Zing intervention on most of the motor, cognitive, executive function, and working memory tests, as well as on trait anxiety, which could potentially suggest that the benefits of the Zing intervention can lead to emotional and affective processing improvements, as well as in general well-being. The results suggest that the benefits of the Zing training were not limited to cerebellar and motor performance, but also transferred to cognitive, memory, fluency, and reading skills.

Chapter 10

General Discussion

This chapter provides an overview of the main findings of the empirical studies conducted in the present doctoral thesis. The chapter also considers the importance of the findings and their contribution to the existing dyslexia literature. The theoretical and practical implications of the findings are discussed, and directions for further research.

10.1 Summary of findings

The aim of this thesis was twofold. First, to explore the impact of psychological disorders, on well-being and cognitive function of adolescents and university students with dyslexia. Second, to evaluate the effectiveness of two psycho-educational interventions, namely a mindfulness-based, and an internet-based 'cerebellar challenge' intervention on adolescents with anxiety, including those with dyslexia. Five empirical studies were conducted. Study 1 (chapter 5) investigated the impact of mental health problems on university undergraduate and post-graduate students with and without dyslexia. Study 2 (chapter 6) focused on the impact of psycho-emotional problems on adolescents with and without dyslexia. Study 3 (chapter 7) evaluated a mindfulness-based intervention on the psychological wellbeing, and cognitive function of the adolescents who participated in Study 2. Study 4 (chapter 8) explored the performance of dyslexic and non-dyslexic adolescents on cognitive and motor tasks, and the association between stress and performance. Study 5 (chapter 9) evaluated the effectiveness of an internet-based 'cerebellar challenge' intervention on the adolescents who participated in Study 4. The main findings of the empirical studies will be presented in relation to the main hypothesis reported in Chapter 4 (see section 4.1).

Study 1 investigated mental health problems in university students with and without dyslexia. The main focus of the study was on the different aspects of anxiety; namely, on social, academic and test anxiety, in tandem with depression and self-esteem symptoms. Overall, considering the three anxiety measures, the dyslexic students had higher self-ratings on all three measures. The results showed that anxiety extends to other areas beyond academic and testing situations in university students, such as in social life. As a group, the dyslexic students also showed higher risk of low self-esteem and depression compared to typically achieving students. Additional results that emerged from Study 1 did not show differences between the undergraduate and postgraduate students on most of the measures. The two groups differed in academic anxiety and test anxiety, with the undergraduates scoring higher in academic anxiety, and the postgraduates scoring higher in test anxiety. Study 1 also investigated gender differences in mental health problems. Although the results showed that female scores from both groups (dyslexic and non-dyslexic) were higher on all three anxiety measures, and on depression, compared to males, significant gender differences were only identified in the dyslexic group. Males from both groups showed higher self-esteem compared to females.

Study 2 explored the internalising problems of adolescents aged 14 and 15 years with and without dyslexia. Study 2 focused on different aspects of anxiety; in particular, on state, trait, and test anxiety, along with low self-esteem. Students with dyslexia showed higher levels of general anxiety, as in the state and trait domains of anxiety, as well as in academic aspects of anxiety, such as in test anxiety. The results also indicated that along with high levels of anxiety, the dyslexic adolescents reported lower self-esteem compared to typically achieving peers. Gender differences were not identified in Study 2, but negative correlations between higher anxiety and lower self-esteem were found for girls only.

Study 3 tested whether an 8-week mindfulness practice would have a positive effect on psychological well-being and cognitive performance of adolescents with and without dyslexia. There were significant improvements for the intervention group on post-test measures of state anxiety, trait anxiety, and test anxiety, compared to the control group which did not show improvements. Positive effects of mindfulness practice were also reported for self-esteem and mindfulness skills in the intervention group at post-test. Reliable improvements were also found for the mindfulness group on cognitive performance at post-test, namely on verbal fluency and backwards digit span tasks. Results from psychological well-being and cognitive performance measures showed stability across time (post-test and follow-up). Medium effect sizes were also found for the psychological and cognitive measures from pre-test to follow-up for the intervention group. Concerning differences between the dyslexic and non-dyslexic adolescents in the intervention group, no differences were found in terms of improvements in psychological well-being and cognitive performance. That means that the dyslexic adolescents scored lower on anxiety and higher on cognitive performance, after practicing mindfulness, similar to the non-dyslexic group. The dyslexic and non-dyslexic group, however, differed in self-esteem scores post-intervention, as only the non-dyslexic group had improved self-esteem after the mindfulness training.

Study 4 explored the performance of dyslexic and non-dyslexic adolescents on a number of literacy, memory, and motor function tasks. Memory tasks focused on declarative and procedural memory systems, based on the Procedural Learning Deficit Hypothesis of dyslexia. Study 4 also assessed the association between stress, cognitive, and motor function, and whether stress has a negative impact on students' performance. The dyslexic adolescents performed less well on almost all the DST-S tasks, particularly on literacy, working memory, and motor function tasks. Furthermore, declarative, and procedural memory performance was slower and less accurate compared to the non-dyslexic group. Overall, the non-dyslexic adolescents showed below average performance in some of the literacy and cognitive tasks but were still better than the dyslexic adolescents' performance. The dyslexic group scored higher on the anxiety measures than did the non-dyslexic group. The results showed that stress was not associated with performance on most tasks, however, the lack of association between stress and below average performance does not prove the lack of causation.

Study 5 evaluated the effectiveness of the Zing intervention, a cerebellar-based intervention, on motor and cognitive function in adolescents with and without dyslexia. The results showed that the Zing intervention led to benefits on cognitive and motor function in adolescents with and without dyslexia who were at risk from dropping out of school. Improvements were found in the intervention group post-intervention, not only on motor tasks, such as on postural stability, but also on other skills such as cognitive and executive function skills including verbal working memory, as well as declarative and procedural memory. The benefits of the Zing intervention also transferred to emotional and affective processing, as in reduced trait anxiety levels. Medium effect sizes between pre- and post-intervention were found for tasks in the intervention group, such as for motor, reading, fluency, and verbal working memory tasks. In terms of differences between the dyslexic and non-dyslexic adolescents in the intervention group, the benefits of Zing intervention were very similar for both groups, except for Rapid Naming, Verbal fluency, and State anxiety, in which tasks the dyslexic group showed greater improvements compared to the non-dyslexic group.

10.2 The relation of the current findings to the overall hypotheses

The results of the current research are presented in this section in terms of the three main hypotheses presented in the Introduction.

Hypothesis 1: It was predicted that the dyslexic participants would show higher levels of internalising problems compared to the non-dyslexic participants.

Based on previous literature (Casey et al., 1992; Gregg et al., 1992; Hoy et al., 1997; Riddick et al., 1999; Willcutt & Pennington, 2000; Humphrey, 2002; McNulty, 2003; Carroll & Iles, 2006; Baker & Ireland, 2007; Terras et al., 2009; Boyes et al., 2016; Livingston et al., 2018) it was predicted that the dyslexic participants of this research would score higher on psychological measures, including general and specific domains of anxiety, and depression, and lower on emotional state measures, including self-esteem, compared to non-dyslexic participants.

The results showed significant differences between the dyslexic and non-dyslexic groups of adolescents and young adults (university students) in terms of psychological and emotional problems. The results supported Hypothesis 1, as the dyslexic groups, both adolescents and young adults, scored higher on measures of anxiety, and lower on measures of self-esteem. In particular, the university students with dyslexia had higher anxiety related to academic as well as social situations. Exams and test taking situations are an important source of academic anxiety at university, and academic anxiety is probably more exacerbated for students with dyslexia, as was supported by the results of the present research. Depression was another factor contributing to the low psychological well-being of university students with dyslexia, who showed higher levels of depression than did their non-dyslexic peers. Other researchers have reported positive correlations between depression and specific learning difficulties (Heath, 1995; Dalley et al., 1992) which can lead to impaired information processing (Hubbard et al., 2016; Lau & Waters, 2017; Schweizer et al., 2019), a necessary academic skill.

High scores for anxiety were also found in the group of adolescents with dyslexia, particularly on the general measures of anxiety, including state and trait anxiety, as well as on the specific domain of test anxiety. Test anxiety is a major source of anxiety at school, and previous researchers have reported that around 20% of students who suffer with test anxiety drop out of school because of low self-esteem related to repeated academic failures (Wachelka & Katz, 1999). Anxiety disorders in adolescence are a risk factor for mental health problems in adulthood (Van Ameringen et al., 2014; Krohne & Hock, 2011; Clark et al., 2007). The emotional state of adolescents and young adults was tested with a self-esteem measure, in which both dyslexic groups showed lower levels of self-esteem compared to their non-dyslexic peers. Low self-esteem is a risk factor for psychological problems (Beck et al., 2001; Millings et al., 2012) and students with dyslexia leave school at higher rates because of low self-esteem and negative school experiences (Alexander-Passe, 2015). Findings from Study 1 and Study 2 showed that anxiety disorders are evident from adolescence, particularly in students with dyslexia, to young adulthood, particularly in dyslexic students who continue to university.

Hypothesis 2: It was predicted that there would be an association between anxiety and cognitive performance.

Based on previous research (Ribary, 2007; Kempe et al., 2011; Lukasik et al., 2019; Habib & Naz, 2015) it was predicted that there would be a negative correlation between higher anxiety and lower cognitive performance in adolescents, particularly in those with dyslexia.

The present research showed that although the dyslexic adolescents had higher anxiety levels than the non-dyslexic adolescents, the prediction about the association between anxiety and cognitive performance was not supported. The dyslexic group performed worse on cognitive function measures, particularly on verbal working memory, declarative, and procedural memory, as well as on motor tasks, including postural stability, as compared to their non-dyslexic peers. Although the results showed that their impaired performance was not associated with their anxiety levels, this could mean that dyslexic performance is poor under normal conditions, and thus it is further impacted by added stress.

Hypothesis 3: It was predicted that psychoeducational interventions would have a positive effect on anxiety disorders and cognitive performance of adolescents.

Two psychoeducational interventions were implemented in the present research, namely a mindfulness-based and a cerebellar-based practice, which both aimed to alleviate symptoms of anxiety and enhance cognitive performance in adolescents at risk of dropping out from school. The results showed that both interventions had a positive impact on the psychological well-being and cognitive capacity of adolescents, which supported Hypothesis 3. Results from the mindfulness intervention indicated that anxiety was reduced, and self-esteem was improved at post-test in the intervention group. In addition, mindfulness practice had a positive impact on cognitive performance, as the intervention group improved on verbal working memory and executive function measures post-intervention. As for the effects of mindfulness practice on dyslexic and non-dyslexic adolescents, there were no substantial differences between the two groups, suggesting that dyslexic students can benefit, as well as non-dyslexic students, from a mindfulness-based practice on both cognitive function and psychological well-being.

Similar to the mindfulness intervention, the Zing intervention had a positive impact on cognitive performance and affective processing in adolescents; a finding which also supported Hypothesis 3. In particular, the intervention group improved their cognitive and motor performance, and decreased their anxiety levels at post-test. The benefits of the Zing training were similar for both the dyslexic and non-dyslexic group, suggesting that dyslexic students can also benefit from an intervention focusing on enhancing cognitive capacity and reducing anxiety symptoms for an optimal cognitive performance.

10.3 Contribution to the existing literature

This thesis aimed to fill a gap in the existing literature about the emotional and psychological problems among adolescents and young adults with dyslexia compared to typically achieving peers. The thesis highlighted the importance of early assessment and identification, and early intervention for psychological problems in adolescents with dyslexia. The results contribute to the limited literature about the secondary, psychological effects, of dyslexia in university students. The thesis also highlighted the psychological effects of dyslexia on both cognitive function and psychological well-being for adolescents with dyslexia. Throughout all the studies, the dyslexic groups showed exceptionally high levels of anxiety, in both general and specific domains of anxiety, and low self-esteem compared to non-dyslexic groups.

Study 1 identified the high prevalence of mental health problems in students with dyslexia in higher education. An important aspect of Study 1 was the inclusion of different domains of anxiety assessing academic, social, and test anxiety levels. There were no previous studies that assessed anxiety in dyslexic students and included all the three measures of anxiety as in the present study. The results indicated that the students with dyslexia in higher education have exceptionally high anxiety, which is not restricted to academic stresses only but also extends to social situations, a finding which is consistent with that of other studies (Carroll & Iles, 2006; Riddick et al., 1999; Jordan et al., 2014). Topham and Russell (2012) have found that social anxiety affected students' performance not only in social situations, but also in academic situations (Topham & Russell, 2012). Similarly, Carroll and Iles (2006) have found that social situations are part of the academic life of university students, therefore their course mates can also be part of their social, non-academic, life. An important contribution was the inclusion of the test anxiety measure in Study 1. Test anxiety has not previously been studied in UK higher education students with dyslexia. The results of Study 1 showed that test anxiety was a significant source of academic anxiety for students with dyslexia, which is consistent with previous work showing high levels of test anxiety in typically achieving students (Putwain, 2007). In addition, previous researchers have found that test anxiety is related to academic performance (Aysan, et al., 2001; Cohen et al., 2008). Test anxiety is a significant source of anxiety for students, as it can have negative effects on students' cognitive and academic performance, as well as on academic testing (Nelson, Lindstrom & Foels, 2015), particularly for those students with low academic self-concept (Hill, 1996).

Study 1 supported most of previous studies which identified anxiety disorders (Carroll & Iles, 2006; Riddick et al., 1999; Jordan et al., 2014; Gaudry & Spielberger, 1971; Nelson & Hartwood, 2011) and psychoemotional disorders, such as depression (Scott, 2004; Wilson, et al., 2009; Gregg et al., 1992; Riddick et al., 1999) and self-esteem (Ghisi et al., 2016; Alexander-Passe, 2006) in young adult dyslexic students. Previous researchers (Kean & Loades, 2017; Nguyen et al., 2019) have suggested that self-esteem and self-confidence problems can arise with concurrent anxiety or depressive symptoms. Alexander-Passe (2006) found that self-esteem can be affected by academic difficulties, but also by negative and stressful experiences from earlier life which continue to have a negative impact later in life. However, a difference between Study 1 and previous studies (mentioned above) is that most of previous studies did not assess anxiety along with measures of depression and/or self-esteem. Overall, the findings of Study 1 identified the psychological profile of students with dyslexia at university, which makes a contribution because Study 1 included a number of psychological and emotional measures. Study 1 also included both undergraduate and postgraduate students, while previous researchers (Carroll & Iles, 2006; Riddick et al., 1999; Jordan et al., 2014) have focused only on undergraduate students with dyslexia. The importance of including both undergraduate and postgraduate students in Study 1 was evidenced by the differences between the groups in anxiety levels, as well by the differences between the dyslexic and non-dyslexic students.

Previous researchers have investigated dyslexia in adolescence and its association with anxiety disorders (Carroll et al, 2005; Jordan & Dyer, 2017; Boyes et al., 2019; Arnold et al., 2005; Mugnaini et al., 2009) and low self-esteem (Humphrey, 2002; Elbaum & Vaugh, 2002). Study 2 showed that dyslexia contributed to higher levels of anxiety in secondary school students. A contribution of Study 2 was that different domains of anxiety were assessed in Study 2, including state, trait, and test anxiety, which contributed to the overall profile of anxiety disorders in adolescence. Study 2 identified a number of anxiety symptoms, which are not only about general anxiety, but are also extended to specific domains of anxiety, such as test anxiety. Test anxiety has rarely been considered in previous research (Lufi et al., 2004; Swanson et al., 1996), especially in adolescents with dyslexia. Cassady and Johnson (2002) found positive correlations between specific learning difficulties, anxiety, and physiological and cognitive reactions. Lancaster et al. (2001) also reported that the greatest difficulties encountered by students with specific learning difficulties in school concerned testing situations and exams. The findings of Study 2 supported previous research in anxiety and emotional disorders in adolescence, and research into self-esteem (Huntington & Bender, 2003; Carroll & Iles, 2006; Cassady & Johnson, 2002). Most of previous research has investigated global self-esteem. Study 2 explored specific domains of self-esteem using Battle’s self-esteem inventory (CFSEI-3, 2002) including domains of academic, general, parental, personal, and social self-esteem. The results of Study 2 showed that the adolescents with dyslexia not only had low self-esteem in general situations, but also in academic situations and in the home/family environment. Eissa (2010) reported that dyslexic students may have low self-esteem in academic situations because of repeated school failures, and less academic success compared to their normally achieving peers. Similar results were reported by Alexander-Passe (2006) who found low levels in different domains of self-esteem including Global self-esteem, Academic, and Parental/Home self-esteem. Therefore, adolescents with dyslexia show lower self-esteem in school situations, as well as in the general and family environment.

Previous research has identified gender differences in anxiety and emotional disorders (Zahn-Waxler et al., 2008; Levinsohn et al., 1998; Merikangas et al., 2010; Willcutt & Pennington, 2000), with females experiencing anxiety disorders more frequently than males. Although Study 1 supported such previous studies, as the dyslexic females of Study 1 reported considerably higher levels of anxiety and depression than did the males, there was a lack of an association between gender, anxiety, and self-esteem both in adolescents and in higher education students; a finding which is not in line with previous research. Although previous research has suggested that males and females use different coping strategies to respond to stressful situations (Endler & Parker, 1990), such differences in coping styles might have not been developed yet in adolescents. Nonetheless, it is important to investigate and identify gender differences in early years, as this would enable schools, educational psychologists, and educational practitioners to provide the appropriate interventions for boys and girls, depending on their needs.

The findings of Study 2 follow a similar pattern of results to those found in Study 1. The present research showed that anxiety disorders frequently occur in adolescents with dyslexia and continue to early adulthood. The current thesis has put forward the argument of early identification and intervention for anxiety disorders in adolescents. Early diagnosis and early interventions for anxiety and emotional difficulties is of importance in adolescence, as untreated anxiety problems can result in mental health problems in adulthood (Cicchetti, 1998), as was evidenced in Study 1.

Based on the findings of Study 2, Study 3 evaluated the effectiveness of a mindfulness-based practice not only on psychological well-being, but also on cognitive function. Previous researchers (Sanger & Dorjee, 2015; Sanger et al., 2016; Pepping et al., 2016; Zenner et al., 2014; Johnson et al., 2017) have found that schools have started using mindfulness training to improve the psychological well-being of students. An important aspect of Study 3 was the inclusion of dyslexic adolescents in the intervention, because there has been no previous research into the effects of mindfulness on the cognitive ability and psychological well-being of dyslexic adolescents. Furthermore, previous research (Alexander-Passe, 2006; Elbaum & Vaughn, 2001; Humphrey, 2002) has established that low self-esteem has a negative impact on adolescents, which can lead to negative experiences throughout life.

Study 3 showed that schools can be an ideal place for implementing interventions in groups of students, as evidenced by other researchers (Emerson et al., 2017a; Pepping et al., 2016). Although improvements after mindfulness practice were noted for all the adolescents in anxiety, self-esteem, and cognitive performance, the benefits of mindfulness were particularly important for the dyslexic adolescents for skills which are mostly impaired in dyslexic individuals, such as for attention, working memory, and fluency. As McNulty (2003) suggested, the most successful way to help dyslexic individuals is to offer treatment for both academic difficulties and psychological problems. Overall, Study 3 showed the effectiveness of positive education and positive psychology interventions on well-being and academic performance of adolescents (Seligman et al., 2009; Norrish et al., 2013) including those with dyslexia. By taking part in a positive psychology intervention, the participants were able to identify their strengths and positive emotions and use them in the intervention. Positive education programmes promote an education that supports the development of life skills and well-being (Schiavon et al., 2020; Norrish et al., 2013). If positive education becomes part of the general education and the school curriculum, then it can help students flourish and learn the appropriate skills needed to succeed in society; skills that are not limited to academic life but extend to positive psychological well-being (Seligman et al., 2009; Duan, Chen, & Ho, 2020).

Study 4 investigated the performance of dyslexic and non-dyslexic adolescents on procedural and declarative memory tasks, as well as on motor tasks. Study 4 also investigated the impact of anxiety on cognitive and motor function. Based on the Procedural Learning Deficit Hypothesis (PLDH) (Nicolson & Fawcett, 2007) individuals with dyslexia have impaired procedural memory, while the declarative memory remains intact. The PLDH also suggests a motor function deficit in individuals with dyslexia due to skill automatization deficits (Nicolson & Fawcett, 1990). Previous research (Nicolson et al., 2010, Nicolson & Fawcett, 2018; Brookes et al., 2007) has found that students with dyslexia had impaired performance in procedural learning and motor tasks, such as in balance and postural stability (Nicolson et al., 1995; Fawcett et al., 1996; Fawcett & Nicolson, 1999; Finch et al., 2002). The findings of Study 4 provided evidence for both the PLDH and the ADH, as the dyslexic group performed worse on the procedural learning tasks (Motor Sequence and Word Identification task), and the motor function tasks (Postural stability and Bead threading). Previous researchers have suggested that cognitive and motor function is impaired under stress (Sandi, 2013; McEwen, 1998; Bremner & Vermetten, 2001; Bierzynska et al., 2016). However, the findings of Study 4 did not indicate an association between anxiety and cognitive performance in adolescents (with or without dyslexia), possibly because of the lack of exposure to a stressful condition and the lack of physiological measures. According to Schwabe et al. (2009; 2012), the procedural system is not affected by stress, although stress has damaging effects on memory systems. The finding from Study 4, that there was no association between anxiety and procedural memory, also supported the results from Schwabe's et al. (2009; 2012) studies.

Although an association between anxiety and cognitive performance was not found in Study 4, the dyslexic group scored higher in state and trait anxiety than did the non-dyslexic group. The finding is in line with a number of previous studies which reported considerably higher anxiety in students with dyslexia compared to those without dyslexia (Carroll & Iles, 2006;

Riddick et al., 1999; Jordan et al., 2014; Arnold et al., 2005). A contribution of Study 4 to the existing literature is the concomitant investigation of procedural and declarative memory function in dyslexic students, as previous researchers have mostly explored the two memory systems independently in dyslexic individuals. In addition, Study 4 put forward the argument that appropriate conditions and measures are needed to explore cognitive performance under actual stress.

After identifying impaired cognitive and motor performance, along with impaired affective processing in the dyslexic students of Study 4, Study 5 evaluated the effectiveness of a novel internet-based 'cerebellar challenge' intervention, called the Zing intervention on adolescents (Gallant & Nicolson, 2017). The Zing intervention was designed to stimulate the cerebellum and enhance performance in sensorimotor coordination, dual tasking, balance, and cognitive processing. The main idea of Zing was that when the cerebellum becomes fully functional, learning becomes simpler, cognitive skills improve, and emotional wellbeing increases (Dore, 2019). Most of dyslexia research has focused on literacy related interventions (Lynch et al., 2000; Aryan van der Leij, 2013; Torgesen et al., 2009; Lyytinen et al., 2007), thus the Zing intervention was a new contribution as previous studies have not tested a similar intervention with students with dyslexia. The importance of Zing was evidenced by the positive effects in three functional dimensions, including physical wellbeing, cognitive wellbeing, and affective wellbeing in students' performance. In Study 5 the intervention group improved on measures of balance and bead threading, including students with dyslexia, who had below average performance preintervention. The intervention group also improved on measures of declarative memory and verbal working memory, which are critical skills for school performance as well as improved on measures of motor function. The adolescents also showed high levels of anxiety, with those with dyslexia showing higher overall levels, which were reduced by the Zing training. Overall, the benefits of the Zing intervention were not limited to cerebellar and motor performance but were also transferred to cognitive function, memory ability, reading skills, and affective processing. The results of Study 5 could suggest that the benefits of the Zing intervention can lead to emotional and affective processing improvements, as well as improvements in general well-being. The benefits of the Zing training on the hippocampus and hippocampal circuitry contribute to the significance of Study 4. These circuits underpin declarative learning and declarative memory, which are significant skills for the school-critical ability to retain information for a long time, and the ability to extract detail from complex information.

10.4 Limitations of the present research

The limitations of each separate study have been addressed in the related chapters. This section presents more general limitations of the research undertaken in the present thesis.

One limitation was the use of self-report measures to assess anxiety and emotional disorders which are considered to be less reliable than having professional assessment. Previous research suggests that a combination of psychological and physiological assessments are the most appropriate tools in psychological research (Leckman et al., 1982).

The representativeness of the samples of adolescents in Study 2 and Study 4 was a limitation. Although most of the results were significant in both studies, the findings of the studies should be interpreted with caution due to the small sample size.

10.5 Theoretical implications

Research on developmental dyslexia has an impact on both theory and practice (Frith, 1999). The present thesis identified a number of both theoretical and practical implications. In terms of theoretical implications, one of the most debatable topics in the dyslexia literature is the definition of developmental dyslexia. Despite many years of research, there is still disagreement on the most appropriate definition of dyslexia (Fletcher, 2009; Fisher & DeFries, 2002). According to Tunmer and Greaney (2010), a holistic definition of dyslexia should include four components, such as long-lasting specific learning difficulties, exclusionary criteria, inclusionary criteria, and provision for instruction and intervention. Despite these characteristics, a theoretical implication emerging from the current definitions is that none of these definitions encompasses secondary symptoms of dyslexia, such as anxiety and mental health problems, which were found to be important from the findings of the current thesis, for the better understanding of the dyslexia disorder.

Morton and Frith (1995) suggested a three-level causal framework for the theoretical explanations of dyslexia, including the biological, cognitive, and behavioural levels. Although the three levels of explanation contribute to the better understanding of dyslexia, there is disagreement over which theory of dyslexia, associated with each of these levels, provides a thorough explanation of dyslexia which can lead to theoretical implications. The phonological deficit theory, which is associated with the cognitive level, is the most accepted theory of dyslexia, because of the causal role of phonology with dyslexia (Vellutino, 1979; Snowling, 1987; Stanovich, 1988). However, the phonological deficit theory does not provide an explanation for the underlying causes of dyslexia, particularly for sensory and motor disorders (Ramus et al., 2003).

The automatization deficit theory (Nicolson & Fawcett, 1990), which is also associated with the cognitive level, suggests that children with dyslexia struggle to learn skills at the point that they become automatic and fluent. An automatization deficit would therefore affect the acquisition of graphene-phoneme correspondence (Ramus et al., 2003). The automatization deficit theory is supported by the cerebellar deficit theory (Nicolson et al., 2001), which is associated with the biological level. The cerebellar deficit theory claims that individuals with dyslexia have a cerebellar impairment that affects the acquisition and execution of motor and cognitive skills. The automaticity and cerebellar theories accept the phonological deficits in dyslexia and provide an explanation for the underlying causes of dyslexia, which lies in cerebellar and motor dysfunction. But these theories have been criticized due to inconsistent results that were found in previous studies (Wimmer et al., 1999; Ramus et al., 2003). For instance, some studies have not found any association, whilst other studies have found motor impairments only in subgroups of dyslexic individuals, who had comorbidity with ADHD. The procedural learning deficit hypothesis (PLDH) provides a more general explanation of dyslexia, on the neural systems level, which associates brain function to cognitive function. The PLDH along with the cerebellar deficit theory provide an explanation of the underlying causes of dyslexia (Nicolson & Fawcett, 2008).

According to Ramus et al. (2003), there is a lack of a unified theory that can account for all the manifestations of dyslexia. Morton and Frith (1995) claimed that none of the levels or theories of dyslexia are better than the others and emphasised the importance of the theoretical explanations to not be restricted to one level or the other, but to be linked together to provide a thorough understanding of the dyslexia disorder. According to Frith (1999), the behavioural manifestations of dyslexia should be linked to biological, genetic, and cognitive deficits, as they are caused by the interaction of different factors. Although previous researchers (Ramus et al., 2003; Morton & Frith, 1995) claimed that none of the theories of dyslexia can provide a holistic approach to the causes of dyslexia, the cerebellar deficit theory (Nicolson et al., 2001) could possibly provide a causal explanation for dyslexia, as clinical and theoretical evidence has showed that phonological and memory impairments are consistent with a cerebellar deficit. The dyslexia related difficulties are not confined to reading and spelling difficulties only but extend to motor difficulties that are associated with cerebellar deficit (Nicolson et al., 2001).

In addition, the Automatization Deficit Hypothesis (Nicolson & Fawcett, 1990) can explain the core phonological and literacy deficits in terms of poor automatization skills of dyslexic individuals (Nicolson & Fawcett, 2005). The Procedural Learning Deficit theory (Nicolson & Fawcett, 2007) may also account for the impaired automatization skills in learning, not only related to motor but also to phonological and reading skills, in individuals with dyslexia. Evidence suggests that the cognitive-level and the neural-level symptoms of dyslexia are caused by abnormal cerebellar function (Nicolson & Fawcett, 1990; 2005; 2007), since the cerebellum is involved in learning, in language-related skills, and in the proceduralization of cognitive and motor skills (Leiner et al., 1989). Therefore, the automatization, the cerebellar and the procedural learning deficit framework can explain the phonological, motor, and automatization deficits of dyslexia, and provide a unified approach to the underlying causes of developmental dyslexia.

The comorbidity between developmental disorders causes difficulties in the diagnosis of dyslexia, which leads to theoretical implications in dyslexia research (Frith, 1999; Nicolson & Fawcett, 2008). Since many symptoms of dyslexia co-occur, it is not possible to diagnose dyslexia as a single disorder without considering comorbidity with other developmental disorders such as ADHD, Specific Language Impairment (SLI), and Developmental Coordination Disorder (DCD) (Mc Arthur et al., 2000; Boada et al., 2012; Peterson & Pennington, 2012). In particular, the discrepancy-based diagnosis has been criticized the most in dyslexia due to inadequate psychometric intelligence tests, and due to inadequate separation of poor readers who perform below average on reading tasks but are not classified as reading disabled (Siegel, 1989; Shaywitz & Shaywitz, 2003). Miles (1995) also suggested that the diagnosis of dyslexia should not only include an assessment of reading and writing difficulties, but also a neuropsychological assessment.

10.6 Practical implications

The findings of this thesis have educational and clinical implications, as dyslexia has long-term effects on the psychological and emotional well-being of students (McNulty, 2003; Arnold et al., 2005; Carroll et al, 2005; Jordan & Dyer, 2017; Ingesson, 2007). Students with dyslexia are considered as an at-risk population for developing psychological problems (Arnold et al., 2005; Mugnaini et al., 2009; Carroll & Iles, 2006; Alexander-Passe, 2015). The heightened risk of mental health problems in students with dyslexia (Boetsch et al., 1996; Scorza et al., 2018; Novita, 2016) emphasizes the need for early identification and intervention from schools, practitioners, and universities. Late diagnosis and late intervention can lead to long-lasting negative effects on self-esteem, self-confidence, and academic success in students with dyslexia (Angold et al., 1999).

Previous researchers (Spreen, 1989; Boetsch et al., 1996; Carroll & Iles, 2006; Heiman & Precel, 2003; Nelson et al., 2015; Jordan & Dyer, 2017; Arnold et al., 2005) have suggested that mental health problems are a consequence of learning and reading difficulties, therefore, the educational psychologists and school practitioners who are responsible for the identification and diagnosis of specific learning difficulties should consider the inclusion of mental health measures in the diagnostic process, to identify co-existing psychological problems (Boyes et al., 2016). This practice could lead to academic and psychological benefits for children and adolescents with dyslexia (Jordan & Dyer, 2017).

An integrated approach of supporting students with dyslexia and psychological problems would be to provide multicomponent interventions and remediation programmes for concurrent reading and psychological problems (Terras et al., 2009). Such an approach is supported by the Positive Education paradigm (Seligman et al., 2009) which helps students develop both academic and positive psychological well-being skills (Norrish et al., 2013; Duan et al., 2020). An integrated approach could help students with dyslexia enhance their learning potential and achieve academic success and personal growth (Policy Research Unit Children and Families, 2020). School administrators should consider incorporating mindfulness-based practices, which improve psychological well-being and cognitive performance, within the school environment or the classroom schedule, by training and supporting staff to implement such interventions (Emerson et al., 2017a; Pepping et al., 2016; Zenner et al., 2014; Johnson et al., 2017).

The evidence supports an association between dyslexia and the cerebellar/vestibular system (Frank & Lewison, 1973; Nicolson et al., 1999; Nicolson et al., 2001; Pope & Whiteley, 2010). Symptoms of dyslexia, such as impaired balance and postural stability, may be due to a cerebellar and vestibular disorder (Nicolson et al., 1999). As was discussed previously (Nicolson & Fawcett, 2001; 2004), the cerebellum is involved in cognitive and motor function, and therefore, physical exercise and cerebellar challenge interventions may help ameliorate the dyslexia difficulties by controlling the vestibular input to the cerebellar system (Pope & Whiteley, 2010; Gallant & Nicolson, 2017). The cerebellar deficit theory, together with interventions stimulating the cerebellar/vestibular system, may constitute an integrated theory of the whole picture of dyslexia. Assessment and a holistic approach to support dyslexia related symptoms are of importance in dyslexia research.

The findings from this thesis also have implications for universities. It is important that universities work in collaboration with dyslexia tutors and counselling services to provide a holistic approach to dyslexia-related difficulties and concurrent mental health problems. The provision of remediation and intervention programmes for the psychological well-being of students should be of importance in universities. Receiving the appropriate psychological support at university, which can cause elevated levels of stress and anxiety in all students but even more to students with dyslexia, can help students reach their potential and have a successful academic life. Above all, remedial practices should start from school settings and continue to university settings.

10.7 Directions for future research

Throughout this thesis, it has been highlighted that research into mental health problems and remediation programmes of adolescents and university students with dyslexia has been limited. Early identification, assessment, and early interventions are crucial, as undiagnosed, and untreated psychological problems can lead to severe and chronic mental health problems (Carawan et al., 2015).

Future researchers could include primary school children in the sample which would provide a complete approach to the identification of mental health problems in individuals with dyslexia from childhood to adolescence and to young adulthood. Mental health problems have different manifestations at each developmental stage, and therefore, the inclusion of primary school children might have provided a better understanding of psychological symptoms of dyslexia and strengthen the results of the present thesis. The inclusion of primary school children would particularly allow to investigate the residue of stress and anxiety from childhood to adolescence and to young adulthood. It is important to study the educational and emotional experiences of growing up with dyslexia (Ingesson, 2007; Doikou & Avlidou, 2015).

To better assess anxiety disorders in adolescence it is necessary to have reports from different informants such as from teachers, parents, and students, as well as from different measures such as self-reports, psychological assessments, physiological measures, and behavioural observations (Leckman et al., 1982). Researchers have suggested that self-report measures fail to distinguish levels of anxiety between anxious and non-anxious children, because of the comorbidity between different anxiety disorders or because of measurement difficulties (Perrin & Last, 1992). To better understand the impact of anxiety on performance, it is necessary to have the appropriate stressful conditions, along with physiological measures of anxiety (McLeod et al.,1986; Kantor et al., 2001). The inclusion of a stressful condition in the present research, such as a reading task, would have allowed a better assessment of stress and anxiety. In particular, Study 4 would have benefitted from the inclusion of a stressful condition such as the one used by Schwabe and Wolf (2012) which included a bowl of ice water (0-2°) in which participants had to put their hand in a bowl of ice before completing the cognitive tasks. This provoked a temporary level of physiological and psychological stress.

10.8 Conclusion

The findings indicate that mental health problems are evident in adolescence and continue to young adulthood for students with dyslexia. In particular, a residue of stress and anxiety was identified both in adolescence and young adulthood, especially in students with dyslexia. Primary consequences of dyslexia were identified in literacy and cognitive performance, particularly in memory, but also in motor performance. Secondary consequences of dyslexia were identified in heightened levels of anxiety and depression, as well as in low self-esteem and low self-confidence. Self-esteem was found as an associated factor between the relationship of dyslexia and anxiety disorders, particularly for HE students. The current thesis has highlighted the need for early identification of both dyslexia and the associated psychological problems, and early intervention programmes for academic and psychoemotional support. The findings have identified positive effects of mindfulness practice and cerebellar-based practice for psychological and emotional well-being as well as for improved cognitive performance in adolescents, including those with dyslexia. The inclusion of psychological practices and interventions is recommended in school and university settings to support and improve students' well-being. The primary and secondary symptoms of dyslexia are interrelated, and therefore multicomponent support programmes, including academic, emotional, and psychological support are important for schools and HE institutions. Positive education and Positive psychology programmes are particularly important in education, as they can help students flourish, and develop academic and life skills as well as positive emotions and well-being; all of which are necessary skills for a successful and happy life.

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