UNIVERSITY OF SOUTHAMPTON

FACULTY OF SOCIAL, HUMAN AND MATHEMATICAL SCIENCES

School of Psychology

The Impact of Small Motor Activity on Attention and Learning in Children

by

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Thesis for the degree of Doctorate in Educational Psychology

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ABSTRACT

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Research has suggested that small movements may improve attention in children by increasing arousal. However, no systematic review has examined this literature. This review aimed to conduct a broad and thorough search, combining relevant evidence in a systematic and critical way in order to establish whether small motor activity improves attention and learning in children. Fifteen studies were reviewed, relating to fidgeting, doodling, chewing gum and alternative seating. The overall evidence was inconsistent with a weighting towards positive findings; however, the insufficient quantity and quality of studies precluded any firm conclusions. A need was identified for further studies using improved designs and including measures of arousal.

The empirical study aimed to investigate links between doodling, arousal and attention in children using a robust, repeated-measures experimental design, including a measure of arousal and exploring moderating effects of other related factors. Fifty-five children (aged 9 to 10 years) individually completed tests of sustained attention (SA) and working memory (WM) under two counterbalanced conditions (doodling/control). Heart rate (HR) was measured during each test. Self-reported state anxiety and fatigue were measured as potential confounders. Self-reported attentional control (AC), trait anxiety and sleepiness were considered as potential moderators. Data were analysed using linear mixed models. Results showed that SA declined while doodling. No main effect of condition on WM was found; however, a near-significant interaction effect indicated that children who reported low AC performed better while doodling, whereas children who reported high AC performed better under the non-doodling condition. HR increased while doodling; however, changes in HR did not predict

changes in SA or WM performance. This study concluded that doodling increases arousal but cannot be recommended to improve SA. Doodling may improve WM for children who struggle with AC. Interference effects may explain the detrimental effects of doodling.

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Academic Thesis: Declaration Of Authorship

I, Helen Mary Jones, declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

The Impact of Small Motor Activity on Attention and Learning in Children

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission;

Signed: ....

Date: ....

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Definitions and Abbreviations

ACS-C – Attentional Control Scale for Children

ADHD – Attention Deficit Hyperactivity Disorder

ASD – Autism Spectrum Disorder

CAM-S – Children's Anxiety Meter – State

cgdADHD – Children Given a Diagnosis of ADHD

D – Doodling

DL-KG – Differentieller Leistungstest-Konzentration Grand Schule

DV – Dependent Variable

ESS – Epworth Sleepiness Scale

FSQ – Fatigue State Questionnaire

GGG – Get it, Got it, Go Assessment

HR – Heart Rate

IV – Independent Variable

MAP – Measures of Academic Progress

MCA – Minnesota Comprehensive Assessments

ML – Maximum Likelihood

ND – Non-doodling

RCMAS-2 – Revised Children's Manifest Anxiety Scale – 2

REML – Restricted Maximum Likelihood

SA – Sustained Attention

SCED – Single Case Experimental Design

SDQ – Strengths and Difficulties Questionnaire

Chapter 1

SEN – Special Educational Needs

SMA – Small Motor Activity

TAKS – Texas Assessment of Knowledge and Skills

TD – Typically Developing

TEA-Ch – Test of Everyday Attention – Children

WISC-IV – Weschler Intelligence Scales for Children – Fourth Edition

WM – Working Memory

Chapter 1 Does small motor activity increase attention and learning in children and young people?

1.1 Introduction

Schools are increasingly expected to meet a wide range of learning needs within mainstream settings (Armstrong, Armstrong, & Barton, 2016; UNESCO, 2005). Responsibility for the educational outcomes of all children, regardless of need, lies with class teachers (Department for Education & Health, 2015). This means that teachers increasingly need to recognise and understand the diversity in children's learning profiles and adapt their teaching to meet individual need. Moreover, they must choose approaches and strategies that are supported by evidence of effectiveness (Department for Education & Health, 2015). Research investigating methods of improving learning and achievement is, therefore, relevant and important for teachers and other educational professionals. Recently, fidget toys, such as squeeze balls, tangles and fidget spinners, have been used by many to improve attention in school but, also, banned by many as distractions (Singh, Horton, & Fuller, 2017). In order to support evidence-based decision-making about when and whether to use objects, such as fidget toys, when learning, it is important for educational professionals to have access to high quality research that evaluates their impact.

This literature review aims to provide a thorough and critical evaluation of the evidence concerning the impact of small motor activity (SMA) on attention and learning. This will assist educational professionals in their decision-making and will support researchers to progress understanding in this field.

1.1.1 Theoretical Context

Psychological research has generated a substantial literature linking exercise to improved cognitive performance in adults (e.g., Bherer, Erickson, & Liu-Ambrose, 2013) and children (e.g., Álvarez-Bueno et al., 2017; Cornelius, Fedewa, & Ahn, 2017; Hillman, Kamijo, & Scudder, 2011). The impact of small movements has, however, not received the same attention. In the context of teaching and learning, these may include meaningful gestures (e.g., pointing or using fingers to count) that are related to information to be learned or held in mind, and are associated with improved learning and cognition (e.g., Goldin-Meadow & Alibali, 2013; Goldin-Meadow & Wagner, 2005).

In contrast, small movements, or small motor activity (SMA), that have no meaning are often linked to inattention and poor learning practices. For example, research has linked fidgeting with increased mind wandering (Carriere, Seli, & Smilek, 2013; Farley, Risko, & Kingstone, 2013; Seli et al., 2014) In addition, fidgeting and squirming are symptoms of attention deficit hyperactivity disorder (ADHD; American Psychiatric Association, 2013). While the association between SMA and inattention appears robust, a hypothesis gaining increasing support suggests that SMA represents an individual's attempt to improve faltering attention (e.g., Zentall, 2006).

Optimal arousal theory, for example, proposes the existence of an optimal level of physiological arousal for cognitive performance, which can be regulated by increasing or decreasing stimulation (Hebb, 1955; Leuba, 1955). SMA is suggested to provide enough stimulation to regulate arousal and, thereby, enhance cognitive performance.

Some theorists have linked optimal arousal to sensory modulation, with sensory processing difficulties hypothesised to lead to unhelpfully high or low arousal (Dunn, 2001; Kimball, 1999; Mulligan, 2001). Other theorists have applied optimal arousal theory specifically to underpinning neuropsychological processes, arguing that adequate stimulation of the cortex is required for attentional focus (Birbaumer & Schmidt, 2003).

Chewing and doodling, as specific types of SMA, have also been considered in related theoretical frameworks. For example, some researchers propose that chewing improves cognitive function by increasing blood flow in the brain (Shinagawa et al., 2004; Takada & Miyamoto, 2004) and insulin release, leading to glucose uptake and improved cognitive function (Scholey, 2004; Stephens & Tunney, 2004). Doodling has been presented as a means through which both hemispheres of the brain are engaged (Tadayon & Afhami, 2016), as well as a method of preventing daydreaming without interfering with concentration (Andrade, 2010; Chan, 2012).

1.1.2 Arousal and Attention Difficulties

Optimal arousal theory has received particular support as an explanation for some of the difficulties and behaviours observed in people with attention difficulties. Difficulties with attention, hyperactivity and impulsivity can vary across the (non-clinical) population and, at one end of this distribution, this cluster of symptoms make up the core symptoms of a clinical diagnosis of ADHD (American Psychiatric Association, 2013).

Optimal arousal theory proposes that people with attention difficulties experience chronically low levels of arousal, causing them to engage in stimulation-seeking behaviours, such as excessive movement (Zentall & Zentall, 1983). Cortical underarousal in children given a diagnosis of ADHD (cgdADHD[1]); versus typically developing (TD) children is well documented in EEG (Dickstein et al., 2005; El-Sayed, Larsson, Persson, & Rydelius, 2002; Mann, Lubar, Zimmerman, Miller, & Muenchen, 1992) and fMRI (Castellanos et al., 1996; Rubia et al., 1999) studies. For example, El-Sayed et al. (2002) found increased slow wave (theta) and decreased fast wave (beta) cortical activity in cgdADHD compared to controls during a sustained attention task. These differences are consistently reduced or eliminated in the context of stimulant medications. For example, Clarke, Barry, Bond, Mccarthy, and Selikowitz (2002) took resting EEG readings in 50 boys given diagnoses of ADHD and 40 controls before and after a six-month stimulant medication trial. CgdADHD initially showed the increased slow wave and decreased fast wave activity typical in cgdADHD; however, following stimulant medication, EEG patterns were in line with TD controls.

The optimal arousal theory of attention difficulties has also been applied specifically to working memory (WM) processes (Rapport et al., 2008; Rapport, Chung, Shore, & Isaacs, 2001). For example, (Rapport et al., 2009) measured the movement levels of cgdADHD and TD children and found significantly higher rates of movement in both groups while completing WM tasks, compared to a low WM control condition (free use of Microsoft Paint software). The authors

[1] The term ‘children given a diagnosis of ADHD’, abbreviated cgdADHD, has been used in preference to other descriptions such as ADHD children or children with ADHD in order to capture it as a social rather than within-person construct.

interpreted this association as initial evidence of a functional relationship between WM and activity level.

The optimal arousal theory of attention is further strengthened by studies finding beneficial effects of other types of sensory stimulation on attention and learning in cgdADHD. For example, in a sample of 40 boys, Abikoff, Courtney, Szeibel and Koplewicz (1996) found a positive effect of music on maths performance for cgdADHD, but not controls. The authors suggested that salient auditory stimulation (i.e., music chosen and liked by participants) may remediate underarousal in cgdADHD and, thereby, improve performance.

Further researchers have proposed a more nuanced 'moderate brain arousal' model, liked to optimal arousal theory, in order to explain the effects of auditory stimulation in cgdADHD. Within this model, white noise is argued to improve the clarity of neural signals through stochastic resonance, a phenomenon in which a signal that is too weak to be detected can be boosted by adding random interference – which contains a wide spectrum of frequencies – to the signal (Moss, Ward, & Sannita, 2004). This confers selective benefits in individuals with the low levels of 'neural noise' (i.e., low dopamine activity) associated with attention difficulties (Helps, Bamford, Sonuga-barke, & Söderland, 2014). In support of this theory, a positive effect of white noise on cognitive task performance was found for 21 cgdADHD but a detrimental effect was found for TD children (Söderlund, Sikstrom, & Smart, 2007). Similarly, in a further study, 51 secondary school pupils were grouped according to teacher-rated attention difficulties. Pupils were asked to recall lists of 12 short verb-noun sentences (e.g. 'roll the ball') under a white noise and a no noise condition. The results showed that white noise improved performance on verbal recall tasks in children assessed as inattentive, but worsened performance in controls (Söderlund, Sikström, Loftesnes, & Sonuga-barke, 2010). Taken together these studies suggest that auditory stimulation can moderate cognitive performance, worsening performance in TD individuals but offering beneficial effects where neural activity is typically low (i.e., in attention difficulties).

1.1.3 The Wider Context of SMA Research

The impact of SMA has been explored in adult populations. Andrade (2010) asked 40 adults to listen to a mock answerphone message and remember certain details, while doodling (N = 20) or not doodling (N = 20). The doodling group performed better than controls, both in the monitoring task and on an unexpected memory test. Chan (2012) investigated the effect of doodling on visual recall in 14 participants. Participants were shown a set of images and asked to identify them from a second set presented straight afterwards. While viewing the target images, seven participants were asked to doodle. The results showed that doodlers recalled fewer images than non-doodlers. Taken together, these findings were explained in terms of competing task demands. In Chan's (2012) study, the visual task and the instruction to doodle both required visual processing resources. In contrast, in Andrade's (2010) study of auditory recall, doodling did not compete for resources within the same modality as the task (see Chan, 2012).

Several studies have investigated the effect of chewing gum on attention and learning in adults. Allen and Smith (2011) reviewed 42 papers on the effects of chewing on stress, alertness and attention in TD adult populations. They concluded that there is reasonable evidence for a positive effect of chewing on WM processes and mixed evidence for a similar effect on sustained and selective attention, but no effect on divided attention. The researchers suggested that chewing gum may improve some areas of cognitive performance through maintaining alertness. However, they state that further research, using consistent methods, is needed to identify robust effects and to understand underlying mechanisms.

In children, therapy ball use (i.e., sitting on a large, air-filled ball) has been linked to improvements in functional classroom behaviours, such as in-seat and on-task behaviour, and has increased engagement in children experiencing attention difficulties (Fedewa & Erwin, 2011) and those given a diagnosis of autism spectrum disorder (ASD; Schilling & Schwartz, 2004). The overall benefits of therapy balls are, however, unclear, with some researchers finding no effect of air cushions on in-seat or on-task behaviour (Umeda & Deitz, 2011).

Taken as a whole, the evidence above suggests that the impact of SMA is unclear. SMA may or may not help individuals to regulate arousal or improve attention and learning. It would, therefore, be helpful to gather further evidence to clarify for whom and under what conditions SMA may help or hinder performance.

1.1.4 Focus of this Review

Research to-date has started to generate evidence of a positive effect of several types of SMA on attention and learning. A number of mechanisms have been considered, most relating to arousal. The volume and quality of research is particularly strong in relation to individuals with attention difficulties. Research in this area varies widely with respect to the SMA investigated, the research design and the outcome measures. Researchers have not always made links between different areas, despite utilising the same or similar theoretical frameworks, making it difficult for researchers to develop a clear programme of investigation.

The aim of this review was to conduct a systematic search of available literature investigating the effects of SMA on attention and learning in children. Specifically, it aimed to provide a critical overview of evidence to consider the proposition that SMA has a positive impact on attention and learning in TD children and young people aged 0-18 years, as well as those individuals who are recognised as experiencing attention difficulties.

1.2 Method

1.2.1 Search Strategy

Initial search terms were taken from key terms listed on known target papers, highlighted through initial searching (e.g., Kercood & Banda, 2012; Tänzer et al., 2009). EBSCO was used as a platform for the initial exploration of search terms, as it supported two of the four databases to be searched (PsycInfo and Medline). Initial search results were inspected to ensure the presence of known target papers.

Known target papers referred to a range of different types of motor activity; therefore, specific terms (e.g. “chewing”) were used, along with the broader and more inclusive term “physical activity”. This was to ensure that relevant papers would be found even if the specific type of SMA was not predicted and specifically searched. Known target papers also used a range of ways of measuring attention and learning; therefore, broad terms were used to capture these attributes. Finally, a set of key words were used to limit the age range in a consistent way across all databases, as no age filter was available on ERIC or Web of Science. The final search terms are shown in Table 1.

Table 1.

Final Search Terms

	Term 1			Term 2			Term 3
	Learning			Physical Activity			Infants
OR	Attention		OR	Chewing		OR	Children
OR	Attention Deficit Disorder		OR	Doodl*		OR	Adolescents
OR	Memory	AND	OR	Fidget*	AND	OR	Students
OR	Cognition		OR	Movement*			
OR	Academic Achievement		OR	Exercise ball*			
			OR	Therapy ball*			
			OR	Stability ball*			

All terms available as dictionary/thesaurus terms were exploded in order to be as inclusive as possible. In Web of Science, where no dictionary was available, the additional term “attention deficit hyperactivity disorder” was used to ensure the inclusion of relevant papers. Exact searches in each database are detailed in Appendix A. Results were refined across all databases by language and type of article. Only peer-reviewed journal articles in English were included.

Due to the large number of irrelevant results in Web of Science, categories were used to exclude results addressing irrelevant topics. Categories and number of papers excluded at this stage are shown in Appendix B. All results were uploaded to Mendeley for screening (see Figure 1 for PRISMA flow diagram detailing the number of articles included and excluded at each stage). Three thousand, one hundred and twelve records were screened using titles and abstracts and 30 were screened using the full text. Nine articles remained after this process. Hand searching, including a systematic inspection of backward and forward citations, was then used to locate a further 6 relevant studies, giving a total of 15 studies.

A validity check was carried out by a research assistant, who replicated the search in one database and independently applied the inclusion and exclusion criteria to the results. Medline was selected as the database as the results constituted over a third of the total results. Four studies were allocated differently by the research assistant: two additional studies included and two of the identified studies excluded. These were discussed with close reference to the inclusion and exclusion criteria and their inclusion or exclusion agreed together, favouring the original allocation in all cases.

1.2.2 Inclusion and exclusion criteria

The following inclusion and exclusion criteria were applied to search results:

Table 2.

Inclusion and Exclusion Criteria

	Inclusion Criteria	Exclusion Criteria
Participants	• Participants aged 0-18 years.	• Participants aged 19 years and above.
Intervention	• Interventions involving small movements that can be carried out while working at a desk (e.g. fidgeting, chewing, doodling, therapy balls)	• Interventions involving exercise. • Interventions involving movement that requires moving around the room or that cannot be done while working at a desk. • Interventions involving a significant confounding variable e.g. chewing gum containing glucose.
Outcome measures	• Studies using at least one direct measure of attention or learning, including tests of attention (specific elements of attention or	• Studies measuring IQ. • Observational measures, including questionnaires.

	broader tasks whose outcomes depend on attention, e.g., maths problem solving) and tests of material that has been learned during the intervention.	
Design	• Interventions including a movement and a non-movement condition or group. • Studies in which the movement intervention occurs during the test of attention or during the learning of the material to be tested. • Studies using quantitative methodology	• Studies without an intervention. • Studies using qualitative methodology. • Studies with no control group or condition.
Study characteristics	• Studies reporting original research • Studies published in a peer reviewed journal	• Review papers, meta-analyses • Books • Unpublished theses

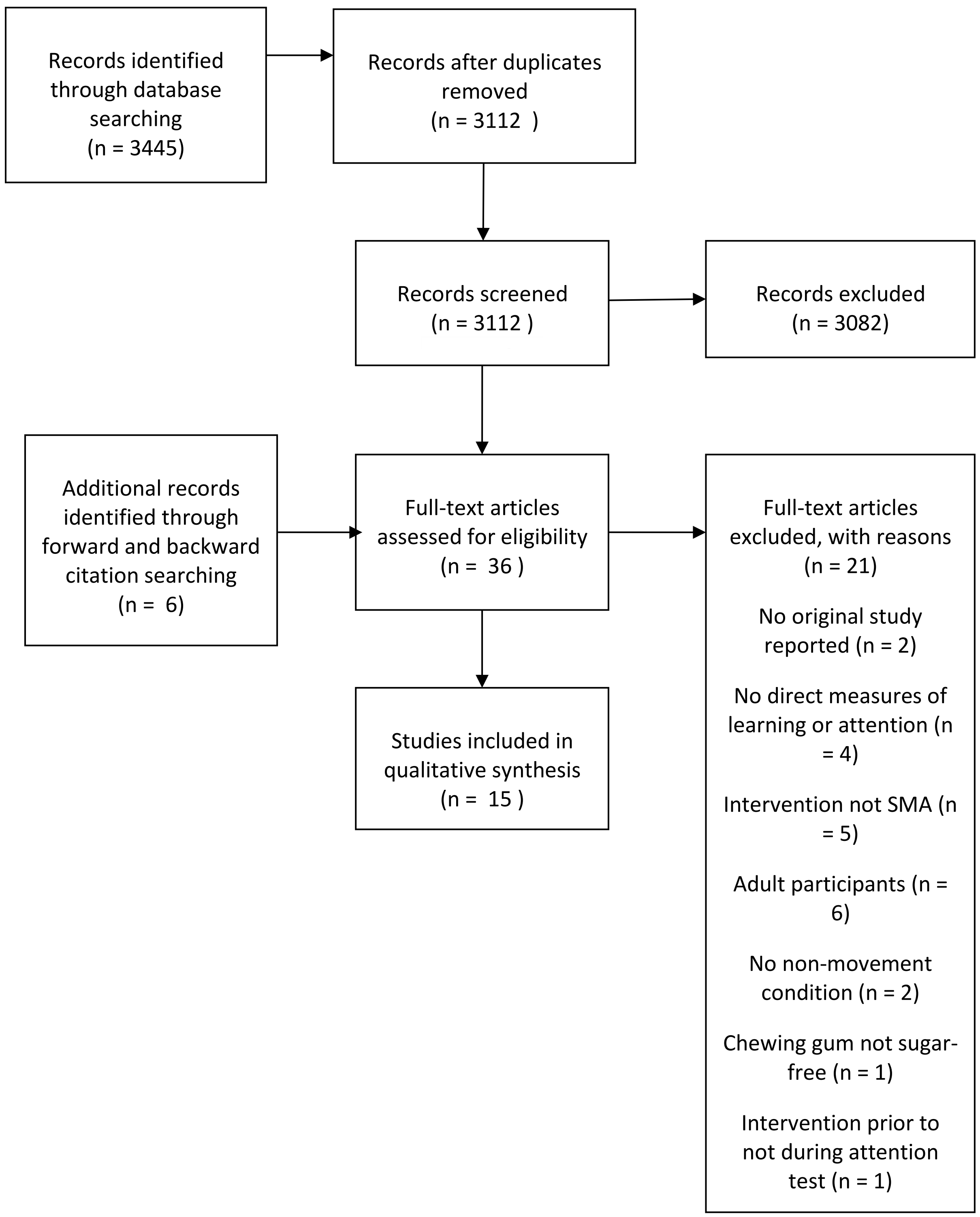


Figure 1. PRISMA flow diagram to show the stages of the systematic search.

1.2.3 Information Extraction

Key information was extracted from studies using a data extraction form. A summary of each study, presented in the table form used for data extraction, is shown in Table 3 in the results section.

1.2.4 Quality Check

The Downs and Black Quality Checklist (Downs & Black, 1998) was adapted to assess the quality of each study (see Appendix C). Due to a wide variation in study methodology and, in particular, the inclusion of a number studies using single case experimental designs (SCED), not all questions were considered relevant to each study. Therefore, to improve the validity of the checklist for comparison of the diverse studies reviewed, some questions were adapted. Instead of a total score, a proportion score was calculated for each study, by dividing the total score (based on questions considered to be relevant) by the number of questions applied to generate that score. It was recognised that this application of the quality checklist introduced an additional element of subjectivity and the designation of questions to a third of the studies was discussed with a research assistant as a validity check. A Table containing the scores of each study in relation to each checklist question applied, as well as the total and proportion scores generated is included in Appendix D.

1.3 Results

This section will begin with an overview of study quality, followed by the findings of the studies, grouped by the type of SMA. For each of the 15 reviewed studies, information about the design, participants, intervention, outcome measures, key findings and study quality are reported in Table 3.

Table 3.

Data Extraction and Study Information

Num ber	Autors	Study Characteristics	Participant Characteristics	Outcome Measures	Main Findings	Quality Assessment Score
1	Schilling, Washington, Billingsley and Deitz (2003)	**Design** Single subject ABAB interrupted time series design **Intervention** Therapy balls **Country** USA	**N** = 3 **Age:** (9 years), **Gender:** 1 female, 2 male **Ethnicity:** **SEN:** ADHD medicated	Legible word productivity	All participants' legible word productivity was higher on balls.	0.68
2	Kercood, Grskovic, Lee	**Design** Single subject	**N** = 4 **Age:** (4th grade, 9	Number of maths problems correct.	Two students performed better under intervention	0.58

	and Emmert (2007)	alternating treatments design **Intervention** Fidgeting **Country** USA	years), **Gender:** 3 male, 1 female (from names) **Ethnicity:** **SEN:** attention problems, no medication		condition according to means. No difference seen in the other two. Graphs unclear.	
3	Tänzer et al. (2009)	**Design** Between-groups experimental design **Intervention** Chewing gum **Country**	**N** = 85 (4 classes) **Age:** 8-9 years (42 chewing, 43 control, 1 omitted), **Gender:** not reported **Ethnicity:** **SEN:** not reported	16-min concentration test	Participants with gum performed less well to start with but better in last 4 minutes of the test. Significant correlation between chewing gum and performance over time ($F_{1,726}$ = 6.47, p	0.56

		Germany			< .003; partial η2 = 0.07), and significant interaction of gum chewing with time ($F_{1,726} = 6.47$, $p < .004$; partial η2 = 0.07).	
4	Emmert, Kercood and Grskovic (2009)	**Design** Single subject alternating treatments design with baseline, reversal and choice phases **Intervention** Fidgeting	**N** = 3 **Age:** two 5th grade, one 4th grade **Gender:** 2 male, 1 female (from names) **Ethnicity:** **SEN:** attention problems, no medication	Number of maths problems attempted. Number of maths problems correct.	Students attempted and solved slightly more maths problems in the stimulation conditions than in baseline.	0.58

		(20 min sessions) **Country** USA				
5	Kercood and Grskovic (2010)	Study 1: **Design** Single subject alternating treatments design with baseline phase **Intervention** Fidgeting **Country** USA	Study 1: **N** = 3 **Age:** 10 years (two 4th grade, one 5th grade), **Gender:** male **Ethnicity:** **SEN:** ADHD, medicated Study 2: **N** = 3 **Age:** 10 years	Correct responses to maths story problems.	Study 1: All ppts gave more correct answers when fidgeting Study 2: auditory distraction impeded performance but fidgeting mitigated effects of distraction – in two out of the three students. No clear effect of fine motor only.	0.63

		Study 2: **Design** Single subject design with baseline phase and three consecutive treatment phases **Intervention** Fidgeting **Country** USA	**Gender:** 2 male 1 female **Ethnicity:** **SEN:** ADHD, medicated			
6	Tucha et al. (2010)	**Design** Crossover design **Intervention**	**N** = 64 (32 in each group) **Age:** mean age = 10.8, SEM = 0.4	15 min test of vigilance and sustained attention	ADHD participants more errors than controls in both conditions. No difference in reaction	0.68

		Chewing gum **Country** UK	**Gender:** 8 female, 24 male in each group **Ethnicity:** **SEN:** (32 ADHD medicated, 32 non ADHD)		times between groups. Both groups increased reaction times with gum.	
7	Johnston, Tyler, Stansberry, Moreno and Foreyt (2012)	**Design** Between groups pre-test post-test experimental design **Intervention** Chewing gum **Country**	**N** = 106 (4 classes) **Age:** 13-16, mean age 14.6, SD = 0.7 **Gender:** 52 female, 54 male **Ethnicity:** **SEN:** not reported	Maths performance: TAKS Class grades	Participants in gum condition had significantly greater increase in TAKS scores and smaller decline in class grades.	0.8

		USA					
8	Kercood and Banda (2012)	**Design** Single subject alternating treatments design with baseline and reversal phases **Intervention** Doodling and therapy balls **Country** USA	**N** = 4 **Age:** 10 and 12 years **Gender:** 2 male, 2 female **Ethnicity:** **SEN:** mixed diagnoses: no difficulties, attention problems, learning difficulties, ADHD; no medication	Percentage correct answers to listening comprehension questions. Time taken to complete the questions (total) in secs	All participants worked faster and more accurately during both intervention conditions compared to baseline. On reintroduction all participants continued to work faster but 3 out of 4 declined in performance. Graphs show large number of overlapping data points – findings clearer from means.	0.47	
9	Wu et al. (2012)	**Design** Crossover design	**N** = 29 (15 ADHD, 14 control) **Age:** ADHD: mean	Reaction time and P300 latency	ADHD participants had longer reaction time and greater P300 latency	0.58	

		Intervention Therapy balls **Country** Taiwan	age 8.6 years +- 2.1; control: mean age 8.7 years, +- 2 years **Gender:** **Ethnicity:** **SEN:** 5 ppts medicated but took drug holidays, 11 male, 4 female; 14 ppts non ADHD, 7 male, 7 female		than controls on chair. On ball ADHD participants showed a significant improvement in reaction time and P300 latency. No longer significantly different from controls in reaction times.	
10	Goodmon et al. (2014)	**Design** Between groups pre-test post-test experimental design: time series switching	**N** = 24 **Age:** 9-11 years **Gender:** 19 male, 5 female **Ethnicity:**	Reading comprehension	No significant improvements in reading comprehension Class A: P = .08, d = .48 Class B: P = .69, d = .13	0.66

		replication design, **Intervention** Therapy balls **Country** USA	**SEN:** dyslexia/dyslexia and ADHD			
11	Merritt (2014)	**Design** Between groups pre-test post-test experimental design **Intervention** Air cushions (6 weeks intervention)	**N** = 51 **Age:** 3-6 years (preschool) **Gender:** not reported **Ethnicity:** **SEN:** 23 with label of autism, language delay or developmental	Get it Got it Go assessment of early literacy skills	No differences between group scores or change scores.	0.47

		Country USA	delay			
12	Fedewa, Davis and Ahn (2015)	**Design** Between groups pre-test post-test experimental design **Intervention** Therapy balls **Country** USA	**N** = 67 **Age:** 2^{nd} grade **Gender:** 35 male, 32 female **Ethnicity:** **SEN:** no physical or cognitive limitations that would prevent them from taking part	Math and literacy tests (MAP)	Significant improvement in math and literacy regardless of group – no effect of intervention	0.63
13	Mead, Scibora, Gardner and	**Design** Between groups (3 groups) pre-test	**N** = 81 **Age:** 11-12 years **Gender:** 39 males,	MAP and MCA – standardised math scores	MAP improvement scores sig higher for stability ball than control class	0.7

	Dunn (2016)	post-test experimental design **Intervention** Therapy balls **Country** USA	42 females **Ethnicity:** **SEN:** no special needs			
14	Tadayon and Afhami (2016)	**Design** Between groups pre-test post-test experimental design **Intervention** Doodling	**N** = 54 **Age:** 12-13 years **Gender:** female **Ethnicity:** **SEN:** not reported	Tests assessing learning from lessons	Doodlers scored better than non-doodlers at post-test (mean of scores from ten sessions).	0.5

		Country Iran				
15	(Taipalus, Hixson, Kanouse, Wyse and Fursa (2017)	**Design** Single subject alternating treatments design with baseline and choice phases **Intervention** Therapy balls **Country** USA	**N** = 4 **Age:** 4th grade **Gender:** 2 male, 2 female **Ethnicity:** **SEN:** ADHD medicated	Reading comprehension (Dynamic Indicators of Basic Early Literacy Skills Next Daze progress monitoring passages) Math fluency (1-minute workshops)	No apparent effect of condition on reading comprehension or math fluency.	0.7

1.3.1 Quality Overview

The scores of each study in relation to each checklist question applied, as well as the total and proportion scores generated are shown in Appendix D. Quality scores ranged from 0.47 to 0.8 (mean = 0.62, SD = 0.10) and followed a normal distribution, as assessed by Shapiro-Wilk's test (p = .77). Scores under .6 were considered low, scores from .6 to .79 were considered moderate and scores of .8 or above were considered high.

An overview of study quality within this review is shown in Table 4 below. As can be seen from the scores, the studies included in this review were of overall moderate to low quality.

Table 4.

Overview of Research Quality

Study Quality	Study References	Number of Studies
High (.80 and above)	• Johnston et al (2012)	1
Moderate (.60 to .79)	• Schilling et al. (2003) • Kercood and Grskovic (2010) • Tucha et al. (2010) • Goodmon et al. (2014) • Fedewa et al. (2015) • Mead et al. (2016) • Taipalus et al. (2017)	7
Low (.59 and below)	• Kercood et al. (2007) • Tänzer et al. (2009) • Emmert et al. (2009) • Kercood and Banda (2012) • Wu et al. (2012) • Merritt (2014) • Tadayon and Afhami (2016)	7

1.3.2 Fidgeting

Four studies investigated the effect of fidgeting on attention, all of which used single case experimental designs (SCED) and similar outcome measures. Kercood et al. (2007) used a single case alternating treatment design to investigate the effect of fidgeting on maths problem solving in four 9-year-olds with reported attention difficulties (no medication). Participants completed 18-19 20-minute sessions while seated facing separate corners of an empty classroom. In the fidgeting condition they were given a fidget toy (Tangle Puzzle Jr), shown how to use it and told that using it might help them to focus on their work. Participants completed worksheets, each containing 30 maths story problems sourced from textbooks. For each session, the number of problems attempted and the number correctly completed were measured. Visual inspection of graphs indicated that fidgeting improved maths performance in two out of the four participants, with only a small number of overlapping data points. No effect was evident in the remaining two participants.

Emmert et al. (2009) reported a similar study with contrasting findings. They used a single case alternating treatment design to investigate the effects of fidgeting and auditory stimulation on maths problem solving in a sample of three participants, aged 9-11 years, with reported attention difficulties (no medication). Similarly to Kercood et al.'s (2007) study, participants completed 23 20-minute sessions in an empty classroom and maths problem solving was measured using worksheets based on grade appropriate textbooks. In the fidgeting condition, participants were given the same fidget toy and instructions as in Kercood et al.'s (2007) study. In the auditory stimulation condition, participants listened to classical music through headphones. The number of problems attempted, as well as number of correct responses, was measured. In contrast to Kercood et al.'s (2007) findings, visual inspection of graphs did not reveal any clear effects of fidgeting for any participant. However, mean scores indicated that fidgeting was associated with a very slight increase in the number of correctly solved maths problems.

Using similar designs again, Kercood and Grskovic (2010) presented two further studies that investigated the effect of fidgeting on maths problem solving. In the first study, three 10-year-old cgdADHD (medicated) completed 16 20-minute sessions under alternating conditions, with a baseline phase. Participants were tested individually and the order of conditions was counterbalanced. In contrast to the empty classroom settings used by Kercood et al. (2007) and

Emmert et al. (2009), Kercood and Grskovic (2010) used an 'analog' classroom setting, designed to simulate typical classrooms by including a number of distractions. These included colourful posters, windows in line of sight of participants and adults entering and leaving the classroom. The fidget toys used and instructions given were the same as in Kercood et al. (2007) and Emmert et al. (2009). In this study, maths problems were presented verbally rather than visually. For each session, 20 problems were read aloud and recorded onto audiotape with a 20-second pause between problems. Participants gave verbal answers, which were recorded by researchers sitting 10 feet behind them. The dependent variable measured was number of problems solved correctly. In line with Kercood et al.'s (2007) findings, visual inspection of graphs indicated that all three participants correctly solved more maths problems while fidgeting than under a control condition, with very few overlapping data points.

The second study reported by Kercood and Grskovic (2010) aimed to build on previous findings by investigating whether fidgeting could reduce the detrimental effects of distraction on attention and learning. Three 10-year-old cgdADHD (medicated) were asked to solve maths problems under four counterbalanced conditions: control, auditory distraction, fidgeting and auditory distraction plus fidgeting (5 consecutive sessions under each condition). Auditory distraction was provided by an audio recording of children talking, music, TV sounds, pencils being sharpened and a telephone ringing. Distracting noises occurred approximately every one to four minutes and lasted between 30 seconds and two minutes. During fidgeting conditions, participants were given the same fidget toys and instructions as in studies reported above. Participants worked individually in a conference room in a school. In each session, 25 maths problems were presented visually by PowerPoint and verbal answers were recorded. Visual inspection of graphs indicated that auditory distraction impeded performance on maths problem solving but fidgeting mitigated the effects of distraction for two out of three participants. No clear effect was found for fidgeting alone.

Overall, research into fidgeting shows a mixed effect of fidgeting on maths problem solving and no clear detrimental effect. All four studies presented some positive findings, although in two studies the positive findings did not apply to all participants and in one study the positive effect was not detectable from the graphs. All four studies were carried out by the same research group and were similar in design and outcome measure. One key limitation common to all four studies relates to the instructions given to participants, which introduce a significant risk of demand characteristics, limiting the validity of any positive change. Due to the similarity of the studies, it is not clear if the findings would generalise beyond that specific group of participants or to children without attention difficulties or those of different ages. No measures of arousal were used, meaning that the hypothesised mechanism for the reported positive effects could not be tested. In addition, the effect of fidgeting on different elements of attention and learning was not measured.

1.3.3 Doodling

Only two studies investigated the effect of doodling on attention and learning. In a similar way to the fidgeting studies reported above, Kercood and Banda (2012)'s SCED study used a single subject alternating treatments design with baseline and reversal (return to baseline) phases to investigate the effect of doodling and therapy ball use on listening comprehension in four 10-12-year-olds. Participants varied in their teacher-reported special education needs (SEN): no difficulties, attention problems, learning difficulties, and ADHD (non-medicated), respectively. In each session, participants sat in a quiet room together, at individual desks, and listened to a story played by an audio recorder. In the doodling condition, participants sat on chairs and doodled using a pencil and paper. In the therapy ball condition participants sat on therapy balls instead of chairs. After each story, they completed a listening comprehension test containing 12 multiple-choice questions. The percentage of correct answers and the time taken to complete the total questions (in seconds) were recorded. Mean scores and visual inspection of graphs indicated that, for participants with SEN, listening comprehension improved under both experimental conditions compared with the control condition. No effect of either condition was found for the participant with no SEN. All participants increased their speed during the study, completing the tests more quickly during the reversal phase (vs. the intervention) and during the intervention (vs baseline).

Tadayon and Afhami (2016) used a between-groups design to investigate the effect of doodling on learning in 12-13-year-old girls. One hundred and sixty-nine students participated in 11 40-minute natural science lessons, each followed by a 10-minute test designed to assess learning (scores ranged from zero to nine). The first lesson and test was used to generate pre-test scores from all 169 students. In all subsequent lessons, students were asked to doodle when they felt the desire or need to do so. Students who filled more than 50% of an A4 page with doodles were considered doodlers and those who did not were considered controls. Twenty-seven students were randomly selected from the doodlers and from the controls and a group comparison found that doodlers scored significantly better than non-doodlers.

Group differences (beyond test scores) were not explored in this study, leaving open the possibility that the effect was due to existing group differences rather than to the experimental condition. This omission is particularly problematic given the self-allocation of participants to groups based on preference: it is likely that participants who chose to doodle differed from those who chose not to doodle, on variables that may affect their performance on the tests (e.g. attentional control, sleepiness or motivation).

In summary, the two studies investigating doodling both reported positive findings. As they used very different designs, participants and outcome measures, comparison is difficult. As in the fidgeting research, no measure of arousal was taken, limiting the extent to which findings can be linked to a clear underpinning mechanism. Due to the small number and low quality of the studies investigating doodling, these positive findings must be considered tentative, subject to replication using improved designs.

1.3.4 Chewing

Three studies investigated the effect of chewing on attention and learning. Johnston et al. (2012) used a between-groups pre-test post-test design to investigate the effect of chewing on maths learning over a 14-week period in 106 TD 13-16 year-olds (from four classes). The classes were randomly assigned to either the gum (n = 52) or no gum (n = 54) condition. Two maths teachers each taught one gum and one no gum class, using the same curriculum, to reduce teacher-related confounding variables. In the gum chewing classes, gum was provided during maths lessons, tests and homework time. Chewing gum was otherwise not allowed on campus. Intervention fidelity was assessed through a daily self-report of gum chewing. Students in the gum chewing group reported chewing at least one stick of gum during 86% of maths lessons and 36% of homework times. Students in the control group reported chewing gum during 1% of maths lessons and 9% of homework times. Maths performance was measured using maths grades and the Texas Assessment of Knowledge and Skills (TAKS; Student Assessment Division of the Texas Education Agency, 2010), a state-wide standardised assessment aligned with the Texas curriculum. The practice version of the TAKS was administered at baseline, followed by the real test 14 weeks later. Maths grades were recorded twice, during the autumn and spring terms, respectively. Grades represented student's performance on classwork, tests and homework across the term. Results showed that across both groups, TAKS scores increased and class grades decreased between pre-test and post-test (possibly accounted for by the increasing difficulty of concepts taught during the year or the thorough final exam). Participants who chewed gum showed a significantly greater improvement in TAKS scores compared to controls ($p = .03$, $\eta p^2 = 0.05$), a difference that remained when baseline maths performance was accounted for ($\eta p^2 = 0.04$). A significantly lower decline in class grades was found in classes that chewed gum compared to controls ($p = .04$, $\eta p^2 = 0.04$).

Tänzer et al. (2009) and Tucha et al. (2010) investigated the effect of chewing on attention using standardised attention tests. Tänzer et al. (2009) used a between-groups design in which gum chewing (n = 42) and control (n = 43) groups of TD 8-9 year-olds completed a 16-minute concentration test. The test was a modified version of the Differentieller Leistungstest-Konzentration Grand Schule (DL-KG Test; Kleber, Kleber, & Hans, 1999), in which participants were given sheets of symbols and asked to cross out three types of symbol and mark all others with a dot. Concentration was defined as the number of symbols correctly marked (either crossed out or dotted) minus the numbers of errors. Participants were given a new response sheet every two minutes, resulting in eight separate scores for each participant. To reduce demand characteristics, participants who chewed gum were told that the gum was a gift to thank them for taking part. Analysis found that participants who chewed gum performed less well than controls initially, but outperformed controls during the final four minutes. A small but significant interaction between gum chewing and time was reported ($p < .004$; partial $\eta 2 = 0.07$); however, further analyses did not consider group differences at each time point. These findings suggest that beneficial effects of SMA emerge over time, becoming evident during later stages of a task. However, only classes, not individual participants, were randomly allocated to group and potential group differences could have contributed to the findings.

In Tucha et al.'s (2010) study, the researchers also used a standardised test of attention, but within a crossover design that allowed them to compare the performance of TD children and cgdADHD (medicated) under two counterbalanced conditions (chewing gum and control). Sixty-four children (mean age = 10.8; 32 cgdADHD, 32 TD) were each tested on two occasions, seven days apart. Attention was measured using a 15-minute computerised test of vigilance and sustained attention. In this test, two squares were alternately filled with a pattern and participants were asked to press a button when no change of pattern location occurred (target stimulus). Similarly to Tänzer et al.'s (2009) study, the test was split into two time blocks to calculate the effect of time on task performance (an index of sustained attention). The dependent variables, considered indexes of vigilance, were median reaction time for correct responses, number of omission errors (failure to endorse no pattern change) and the number of commission errors (endorsing a change when none had occurred). Tucha et al. (2010) found that chewing gum led to increased (i.e. slower) reaction times for both the cgdADHD ($Z = -2.00$, $p = .046$, $d = -.76$ and control participants ($Z = -1.97$, $p = .049$, $d = -.74$), compared to a control condition. CgdADHD also made more omission errors while chewing gum ($Z = -1.99$, $p = .047$), reflecting reduced vigilance. No difference was found in the effect of time on task performance, reflecting no difference in sustained attention. While the increases only just reached statistical significance, the study was appropriately powered and the effect sizes were large. These findings represent the only evidence within the studies reviewed of a detrimental effect of SMA on attention.

In summary, the three studies investigating chewing gum reported conflicting findings. Two studies reported positive findings, although one study found a positive effect only in the final minutes of a task, introducing time as a possible moderator of the effect of chewing gum on attention. A third study, that compared cgdADHD to TD children, found that the performance of both groups declined while chewing gum (children's response times reduced and there was evidence of poorer sustained attention).

1.3.5 Alternative seating

Eight studies investigated the effects of alternative seating on attention and learning, four of which used similar between-groups designs and measured learning. Mead et al. (2016) used a between-groups pre-test post-test design to investigate the effect of therapy ball use and activity breaks on maths learning in 81 TD 11-12 year-olds. The students were randomly assigned to three classes at the beginning of the school year and attended daily 80-minute maths lessons. One class (control; N = 23) conducted lessons in the typical way for the duration of the study. In another class (N = 29), students sat on therapy balls. In the final class (N = 29), students engaged in two 5-minute activity breaks in each maths lesson, consisting of 30-second bouts of different activities decided by rolling dice. Two standardised maths tests were used to measure maths learning. The Measures of Academic Progress (MAP; Northwest Evaluation Association, 2013) is a standardised assessment of reading, maths and language. It is computerised and adapts in response to each child's answers. The Minnesota Comprehensive Assessments (MCA; Minnesota Department of Education, 2013) is a state-wide achievement test of maths, reading and science and produces a standardised score. Mead et al. (2016) found that the group who sat on therapy balls improved in MAP scores significantly more than controls ($p = .016$, $d=.88$) but not the activity break group ($p = .25$). Improvement scores on the MCA were significantly higher for the therapy ball group compared to the activity break group ($p = .004$, $d = .83$), but not compared to controls ($p= .19$). Despite dissenting patterns of results, therapy ball use appeared to have a positive effect on maths learning, as measured by both tests.

One possible explanation for the discrepancy in findings based on the different outcome measures relates to the timing of the pre and post tests. Intervention dates were not explicitly reported but can be inferred to be from the beginning of the school term in autumn 2012 to the post-test dates in spring 2013. It is, therefore, likely that the MAP was a more valid measure of intervention effectiveness in this study as changes in MAP scores represented learning during the intervention period only (pre-test autumn 2012), whereas MCA scores were based on learning undertaken during the intervention period plus a long period in which all participants used chairs as usual (pre-test spring 2012).

Fedewa et al. (2015) also used a between-groups pre-test post-test design to investigate the effect of therapy ball use on maths and literacy learning in 67 TD 7-8-year-olds. Participants in two classes sat on therapy balls throughout the school day for nine months. Participants in two different classes acted as controls and sat on chairs. The MAP was used to measure progress in maths and literacy. Results indicated that maths and literacy scores improved significantly over time in both maths ($p < .01$, $\eta p^2 = .69$) and literacy ($p < .01$, $\eta p^2 = .68$). However, in contrast to Mead et al's (2016) findings, no significant effect of intervention was found for maths ($p = .09$, $\eta p^2 = .04$) or literacy ($p = .07$, $\eta p^2 = .05$). In addition, no interaction effect between time and group was found for maths ($p = .09$, $\eta p^2 = .04$), or literacy ($p = .60$, $\eta p^2 = .004$).

Merritt (2014) also used a between-groups pre-test post-test design, in this case to measure the effect of air cushion use on early literacy skills in 51 pre-schoolers aged 3-6 years. Participants in two morning classes ($N = 26$) sat on air cushions during reading instruction for six weeks. Participants in two afternoon classes (N = 25) did not use air cushions and acted as controls. Early literacy skills were measured at the start and end of the intervention using the Get it, Got it, Go Assessment (GGG; Ohio Department of Education, 2008); a standardised assessment tool used in all state funded preschools in Ohio, USA measuring picture naming, rhyming and alliteration. The total score is the sum of the number of items identified or produced in one minute, two minutes and two minutes, respectively. In line with Fedewa et al.'s (2015) findings, t-tests found a slight increase in GGG scores in both groups from pre-test to post-test, but no significant differences in GGG scores between groups at pre-test or at post-test (statistics not reported).

The presence of extraneous variables, such as parental input and other enrichment – particularly influential at this early stage of development – was not investigated. Variance linked to these factors may have made it impossible to distinguish any effects on learning of using the air cushions, even if attention was positively affected.

Goodmon et al. (2014) used a similar but improved design to investigate the effect of therapy ball use on reading comprehension in 24 9-11-year-olds given diagnoses of either dyslexia or comorbid dyslexia and ADHD. They used a switching replication design, in which data were collected during three 15-day time waves. Group A used therapy balls between time waves 1 and 2, whereas Group B used therapy balls between time waves 2 and 3. This allowed the researchers to assess any lasting benefits of the intervention, while accounting for variables related to the whole-class and time. Reading comprehension was measured using three elementary grade level reading comprehension tests per time wave, comprising 12-15 sequencing, multiple choice and true/false questions. Again, no effect of therapy ball use on reading comprehension was found in either class A ($p = .08$, $d = .48$) or class B ($p = .69$, $d = .13$). As a caveat to these findings, the authors suggested that high mean reading comprehension scores may indicate a lack of sensitivity of this measure in their sample. It was also noted by the reviewer that this study lacked the power to detect even a large effect.

Three further studies used single case experimental designs. Schilling et al. (2003) investigated the effect of therapy ball use on legible word productivity in three 9-year-olds given a diagnosis of ADHD (medicated), using a single subject interrupted time series design with four phases, each lasting three weeks. During the two intervention phases, participants (along with the rest of the class) sat on therapy balls during daily 60-minute language arts classes. Legible word productivity was defined as the difference between participant's legible word production and the class mean on same assignment. This was calculated for five randomly selected writing samples per phase. Positive findings were reported in line with Mead et al. (2016): visual inspection of graphs indicated that all three participants performed better when seated on therapy balls compared to chairs, with very few overlapping data points.

These results must be interpreted with caution. As the rest of the class also underwent the same changes in seating condition as participants, class mean legible word productivity represents a potential confounding variable. It is possible that that the observed effects were due to a systematic decrease in class mean legible word productivity, rather than an increase in participant legible word productivity, under the therapy ball condition. Qualitative teacher reports did not suggest this to be the case and it was noted that the teacher continued to use therapy balls after the completion of the study. Without access to class data, however, a confounding effect of therapy ball use on class mean legible word productivity cannot be ruled out.

Taipalus et al. (2017) used a single subject alternating treatments design with baseline and choice phases to investigate the effect of therapy ball use on reading comprehension and maths fluency in four 9-10-year-olds given a diagnosis of ADHD (medicated). Seating type (therapy ball versus chair) was alternated daily during 20-30 minute independent seatwork periods. Reading comprehension was measured using the Dynamic Indicators of Basic Early Literacy Skills Next Daze (Good et al., 2013), a standardised assessment designed to measure progress over time in individuals. One-minute worksheets containing maths problems were used to measure maths fluency. Both measures were administered daily: five times during the baseline, therapy ball, chair and choice phases, respectively. Consistent with results found by Fedewa et al. (2015), Merritt (2014) and Goodmon et al. (2014), visual inspection of graphs indicated no effect of therapy ball use on reading comprehension or maths fluency in any of the participants.

While the assessments were clearly described, incomplete information regarding the intervention period means that it is not clear what specific constructs were measured by the assessments. As the specific activities undertaken during the independent seatwork periods were not reported, two interpretations are possible. Firstly, it is possible that participants worked on their reading comprehension and/or their maths fluency, meaning that assessments measured differences in learning under the different conditions. Alternatively, it is possible that participants completed unrelated work and the assessments measured differences in attention or related factors under the different conditions. Nevertheless, graphs clearly showed no effect of intervention, challenging the view that SMA improves attention or learning in children with attention difficulties (see also Tucha et al., 2010 above for similar findings).

The final study to investigate alternative seating (Wu et al., 2012) used the only neuropsychological index of attention in this literature. Fifteen cgdADHD (mean age = 8.6 years) and 14 controls (mean age = 8.7 years) completed an auditory oddball task six times under two randomised seating conditions (therapy ball and chair; three 5-minute sessions each). Participants were asked to press a button as quickly as possible after hearing a high-frequency tone and to do nothing after hearing a low-frequency tone. The dependent variables were response accuracy, reaction times and auditory evoked potentials in EEG measurement, including the latency of the P300 (an event related potential (ERP) component linked to decision making). Results showed that, under the chair condition, controls outperformed cgdADHD in (faster) reaction times, as evidenced in behavioural responding ($p = .003$, $d = 1.40$) and the ERP P300 latency ($p = .042$, $d = 2.45$). Under the therapy ball condition, the difference in reaction times between groups was insignificant ($p = .604$). No significant differences between conditions were found in the control group; however, therapy ball use resulted in significant improvements for cgdADHD in reaction time ($p = .01$) and P300 latency ($p = .046$) compared to a chair condition, indicating an interaction between group and condition. These findings provide support for the use of therapy balls to improve attention in cgdADHD; however, they challenge the view that therapy balls improved attention in TD children.

Consistent with other SMA interventions (e.g., chewing gum), the studies investigating alternative seating used a variety of designs and reported inconsistent findings (although none reported a detrimental effect). This inconsistency was present even when considering the studies in groups of similar designs, participants, outcome measures and quality.

1.4 Discussion

This literature review aimed to bring together studies investigating the effectiveness of SMA interventions delivered in a school context on attention and learning in children aged 0 to 18 years. Of the 15 studies reviewed, ten reported positive findings (i.e., of fidgeting, doodling, chewing gum and alternative seating on maths achievement scores and problem solving, listening comprehension, legible word productivity, concentration, reaction times and post-lesson test scores), four reported null findings (i.e., of chewing gum and alternative seating on reading comprehension, early literacy skills, maths and literacy achievement scores and maths fluency) and one reported a detrimental effect (i.e., of chewing gum on vigilance). While evidence is weighted slightly towards the positive, the findings should be interpreted with caution due to issues with study quality.

1.4.1 Quality of Studies

The reviewed studies were of overall moderate to low quality. One study was assessed as high quality, seven studies were assessed as moderate quality and seven studies were assessed as low quality. The methodological strengths and limitations of the reviewed literature will now be discussed.

A methodological problem affecting all studies in this review relates to blinding and the potential for demand characteristics. In a number of studies, participants were led to expect that engaging in SMA might help them to focus on their work (e.g., Kercood et al., 2007; Emmert et al., 2009). Only one study (Tänzer et al., 2009) reported an attempt to blind participants to the study hypotheses. The absence of reported attempts to reduce demand characteristics should be considered when interpreting the findings of these studies.

Another methodological weakness across all the studies related to sampling. No study met the criteria specified by Downs and Black (1998) of clearly stating the target population and how the chosen method of sampling aimed to recruit a representative sample. Sampling methods were reported or inferred to be volunteer or convenience sampling. This limits the generalisability of findings and also hinders comparisons between studies.

A number of studies were also underpowered. In addition to the six SCED studies, nine studies employed between groups or crossover designs and only four were appropriately powered according to calculations run using G* Power 3. Five studies were significantly underpowered (reporting both positive and no effects). Despite the low sample sizes, SCED studies were not penalised in the quality assessment for lack of power providing they reported enough data points to demonstrate an effect.

Studies within this review employed a wide range of outcome measures, some of which were developed for the purposes of the study. While measures were generally clearly described, meeting the quality criteria specified by Downs and Black (1998), not all researchers reported the validity and reliability of their measures. In addition, most assessments were only able to collect general measures of attention and learning. For example, several studies measured maths problem solving, which relies on a number of attention and memory skills, alongside other factors such as motivation and self-efficacy. Given that SMA are suggested to exert differential effects on different elements of attention and learning, the predominant use of nonspecific measures means that it is difficult to pinpoint effects between studies.

Conversely, a strength of the outcome measures overall was their high external validity. In nine studies, participants either completed their usual assessments or worksheets based on school textbooks or syllabus material. The high external validity of the literature as a whole facilitates application of findings to the educational environment intended to benefit from the research.

The external validity of the settings and interventions was also high. Thirteen studies were conducted in schools. Eight took place in typical classrooms and five were carried out in simulated classroom settings (usually empty classrooms). Only two studies were carried out in a laboratory setting. In relation to interventions, those administered during the research were comparable to those that would be experienced outside of the research setting. For example, in studies investigating doodling (Kercood & Banda, 2012; Tadayon & Afhami, 2016), participants were free to doodle as they wished. Participants in chewing research were instructed to chew naturally, fidgeting was modelled but not regulated and alternative seating studies provided operational rules appropriate for the typical classroom environment.

An important limitation of the research is that, while 12 of the reviewed studies were explicitly based on optimal arousal theory, none measured arousal. Inclusion of measures of arousal would assist in understanding conflicting findings, and the lack of any arousal data limits the degree to which the studies can contribute to theoretical understanding.

In summary, the reviewed literature has strengths related to external validity but is weak in areas affecting internal validity. In addition, issues of study design hinder the furthering of theoretical understanding in this area. The findings will now be discussed in the wider research context.

1.4.2 Current Findings Within the Wider Research Context

The variable findings presented within this review mirror the variable findings within the wider SMA literature using adult populations (almost all focused on chewing gum; e.g. Allen & Smith, 2011). Several factors have been hypothesised to explain inconsistencies in the wider literature, including the influence of time, interference effects and differential effects of SMA on aspects of attention and learning. The findings of this literature review will be discussed in relation to the wider literature and these three factors, followed by consideration of theory related to attention difficulties.

A moderating effect of time was suggested by one study in the current review (Tänzer et al., 2009). Chewing gum, exerted an initial negative effect, but in the final four minutes of the task offered an advantage on a test of concentration. Similar results were reported by Tucha and Simpson (2011), in which gum chewing was associated with poorer performance during the first 10 minutes of a 30-minute sustained attention task, but better performance during later stages, relative to a control condition. Tucha and Simpson (2011) linked their findings to research on exercise, which also found an initial negative effect on cognitive performance, followed by a beneficial effect after approximately 20 minutes (Lambourne & Tomporowski, 2010). An interference effect was proposed to explain the initial negative effect of both types of movement, followed by arousal-induced benefits (Tucha & Simpson, 2011; Lambourne & Tomporowski, 2010). While Tänzer et al.'s (2009) study was unable to rule out confounding between-group variables, Tucha and Simpsons's (2011) findings using a more robust crossover design strengthen the arousal-interference hypothesis.

Onyper, Carr, Farrar and Floyd (2011) reported a different pattern of findings that can also be explained by a combination of arousal and interference effects. They conducted a series of studies designed to examine the influence of time on chewing gum effects in adults. They reported a positive effect of chewing gum on cognitive tests when gum was chewed for five minutes before, but not during, testing. These benefits lasted for 15-20 minutes after gum chewing ceased. To explain these findings, the authors proposed that the time-limited benefits of gum chewing related to temporarily increased arousal. The absence of improvements in cognitive performance when gum was chewed during testing was attributed to interference effects.

Aside from Tänzer et al. (2009), no studies within this review specifically investigated changes in effect over time, although tasks were split by time in two studies (Wu et al., 2012; Tucha et al., 2010) No report was made, in either study, of any more detailed analyses of performance over time, meaning that an undetected moderating effect of time could account for the overall negative findings in the shorter test period (Tucha et al., 2010) and positive findings in the longer test period (Wu et al., 2012). The influence of time may also have indirectly influenced research outcomes in other studies.

Interference effects have been reported in relation to doodling in adults. Doodling differs from the other SMA examined in this review in that it involves a visual component. While research is sparse, reports of a positive effect of doodling on auditory (Andrade, 2010) but not visual (Chan, 2012) recall tasks lines up with an interference hypothesis. The two doodling studies in this review (Kercood & Banda, 2012; Tadayon & Afhami, 2016) both used auditory (or mostly auditory) tasks and reported positive findings. Overall, while an interference hypothesis could be applied to the reviewed literature, it cannot confidently explain the inconsistent findings as the reviewed studies were not able to specify when interference effects may or may not be present.

A differential effect of SMA on different elements of attention and learning has been proposed by a number of researchers. For example, Allen and Smith's (2011) review of chewing literature found evidence for a positive effect of chewing on WM, sustained attention and selective attention, but not divided attention. Onyper et al. (2011) reported beneficial effects of gum chewing in tests of WM, episodic memory and processing speed but not verbal fluency. Within the reviewed literature, the heterogeneity in study design and outcome measures (both the assessments used and the constructs they aimed to measure) could, therefore, explain some of the disparity in findings. It is worth noting, however, that the two studies measuring the same specific element of attention (reaction time; Tucha et al., 2010; Wu et al., 2012) and the two studies using the same measure (MAP; Mead et al., 2016; Fedewa et al., 2015) found conflicting results. While Wu et al. (2012) found improved reaction times in cgdADHD seated on therapy balls, Tucha et al. (2010) found that chewing gum worsened reaction times in both TD and cgdADHD. Following a similar pattern, Mead et al. (2016)

found a positive effect of therapy ball use on MAP scores, Fedewa et al. (2015), who also investigated therapy ball use, found no effect.

The optimal arousal theory of attention difficulties predicts a beneficial effect of SMA in chronically understimulated children with attention difficulties (Zentall & Zentall, 1983). Within the present review, two studies, of relatively low quality, (Wu et al., 2012; Kercood & Banda, 2012) reported an effect of SMA on children reported as experiencing attention difficulties, but not on TD controls. This concurs with research investigating other types of stimulation-related interventions such as music and white noise (Abikoff et al., 1996; Söderland et al., 2007; 2010). The only other reviewed study to compare the effects of SMA on cgdADHD and TD participants was of relatively high quality and found a detrimental effect in both groups (Tucha et al., 2010). The inconsistent findings in relation to attention difficulties provide some tentative support for the optimal arousal theory and moderate brain arousal theories of attention difficulties, but the low quantity and quality of evidence precludes firm conclusions.

1.4.3 Strengths and Limitations of this Review

This review was, to the author's knowledge, the first to bring together research investigating different types of SMA. Research covering a wide breadth of topics was combined and synthesised, allowing links to be made between different areas. The broad search terms facilitated a thorough search of available literature, ensuring that findings were not limited by existing reviewer expectations. The search process was systematic and replicable. Validity checks performed by a research assistant added to the robustness of the review process.

A limitation of this review process, related to the scope of this project, is that the search was limited to include only English language studies published in peer-reviewed journals. This means there is a possibility of a language and a publication bias and the findings of this review may not accurately reflect the research that has been conducted in this area.

In addition, the decisions taken regarding the inclusion and exclusion criteria of the studies, while incurring some benefits, also represent a limitation of this review. The inclusion of research investigating other types of small movement, such as gesture, would have allowed these different types to be compared and contrasted, potentially enabling greater insight into the links between movement, attention and learning. Including studies that measured the effects of SMA on classroom behaviours, including on-task behaviour, may have provided greater insight into the nature of any effects on learning.

1.4.4 Directions for Future Research

Few studies have investigated the effects of SMA on attention and learning in children. Moreover, the inconsistency of findings so far indicates a need for improved methodological quality in future research. Researchers should aim to use robust designs, accounting for participant variables where possible; for example, measuring group differences and accounting for them within analyses. Other potential confounders (e.g., anxiety, fatigue) should also be identified and accounted for within analyses. Studies should be appropriately powered in order to identify any effects.

The use of validated measures that run across studies would allow findings to be compared based on the specific constructs measured would enable greater understanding of the ways in which SMA may affect attention and learning. Importantly, future research could contribute to theoretical understanding in this area by including a measure of arousal.

In terms of specific types of SMA, replication is needed in all areas. In addition, studies of fidgeting could use different fidget toys, different outcome measures and participants of different ages, including TD children. The chewing literature includes a range of designs but is most limited in quantity. Therefore, replication of existing studies and new designs, with a focus on high quality methodology, would help to further understanding. Alternative seating research has focused mainly on learning; in addition to replicating these designs, a greater focus on attention would be beneficial. Doodling research is severely limited in quantity and quality and high quality research is needed to explore initial links, to form a foundation for further, more nuanced, study.

1.4.5 Summary and Recommendations for Educational Professionals

This review provides up-to-date information to assist educational professionals in their decision-making about whether to encourage or disallow SMAs in school. This is particularly relevant at the current time, when SMA devices are growing in popularity and are increasingly present in schools.

This review has brought together and examined a diverse literature of 15 studies in order to assess the effects of SMA on attention and learning in children aged 0-18. The overall quality of the research is moderate to low, with only one high quality study. Findings are inconsistent, precluding a clear answer to the research question. In order to advance our understanding of SMA's effects on attention and learning in children, a greater quantity and quality of research is needed, in line with the recommendations for future research detailed above. Action research carried out by educational professionals could contribute to a more robust literature.

With respect to fidgeting, the review highlights some evidence that the use of Tangle Teaser fidget toys may be helpful for junior school aged children who experience difficulties with their attention, to help them with maths problem solving. Therefore, as there is no evidence that using these toys is detrimental to attention or learning outcomes, teachers may wish to provide or allow the use of similar fidget toys for children similar to the study participants. In contrast, no confident recommendations can be made for encouraging doodling based on the limited quantity and problems with study quality.

Based on the available evidence, and in light of the larger body of adult chewing research, chewing gum may support maths learning over time. However, further stringent evaluation of the effectiveness of this strategy is recommended, particularly regarding the influence of timing. Considering the cost and practical issues associated with alternative seating, the available evidence does not support their use for improving attention and learning of large groups of children.

The evidence considered in this review is not sufficient in quantity or in quality to inform strong recommendations for teachers and other educational professionals. It does not support a blanket recommendation to use SMA either in a general population or for children who experience attention difficulties, nor does it offer a strong caution against use of SMA. Although currently available information is insufficient to explain the inconsistencies within the literature, positive findings from a small number of higher quality studies do indicate that SMA can have beneficial effects.

Educational professionals must continue to base decisions on practice-based evidence. An open mind towards SMA is recommended, particularly for children who experience difficulties with attention, as the literature suggests that a beneficial effect of SMA is more likely in these children. In line with the inconsistent research findings, teachers may find that using SMA works well for one child but not for another, or that one particular type of SMA works better than another. In all cases, careful and ethical experimentation and monitoring is recommended.

Chapter 2 Does doodling increase arousal, sustained attention and working memory in children?

2.1 Introduction

2.1.1 Educational context

In recent decades there has been a shift in the philosophy underlying the British education system (Armstrong et al., 2016). Historically, children were expected to conform to pre-existing systems. The expectation now rests on teachers to shape teaching and learning structures around the strengths and needs of individual learners and to effect best educational outcomes (UNESCO, 2005; Code of Practice, 2015). This cultural shift has led to a move away from a 'one size fits all' education system and towards an individualised education for all learners (Armstrong et al., 2016).

Within this educational context, responsibility for the outcomes of all children lies firmly with class teachers, regardless of any special educational needs (SEN; Code of Practice, 2015). A key component of high quality teaching is differentiation: teachers are asked to adapt the structure, content and approach of their teaching to match the strengths and needs of individual learners (Code of Practice, 2015; O'Brien & Guiney, 2001). This approach requires flexibility, as well as familiarity with a range of evidence-informed strategies that can support individuals in their areas of need.

One area of need is to ensure that children who experience challenges in core skills recognised to underpin learning (i.e., attention) are able to achieve in school. In the classroom setting, difficulties with attentional control are associated with increased off-task behaviour (DuPaul et al., 2004) and lower achievement over time (Duncan et al., 2007; Razza, Martin, & Brooks-Gunn, 2012). The investigation of strategies that may improve attention is, therefore, an important pursuit in order to address the needs of children and young people who may require additional support to achieve in school.

2.1.2 Theoretical Context: Attentional control

Attentional control can be conceptualised as a broad construct comprising a number of narrower constructs, including an ability to attend selectively to a particular stimulus, to filter out distractions and to sustain attention over a period of time (Lyons & Krasnegor, 1996). It also involves working memory (WM) processes linked to actively maintaining information related to the immediate task goals (DeCaro & Beilock, 2010; Lui & Tannock, 2007; Nairne, 1996; Wilson & Korn, 2007).

While attentional control has been found to have a heritable component (Fan, Wu, Fossella, & Posner, 2001; Fossella et al., 2002), it is also strongly influenced by internal and environmental factors. Worry and anxiety can reduce performance on difficult maths tasks by, for example, impacting WM processes (Beilock, 2008; review by Moran, 2016; Owens, Stevenson, Norgate, & Hadwin, 2008). Hadwin, Brogan and Stevenson (2005) further found that anxious children were less efficient than non-anxious children in completing verbal WM tasks, expending more time and effort in the process. Sleep deprivation has also been robustly found to negatively impact attention (Lim & Dinges, 2010). The typically observed decline in performance over time is exacerbated with sleep deprivation, regardless of the cognitive domain or type of task (Durmer & Dinges, 2005). Performance in short tasks (e.g., short-term recall and WM) is also lowered by sleep deprivation (Dinges, 1992).

2.1.3 Arousal and Attention

Arousal has a well-documented effect on both physical and cognitive performance (Andreassi, 1995; Barry, Clarke, McCarthy, Selikowitz, & Rushby, 2005; Kahneman, 1973). For example, in sports psychology, arousal regulation strategies, such as relaxation strategies and mental preparation routines have been used for many years to enhance athletic performance (Gould & Uldry, 1994). Consistent with this research, optimal arousal theory proposes an inverted U-shaped relationship between arousal and attention (Hebb, 1955; Kahneman, 1973). Within this framework, a moderate level is best for optimal attention (Hebb, 1955). Overarousal or underarousal lead to reduced attention performance and individuals typically try to keep arousal within an optimal range by seeking or reducing stimulation as needed (Leuba, 1955).

Optimal arousal theory has received some empirical support. Rapport et al. (2009) investigated movement levels in children given a diagnosis of ADHD (cgdADHD) and typically developing (TD) children while engaged in complex WM tasks and tasks requiring minimal WM. CgdADHD moved more than TD children and all participants showed increased movement during a high WM task compared to a low WM task. The authors interpreted these findings as evidence for a functional relationship between activity level and attentional control.

Further support for optimal arousal theory can be found in the literature examining pharmaceutical treatment of ADHD. In cgdADHD, who are chronically understimulated (Mann et al., 1992), treatment with stimulant medication can improve symptoms of ADHD through increasing the availability of synaptic dopamine (Volkow et al., 2001). This change leads to improvements in the symptoms of ADHD, including reduced inattention, impulsivity and hyperactivity and improved on-task behaviour, academic outcomes and social functioning (Greenhill et al., 2001).

Non-pharmaceutical methods of increasing stimulation have also garnered some evidence of effectiveness. For example, (Abikoff et al., 1996) investigated the effect of music on the maths performance of 40 boys. They found a positive effect of music in cgdADHD only and suggested that this auditory stimulation may improve performance by increasing arousal to more typical levels in chronically understimulated cgdADHD. White noise has also been found to exert a beneficial effect on the cognitive performance and off-task behaviour of children with attention difficulties (Cook, Bradley-Johnson, & Johnson, 2014; Söderlund et al., 2010; Söderlund et al., 2007). For example, in 51 secondary school pupils, Söderlund et al. (2010) found that white noise improved verbal recall in adolescents with teacher-rated attention difficulties, but diminished performance in controls. Similarly, a number of studies have found a positive effect of visual stimulation, induced by adding bright colours to tasks, on the sustained attention (SA) of cgdADHD (Belfiore, Grskovic, Murphy, & Zentall, 1996; Lee & Zentall, 2002; Zentall & Dwyer, 1988; Zentall, Grskovic, Javorsky, & Hall, 2000). Non-pharmaceutical methods of increasing stimulation are beneficial as they do not incur the side effects that can be associated with stimulant medication, such as headaches, tics, reduced appetite and difficulty falling asleep (Greenhill et al., 2001).

Small Motor Activity and Attention

Small motor activity (SMA) has been investigated as a way of regulating arousal and attention. SMA is defined as any small motor activity that can be carried out while staying in one space (e.g. while sitting at a desk) and that includes chewing, fidgeting, doodling and alternative seating that promotes small movements, such as therapy balls. Within optimal arousal theory, when arousal is too low for optimal attention, it can be increased through SMA, thereby improving attention (Leuba, 1955, Zentall & Zentall, 1983).

An early investigation of SMA (Csikszentmihalyi, 1975) conceptualised it as a kinaesthetic type of 'microflow' activity, defined as "activities that fill the gaps in daily routine" (p.159) and "unnecessary, simple behaviours" (p. 142). In order to investigate types and prevalence of microflow activities, Csikszentmihalyi asked 20 adults to document their activities for a 48-hour period, paying particular attention to noninstrumental activities that would usually be carried out automatically. Participants were then asked to go about their days as usual but omit these 'play' or noninstrumental activities. Findings indicated that participants' alertness and creativity were reduced following microflow deprivation. While the author acknowledged the small sample size, limited duration of the experiment and the possibility of participant lapses in intervention fidelity, this study represents early evidence to support the importance of SMA and that is consistent with the notion of optimal arousal.

A number of recent studies have investigated the effect of SMA on attention in children, many of which have reported positive effects. Several single case studies reported small positive effect of fidgeting on attention (Emmert, Kercood, & Grskovic, 2009; Kercood & Grskovic, 2010; Kercood, Grskovic, Lee, & Emmert, 2007). For example, Kercood et al. (2007) used a single case alternating treatment design to investigate the effect of fidgeting on maths problem solving in four 9-year-olds with teacher-reported attention difficulties. The authors reported that fidgeting improved maths performance in two out of the four participants.

Studies have also reported positive effects of doodling on attention and learning in adults and children. For example, Tadayan and Afhami (2016) reported higher post-lesson test scores in 13-16-year-old doodlers compared to non-doodlers. However, the authors did not investigate potential confounding group differences, particularly in relation to the self-allocation of participants to each group through their choice to doodle or not doodle during the lessons. Different task modalities were explored in two adult studies of doodling. Andrade (2010) reported a positive effect of doodling on auditory recall in 40 adults. In a follow-up study using tests of visual, rather than auditory, recall, Chan (2012) found a detrimental effect of doodling. These findings were explained in terms of competing task demands, with Chan's (2012) task and doodling instruction placing multiple demands on visual processing systems.

Several studies have found a positive effect of alternative seating on attention and learning in children (Kercood & Banda, 2012; Mead et al., 2016; Schilling et al., 2003). For example, Mead et al. (2016) found a positive effect of a nine-month therapy ball intervention on the standardised maths test scores of TD 11-12-year-olds. However, a number of single case and experimental studies have found no effect of therapy ball use on educational indices (e.g., reading comprehension, maths fluency; Fedewa et al., 2015; Goodmon et al., 2014; Taipalus et al., 2017) For example, Fedewa et al. (2015) found no effect of a nine-month therapy ball intervention on the maths and literacy learning in TD 7-8 year-olds.

Chewing gum has been investigated in relation to stress, alertness and attention in adults. A review (Allen & Smith, 2011) concluded that evidence supports a positive effect of chewing gum on WM and, more tentatively, on SA. A small number of studies have also investigated the effects of chewing gum on attention and learning in children (Tanzer et al., 2009; Tucha et al., 2010; Johnston et al., 2012). For example, Johnston et al. (2012) investigated the effect of chewing gum during maths lessons, tests and homework for 14 weeks on standardised maths test scores and class grades. In their sample of 106 13-16 year-olds, they found a positive effect of chewing gum on both measures of maths learning.

Individual differences in responsiveness to SMA interventions have been explored in relation to attentional control, with contrasting findings. Tucha et al. (2010) compared the vigilance and SA of TD children and cgdADHD under two counterbalanced conditions (chewing gum and control). Sixty-four children (aged 10-11 years) were each tested on two occasions, using a 15-minute computerised test. The researchers recorded slower reaction times under the gum chewing condition for both groups - indicating poorer vigilance - compared to a control condition. No differences were found in performance over time, indicating no group differences or effects of condition on SA. Wu et al. (2012) used a similar design to examine the effect of therapy ball use for 8-year-old cgdADHD and TD controls. Participants completed an auditory oddball task under two randomised seating conditions (therapy ball and chair) using behavioural reaction time and ERP. Under the chair condition, controls (vs cgdADHD) showed both reduced reaction time and P300 latency. These were significantly improved in cgdADHD under the therapy ball condition. These findings tentatively suggest that SMA may exert selective beneficial effects in children who experience difficulties with attentional control.

The influence of time has been explored by Tänzer et al. (2009), who used a between-groups design in which a gum chewing and a control group of TD 8-9 year-olds completed a 16-minute concentration test. Test responses were split into two-minute blocks, allowing the analysis of performance over time. Analysis found that participants who chewed gum performed less well than controls initially, but outperformed controls during the final four minutes (i.e., the final two blocks). These findings are novel as they introduce the idea that beneficial effects of SMA may become evident during later stages of a task.

Overall, studies investigating the effects of SMA on attention and learning in children have reported inconsistent findings across different methodologies and outcome measures. Individual differences in attentional control have been investigated; however, no other potentially moderating participant variables (e.g., anxiety, sleepiness) have been explored. Almost all studies in this literature propose that increased arousal is responsible for improved attention and learning; however, no study has included a measure of arousal.

2.1.4 Current study

The present study aimed to add to the existing literature by investigating the effect of doodling on attention in children. Based on optimal arousal theory, sustained attention (SA) and working memory (WM) were chosen as dependent variables likely to benefit from SMA. Auditory tests of SA and WM were used to minimise any interference effects. A focus on controlling for confounding variables was operationalised through a repeated-measures design in which two key confounders were measured. Heart rate (HR) was measured as an index of arousal. In addition, we aimed to extend current research to consider possible individual differences that might moderate outcomes, specifically trait anxiety, attentional control and sleepiness.

Our research questions were as follows:

1. Does doodling improve SA and WM?
2. Does doodling increase arousal?
3. Are changes in arousal linked to changes in attention?

4. Are any potential positive effects of doodling influenced by trait anxiety, attentional control or sleepiness?

Our hypotheses were as follows:

1. Better performance on WM and SA tasks was expected under the doodling condition.
2. Higher HR was expected under the doodling condition.
3. It was expected that changes in HR would predict changes in performance.
4. It was expected that doodling may have the strongest positive impact on individuals who reported increased sleepiness, lower attentional control and increased trait anxiety.

2.2 Method

2.2.1 Design

A repeated-measures design was used to measure the effect of condition (independent variable [IV]; doodling [D]/non-doodling [ND]) on SA (dependent variable [DV]) and WM (DV). State anxiety and fatigue were considered as potential confounders. Linear mixed modelling was used to ascertain whether this effect was moderated by self-rated attentional control, trait anxiety or sleepiness.

2.2.2 Participants

Fifty-five participants from four schools took part aged 9 to 10 years old (n = 30 females). Ethnicities represented were White British (80%), Asian (10.9%), White European (5.45%) and White and Black African (3.64%). School attendance ranged from 80.7% to 100% (M = 96.58% SD = 4.45). Schools identified SEN (speech and language difficulties, specific learning difficulties, autism spectrum condition) in 6 (11%) participants and English as an additional language in 5 (9%) participants. Teachers reported that, in literacy, 11 (20%) participants were working at age-related expectations. Thirty-four (61.82) participants were working towards expectations and six (10.91%) were exceeding expectations. In maths, 23 (41.82%) participants were working at age-related expectations. Twenty-seven (49.10%) were working towards expectations and five (9.09%) were exceeding expectations. Participant characteristics measured using the Strengths and Difficulties Questionnaire (SDQ; see Measures section) are presented in

Appendix E. Nine teachers also participated by providing behavioural and demographic information about the children.

Participants were recruited through opt-in consent. First, head teachers were approached for permission to recruit in their schools. Next, consent was obtained from class teachers (see Appendix F). Letters were sent to parents/carers of children in the classes of the teachers who gave consent (see Appendix G). Children whose parents had consented for them to take part were asked to attend a short session with the researcher, in small groups of approximately five children. The researcher read the child information sheet (see Appendix H), demonstrated the fingertip pulse oximeter and answered any questions. Children were then asked to sign an assent form if they wanted to participate (see Appendix H).

2.2.3 Measures and Materials

2.2.3.1 Sustained attention and working memory.

SA was measured using the code transmission subtest from the Test of Everyday Attention for Children (TEA-Ch; Manley, Robertson, Anderson, & Nimmo-Smith, 1999). This test is published in standardised format and has a good test-retest reliability (r=.78) and good construct and discriminant validity (Manley et al., 1999). Scores range from 0 to 40 (one point per correct response) and a high score indicates good SA. This test lasts 12 minutes.

WM was measured using the letter number sequencing subtest of the Weschler Intelligence Scale for Children (WISC-IV; Fourth Edition; Weschler, 2003). This is a standardised test with a high test-retest reliability (r=.83) and good concurrent validity (Weschler, 2003). Scores range from 0 to 30 (one point per correct response) and a high score indicates good WM. The time taken to complete this test in the current sample ranged from 2:20 minutes to 15:35 minutes (M= 5:29 minutes, SD = 2:01 minutes).

2.2.3.2 State and trait anxiety.

State anxiety was measured using the Children's Anxiety Meter – State (CAM-S; Ersig, Kleiber, McCarthy, & Hanrahan, 2013). In this measure children are asked to colour in a thermometer, marked at intervals and labelled 0 to 10, to represent their level of anxiety 'right now'. A high score represents high anxiety. The CAM-S has been validated with children aged four to 10 years old. CAM-S scores correlated with observed behavioural distress (r=.19), parent ratings of child anxiety (r=.18) and parent ratings of expected child distress (r=.25). State anxiety was measured at the start and end of each session and a mean score was calculated in order to represent anxiety during the entire session.

Trait anxiety was measured using the Revised Children's Manifest Anxiety Scale (Second Edition; RCMAS-2; Reynolds & Richmond, 2008). This is a self-report questionnaire with 49 items, which are answered 'yes' or 'no'. The test comprises four subscales: social anxiety, worry, physical anxiety and defensiveness. Total anxiety, used within this analysis, is the sum of the social anxiety, worry and physical anxiety subscales. Raw scores (total possible score = 40) are converted to standard scores, ranging from 0 to 100 and a high score indicates high anxiety. Score ranges are described: 71 and higher indicates extremely problematic; 61-70 indicates moderately problematic; 40-60 indicates no more problematic than for most students; 39 and low indicates less problematic than for most students. Excellent internal consistency (α =0.92) and adequate test retest reliability (0.76) were found as well as good concurrent validity (Reynolds & Richmond, 2008). Internal consistency within the current sample was adequate (α = .784).

2.2.3.3 Sleepiness and fatigue.

Sleepiness was measured using the Epworth Sleepiness Scale—Revised for Children (ESS; Johns, 1991), an eight-item self-report questionnaire. Items are rated from 0 (‘never would doze or sleep’) to 3 (‘high chance of dozing or sleeping’), giving a total score of 0-24, with a high score indicating high sleepiness. Good internal consistency (α =0.75) and discriminant validity have been noted (Melendres, Lutz, Rubin, & Marcus, 2004; Moore et al., 2009). Internal consistency within the current sample was high (α = .818).

Current fatigue was measured using the Fatigue State Questionnaire (FSQ; Greenberg, Aislinn, & Kirsten, 2016). The FSQ is a four-item self-report questionnaire in which questions (e.g. ‘how tired does your body feel right now?’) are rated on a scale from 1 (‘not at all’) to 5 (‘extremely’) (score range = 4 – 20 and higher scores indicate more fatigue). The FSQ has good internal consistency (α=.73), test-retest reliability (r=.71) and external validity (Greenberg et al., 2016). Fatigue was measured at the start and end of each session and a mean score was calculated in order to best represent fatigue during the entire session.

2.2.3.4 Attentional control.

Attentional control was measured using the Attentional Control Scale for Children (ACS-C; Derryberry & Reed, 2002). This is a 20-item self-report questionnaire that measures attentional focusing (9 items) and attentional shifting (11 items). Items are rated on a scale from 1 ('almost never') to 4 ('always') (score range = 20 to 80 and higher scores indicate poorer attentional control) . Internal consistency is adequate (α =.67) (Muris, De Jong, & Engelen, 2004). Internal consistency within the current sample was adequate (α = .76).

The 5-item subscale of the hyperactivity-inattention subscale from the Strengths and Difficulties Questionnaire (SDQ) teacher questionnaire (R. Goodman, 2001) was used to obtain a teacher-reported measure of inattention and hyperactivity. This is a behavioural questionnaire comprised of 25 questions measuring five areas of functioning: emotional problems, conduct problems, hyperactivity-inattention, peer problems and prosocial behaviours. It has acceptable predictive and discriminant validity (Goodman, 1997; Goodman & Scott, 1999) Internal consistency within the current sample was high (α = .85). Each item is scored from 0 to 2, (subscale score range = 0 to 10).

2.2.3.5 Arousal.

Physiological arousal was measured using a fingertip pulse oximeter to record mean heart rate for each task (two means per testing session; four means per child). Resting heart rate varies widely between individuals. Children aged 9 to 10 years have an average heart rate of approximately 85 beats per minute (bpm), ranging from approximately 55bpm to 120 bpm (Fleming et al., 2011).

2.2.3.6 Participant characteristics.

The SDQ (described above) was also used to gather information about participant characteristics.

2.2.3.7 Intervention.

Doodling was produced on A4 pages of alternating square and circle outlines (following Andrade (2010); see appendix J). Participants were shown the doodling sheets and given the following instructions alongside a demonstration. "I've got some sheets of paper with shapes on and I'd like you to scribble in the shapes. You don't have to stay in the lines, as long as you're just scribbling. I don't want you to draw pictures – I just want you to scribble."

The word "scribbling" was used instead of "doodling" to encourage intervention fidelity. Several different acceptable ways of scribbling in the shapes were demonstrated. Each participant then made an attempt on the example sheet while the researcher observed to ensure that participants were making small, repetitive movements without paying too much attention.

2.2.4 Procedure

Each testing session involved the following steps (shown in Figure 2). The fingertip pulse oximeter was placed on the child's non-writing hand and was checked to ensure that a reading was shown. Participants then completed the FSQ and the CAM-S. The pulse oximeter was then switched to 'record' mode and the first test (either letter number sequencing or code transmission) was started (the order of these was counterbalanced). On completion of the first test, recording was stopped on the pulse oximeter and it was switched for another unit. After ensuring that a reading was shown, the second oximeter was switched to record and the second test was started. On completion of the second test, recording was stopped on the pulse oximeter and the unit was removed. Participants then completed the FSQ and CAM-S again, were thanked for their time and returned to class. In the doodling condition, doodling instructions were given after the completion of the first FSQ and CAM-S. The order of the conditions (doodling and non-doodling), as well as the order of the tests, was counterbalanced: each participant completed the tests in one of eight possible orders.

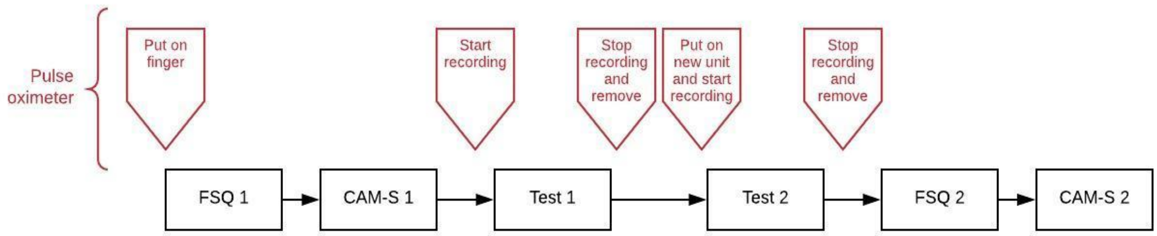


Figure 2. Procedure for individual testing sessions.

Note. FSQ = Fatigue State Questionnaire, CAM-S = Children's Anxiety Meter – State

After both testing sessions were completed, participants were asked to complete the three further questionnaires in groups (i.e., ACS-C, RCMAS-2, ESS). At the end of each group questionnaire session, participants were read and given a debrief sheet (see Appendix I) and their book tokens. Teachers were asked to provide background information and complete a SDQ about each participant.

HR data were uploaded to SP02 Review. A report was generated for each set of data and the mean HR was recorded in SPSS. All other data were entered directly into SPSS for analysis.

2.3 Results

2.3.1 Data Preparation

Scaled scores were calculated for the working memory (WM) and sustained attention (SA) tests, using the tables provided in the scoring manuals. Pearson's correlations indicated that the two fatigue scores within each session were significantly related (ND $r = .57$, $p < .001$; D $r = .53$, $p < .001$); therefore the two scores were collapsed into one mean score for each session. Similarly, the two state anxiety scores within each session (non-doodling [ND] and doodling [D]) were also significantly correlated (ND $r = .57$, $p < .001$; D $r = .49$, $p < .001$); therefore these were also collapsed into one mean score for each session. Change scores were calculated for all six variables that were measured twice (i.e., state anxiety, fatigue, WM, SA, heart rate during working memory [HR{WM}] and heart rate during sustained attention [HR{SA}]) by subtracting doodling scores from non-doodling scores; see Table 7).

2.3.2 Preliminary Analyses

The distribution of each set of data was assessed using skewness and kurtosis z scores and visual inspection of histograms and normal Q-Q plots (see Appendix K). Ten of the 16 sets of data were not normally distributed and were transformed. Z scores, histograms and normal Q-Q plots for the transformed variables are in Appendix L. The normality of SDQ inattention-hyperactivity scores was not improved by transformation so original data were retained.

Following correction of data distribution, all data sets were inspected for outliers. Fifteen were identified across all data sets (see Appendix K for box plots). Outliers were retained as they represented real data and were not judged to be extreme.

2.3.3 Descriptive Statistics

Descriptive statistics were generated for each DV. These are shown in Table 5 and Table 6 below. Performance and heart rate (HR) scores for each task under each condition are shown in Figures 3 and 4.

Descriptive statistics for the change scores are presented in Table 7 below. A positive score indicates a higher score (better performance, higher HR, higher fatigue/anxiety) under the doodling condition. The distribution of change scores was assessed using skewness and kurtosis z scores, visual inspection of histograms and normal Q-Q plots (see Appendix M). Four of the six data sets were not normally distributed.

Of the 55 participants, 41 (74.5%) followed the doodling instructions for the duration of the session. The doodling sheets of 10 participants (18.2%) contained some abstract patterns, and those of four participants (7.3%) contained some meaningful drawings (e.g. animals, faces).

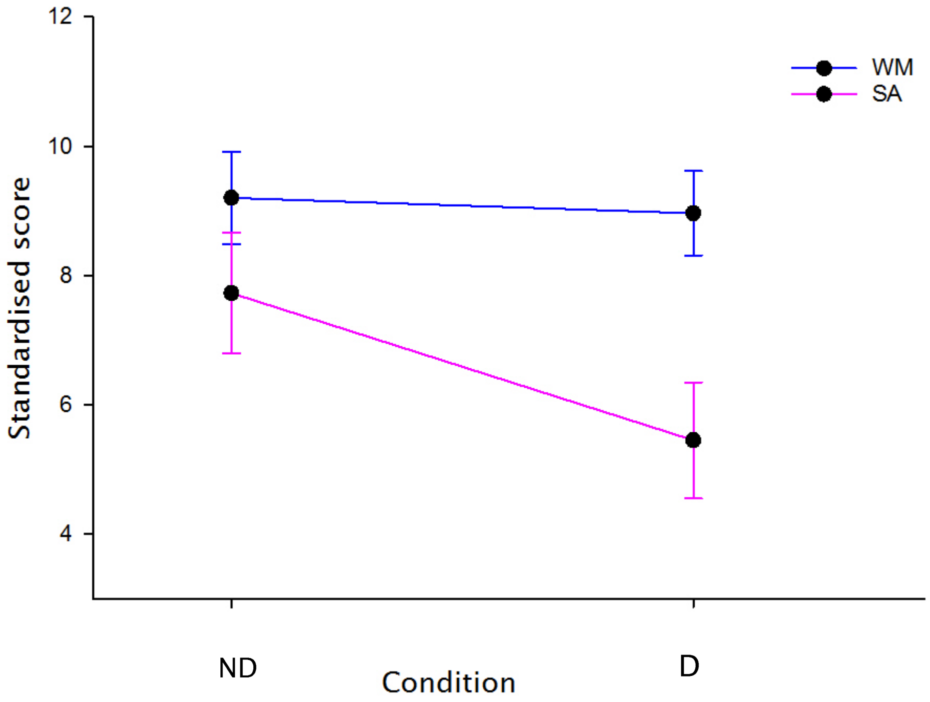


Figure 3. Working memory (WM) and sustained attention (SA) standardised scores under ND and D conditions.

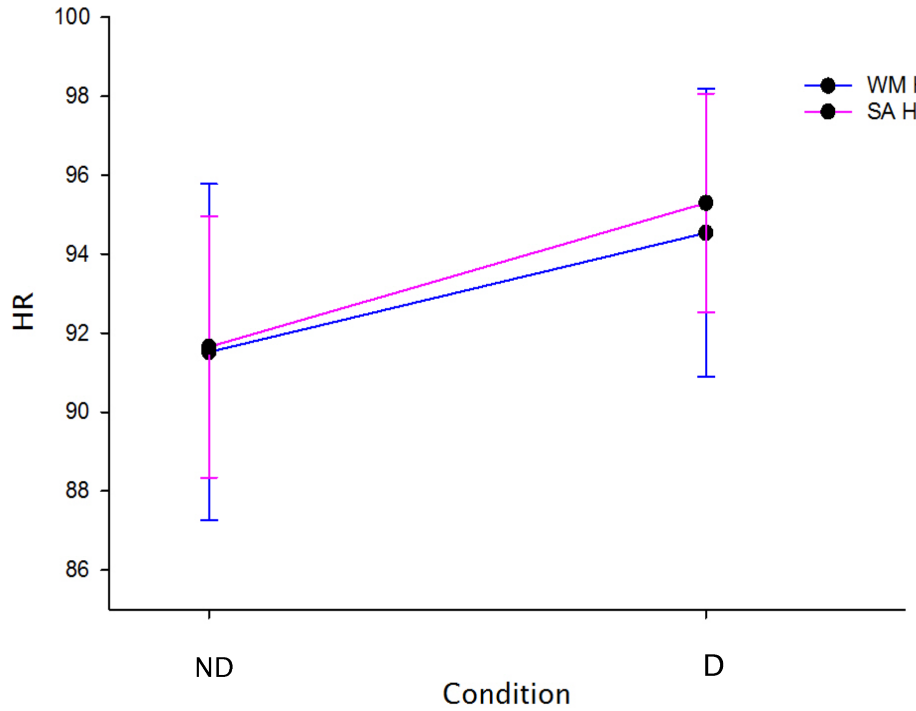


Figure 4. Working memory (WM) heart rate (HR) and sustained attention (SA) HR under ND and D conditions.

Table 5.

Descriptive Statistics for Self-reported and Teacher-reported Questionnaire Data

	N	Possible Range	Min	Max	M	SD	N above cut-off (borderline/abnormal)
ASC-C total	55	20-80	24	74	50.27	10.01	-
RCMAS-2 total	55	0-100	35	73	53.91	9.88	4/36/11/4[1]
ESS	55	0-24	0	24	9.49	6.19	-
SDQ inatt/hyp	55	0-10	0	10	3.13	3.11	5/9[2]

Note. ACS-C = Attentional Control Scale for Children, RCMAS-2 = Revised Children's Manifest Anxiety Scale 2, ESS = Epworth Sleepiness Scale, SDQ = Strengths and Difficulties Questionnaire.

1. Less problematic than for most students/no more problematic than for most students/moderately problematic/extremely problematic.

2. Borderline/abnormal.

Table 6.

Descriptive Statistics for Data from Individual Testing Sessions.

			Non doodling				Doodling			
	N	Possible Range	Min	Max	M	SD	Min	Max	M	SD
WM	55	1–19	2.0	13	9.20	2.70	3.0	13.0	8.96	2.47
HR (WM)	55	–	56.4	154	91.52	15.75	73.0	154.8	94.54	13.49
SA	55	1–13	1.0	13	7.73	3.52	1.0	11.0	5.45	3.38
HR (SA)	55	–	60.0	117.4	91.65	12.24	74.9	117.3	95.30	10.26
Mean anxiety	55	0–10	0.0	7	2.04	1.96	0.0	9.0	2.47	2.26
Mean fatigue	55	4–20	4.0	18	8.89	3.28	4	18.5	8.75	3.50

Note. WM = working memory, SA = sustained attention, HR = heart rate

Table 7.

Descriptive Statistics for Change Scores of Data from Individual Testing Sessions (Doodling – Non-doodling)

	N	Min	Max	M	SD	N with positive score	N with negative score
WM change	55	−5	7	−.24	1.95	19	25
SA change	55	−9	4	−2.27	2.96	5	36
HR (WM) change	55	−58.8	49	3.02	14.88	31	24
HR (SA) change	55	−29.8	31	3.64	10.98	33	22
Fatigue change	55	−7	7.5	−.15	2.85	24	28
Anxiety change	55	−3.5	5.5	.44	1.79	21	14

Note. WM = working memory, SA = sustained attention, HR = heart rate

2.3.4 Exploratory Analyses

Pearson's correlations were run in order to understand the relationships between the variables (see Table 8).

Within the doodling and the non-doodling condition, heart rate during the working memory task (HR[WM]) and heart rate during the sustained attention task (HR[SA]) were correlated, indicating that levels of arousal remained constant within each session. State anxiety and fatigue scores were also correlated within both conditions.

Working memory (WM) and sustained attention (SA) performance were correlated within the doodling condition only, indicating that performances were more similar while doodling. In addition, under the doodling condition, fatigue was correlated with WM performance, with higher fatigue levels related to lower WM performance.

All measures taken to investigate moderating factors (i.e. attentional control, trait anxiety, sleepiness, hyperactivity) were significantly related to each other as expected. Attentional control and hyperactivity were significantly or near significantly related to WM and SA performance under both conditions. Reports of better attention were linked to better performance on the tasks. Sleepiness was significantly related to WM but not SA under both conditions: increased sleepiness was linked to poorer performance. Trait anxiety was related to WM performance under the non-doodling condition at a near significant level.

Table 8.

Two-tailed Correlations between Measures from ND (below diagonal) and D (above diagonal) Sessions and Moderators

		1	2	3	4	5	6	7	8	9	10
	WM $_s$	1	.10	.30*	.00	−.18	−.36**	−.25#	−.22	−.28*	−.30*
2	HR (WM) $_s$	.07	1	.03	.79**	−.01	−.00	.06	.17	−.06	−.14
3	SA	.13	.11	1	−.05	.13	.03	−.40**	−.15	−.13	−.33*
4	HR (SA)	.16	.84**	.06	1	0.1	−.00	.15	.20	−.05	−.17
5	Anxiety $_s$	.00	.11	.08	.16	1	.33*	−.10	.16	.09	.02
6	Fatigue $_s$	−.30*	−.11	−.01	−.11	.31*	1	.24#	.21	.29*	.29*
7	ACS-C	−.42**	−.05	−.33*	−.02	.00	.24#	1	.53**	.57**	.38**
8	RCMAS-2	−.24#	.12	−.12	.13	.19	.32*	.53**	1	.29*	.40**
9	ESS$_s$	−.31*	−.12	−.16	−.10	−.04	.34*	.57**	.29*	1	.46**
10	SDQ $_s$	−.25#	−.25#	−.26#	−.16	−.01	.25#	.38**	.40**	.46**	1

Note: N = 55, # = p≤.10,* = significant at p≤.05, ** = significant at p≤.01,s= Spearman's Rank Order Correlation

2.3.5 Linear Mixed Models

Linear mixed models were used to investigate the effect of condition on performance and heart rate (HR) – while accounting for differences in state anxiety and fatigue – along with any moderating effects of trait anxiety, attentional control and sleepiness. Parallel analyses were run using SDQ hyperactivity scores as an alternative measure of attentional control. All predictors were grand mean centred.

A top-down model-building approach was used beginning with a loaded model, including all factors, as well as all interactions. A hypothesis-driven approach was used to guide the selection of fixed factors: only the main effects of condition and interactions that included condition were of interest. Differences in model fit were assessed as the factors were removed, using critical values for chi-square to assess whether the change in -2 Log Likelihood values was significant (Field, 2013). Where models were not significantly different, the more parsimonious model was retained. Confounding effects of state anxiety and fatigue were assessed by individually adding them into the model as main effects and comparing the regression coefficients for condition with and without these variables. A large change in coefficient would indicate a confounding effect.

2.3.5.1 Does doodling improve sustained attention, and is this moderated by trait anxiety, attentional control or sleepiness?

A linear mixed model was run to investigate the effect of condition on sustained attention (SA) and the moderating effects of trait anxiety, attentional control and sleepiness. Participant ID was entered as the subject variable and condition was entered as the repeated variable. An unstructured covariance structure was selected for the repeated covariance type.

Only fixed effects were included initially and Restricted Maximum Likelihood (REML) estimation was used to explore different random effects and covariance structures. Variances under the two conditions were not equal; therefore, the unstructured covariance structure was retained. Adding a random intercept for condition (to allow the intercept to vary for each participant) resulted in a Hessian matrix warning, indicating that the model results may not be valid; therefore, the random intercept was removed.

Next, a series of models were tested with different factors removed. Main effects were removed along with interaction terms, as only interactions between covariables and condition were of interest. Maximum Likelihood (ML) estimation was used during this stage in order to allow comparison of models with different fixed effects.

The best-fitting and most parsimonious model included only condition as a fixed effect. Similar regression coefficients when state anxiety and fatigue were added into the model indicated that neither state anxiety nor fatigue exerted confounding effects. Residuals were normally distributed (K-S $p = .063$) and there were no outliers.

The final model showed a significant main effect of condition on SA scores, with lower scores recorded under the doodling condition, $F(1, 55) = 33.04$, $p < .001$). No interaction effects were found with attentional control, trait anxiety or sleepiness, indicating that the effect of condition on SA was not moderated by attentional control, trait anxiety, sleepiness, or combinations of these factors. A parallel analysis was run using SDQ hyperactivity-inattention scores instead of ACS-C scores, which generated the same final model.

Table 9.

Parameter Information for Final Model Showing Effect of Condition on Sustained Attention

Parameter	B	SE	T	Sig.
Intercept	5.45	.45	12.09	<.001
Condition (ND)	2.27	.40	5.74	<.001
Condition (D)	0[b]	0	-	-

a. Dependent Variable: SA
b. This parameter is set to zero because it is redundant.

2.3.5.2 Does doodling improve working memory, and is this moderated by trait anxiety, attentional control or sleepiness?

A linear mixed model was run to investigate the effect of condition on working memory (WM) and the moderating effects of trait anxiety, attentional control and sleepiness. The same procedure was used as for sustained attention (SA). Variances under the two conditions were not equal; therefore, the unstructured covariance structure was retained. Adding a random intercept for condition (to allow the intercept to vary for each participant) did not improve the model fit; therefore, it was removed. Next, a series of models were tested with different factors removed, following the procedure reported for SA.

The best-fitting and most parsimonious model included condition, attentional control and the interaction between condition and attentional control as fixed effects. Similar regression coefficients when state anxiety and fatigue were added into the model indicated that neither state anxiety nor fatigue exerted confounding effects. Residuals were normally distributed (K-S $p = .058$) and there were no outliers.

Results indicated that the main effect of condition on WM performance was not significant ($p = .22$). A significant main effect of attentional control on WM performance was found, as expected, $F(1, 55) = 7.3$, $p = .009$. An interaction between attentional control and condition, approaching significance, also predicted WM performance, indicating a moderating effect of attentional control, $F(1, 55) = 3.29$, $p = .075$. Figure 5 indicates that poorer self-reported attentional control was linked with better WM performance under the doodling condition, whereas better self-reported attentional control is linked with better WM performance under the non-doodling condition.

Table 10.

Parameter Information for Final Model Showing Effect of Condition on Working Memory and Moderating Effect of attentional control (ACS-C)

Parameter	B	SE	T	Sig.
Intercept	2.18	.07	31.00	<.001
Condition (ND)	-.07	.05	-1.24	.22
Condition (D)	0[b]	0	-	-
ACS-C	.01	.01	1.83	.073
Condition * ACS-C	.01	.01	1.82	.075

a. Dependent Variable: WM
b. This parameter is set to zero because it is redundant.

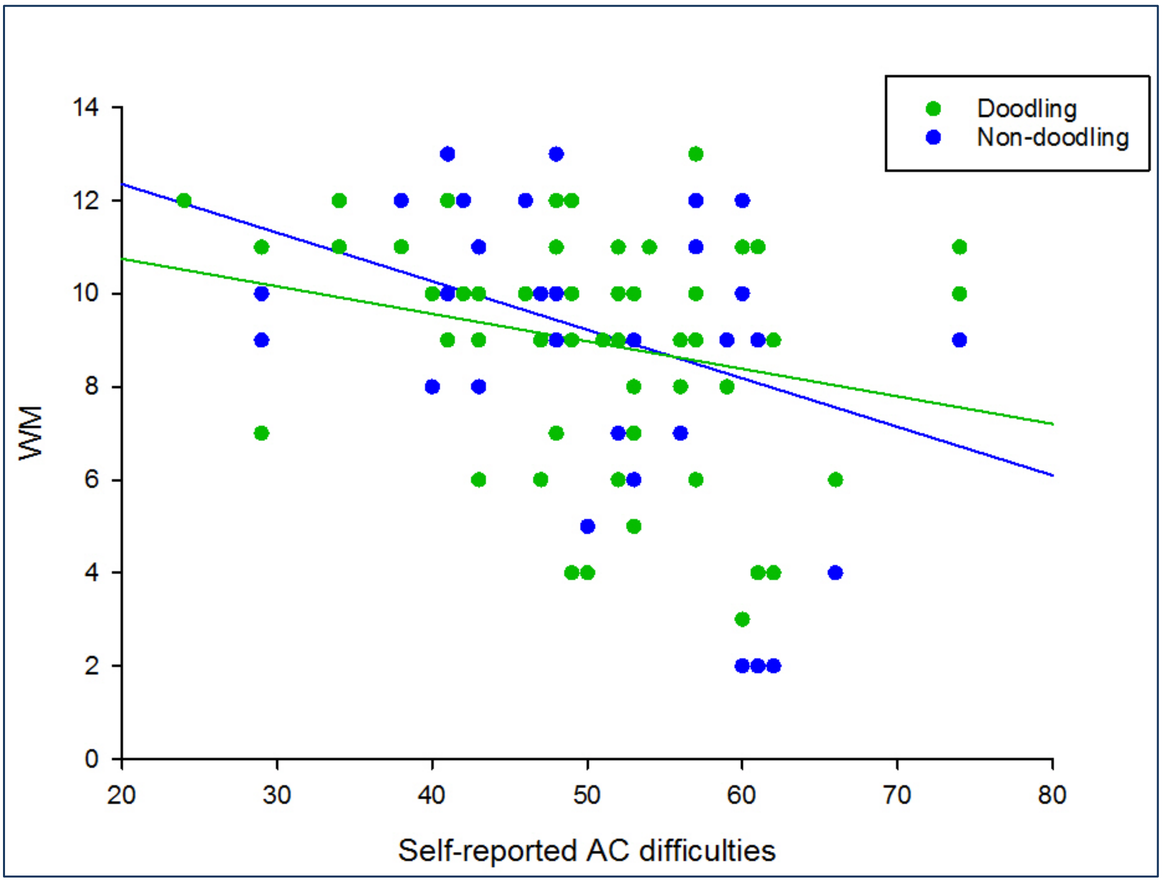


Figure 5. Scatter graph showing interaction between self-reported AC difficulties (ACS-C total) and condition (ND/D) on WM

A parallel analysis was run using SDQ hyperactivity-inattention scores instead of ACS-C scores. Variances under the two conditions were not equal; therefore, the unstructured covariance structure was retained. Adding a random intercept for condition (to allow the intercept to vary for each participant) resulted in a Hessian matrix warning, indicating that the model results may not be valid; therefore, the random intercept was removed.

The best-fitting and most parsimonious model is presented below. State anxiety and fatigue were individually added into the model and the regression coefficients for condition were compared with and without these variables. Similar regression coefficients indicated that state anxiety and fatigue did not exert confounding effects. A Kolmogorov-Smirnov test indicated that the residuals were not normally distributed (K-S $p < .001$); however, inspection of the Normal Q-Q plot and of skewness and kurtosis z scores indicated that the deviation from normality was not severe (skewness $z = 1.80$, kurtosis $z = -0.39$). There were three outliers, which were not extreme.

Table 11.

Parameter Information for Final Model Showing Effect of Condition on Working Memory

Parameter	B	SE	T	Sig.
Intercept	2.18	.07	30.00	<.001
Condition (ND)	-.07	.06	-1.20	.24
Condition (D)	0[b]	0	-	-

a. Dependent Variable: WM
b. This parameter is set to zero because it is redundant.

Results showed an insignificant main effect of condition on WM scores, $F(1, 55) = 1.44$, $p = .24$). No interaction effects were found with attentional control, trait anxiety or sleepiness, indicating that the effect of condition on WM was not moderated by attentional control, trait anxiety, sleepiness, or combinations of these factors.

2.3.5.3 Does doodling increase heart rate during a sustained attention task, and is this moderated by trait anxiety, attentional control or sleepiness?

A linear mixed model was run to investigate the effect of condition on heart rate during the sustained attention task HR(SA) and the moderating effects of trait anxiety, attentional control and sleepiness. The same procedure was used as above. Variances under the two conditions were not equal; therefore, the unstructured covariance structure was retained. Adding a random intercept for condition (to allow the intercept to vary for each participant) resulted in a Hessian matrix warning, indicating that the model results may not be valid; therefore, the random intercept was removed. Next, a series of models were tested with different factors removed, following the same procedure as above.

The best-fitting and most parsimonious model included only condition. Similar regression coefficients when state anxiety and fatigue were added into the model indicated that neither state anxiety nor fatigue exerted confounding effects. Residuals were normally distributed (K-S $p = .20$) and there was one outlier, which was not extreme. A parallel analysis was run using SDQ hyperactivity-inattention scores instead of ACS-C scores, which generated the same final model.

Results showed a significant main effect of condition on HR(SA), indicating that HR(SA) was significantly higher under the doodling condition, $F(1, 55) = 6.17$, $p = .016$).

Table 12.

Parameter Information for Final Model Showing Effect of Condition on HR(SA)

Parameter	β	SE	t	Sig.
Intercept	95.29	1.37	69.55	<.001
Condition (ND)	-3.64	1.47	-2.48	.016
Condition (D)	0[b]	0	-	-

a. Dependent Variable: HR(SA)
b. This parameter is set to zero because it is redundant.

2.3.5.4 Does doodling increase heart rate during a working memory task, and is this moderated by trait anxiety, attentional control or sleepiness?

A linear mixed model was run to investigate the effect of condition on heart rate during the working memory task HR(WM) and the moderating effects of trait anxiety, attentional control and sleepiness. The same procedure was used as above. Variances under the two conditions were not equal; therefore, the unstructured covariance structure was retained. Adding a random intercept for condition (to allow the intercept to vary for each participant) resulted in a Hessian matrix warning, indicating that the model results may not be valid; therefore, the random intercept was removed. Next, a series of models was tested with different factors removed, following the same procedure as above.

The best-fitting and most parsimonious model included only condition. Similar regression coefficients, when state anxiety and fatigue were added into the model, indicated that neither state anxiety nor fatigue exerted confounding effects. Residuals were normally distributed (K-S $p = .20$) and there were four outliers, which were not extreme. A parallel analysis was run using SDQ hyperactivity-inattention scores instead of ACS-C scores, which generated the same final model.

Results showed a near-significant main effect of condition on HR(WM): heart rate was higher under the doodling condition, $F(1, 55) = 3.60$, $p = .063$).

Table 13.

Parameter Information for Final Model Showing Effect of Condition on HR(WM)

Parameter	B	SE	t	Sig.
Intercept	1.97	.01	256.77	<.001
Condition (ND)	-.02	-.01	-1.90	.063
Condition (D)	0^b	0	-	-

a. Dependent Variable: HR(WM)
b. This parameter is set to zero because it is redundant.

2.3.6 Are changes in arousal linked to changes in attention?

Linear regressions were run using change scores to ascertain if changes in performance scores (working memory [WM] and sustained attention [SA]) were predicted by change in heart rate [HR] (HR[WM] and HR[SA], respectively). For WM, one outlier was identified. Findings did not differ when the outlier was removed; therefore, it was retained as it represented real data. For SA, all assumptions were met. Results indicated that change in HR was not associated with change in performance for either WM ($p = .737$) or SA ($p = .947$).

2.4 Discussion

The aim of this study was to investigate performance on sustained attention (SA) and working memory (WM) tasks across doodling and non-doodling conditions, and to consider, the role played by arousal (HR) and the moderating effects of attentional control, trait anxiety and sleepiness. We anticipated that SA and WM would improve with doodling alongside an increase in HR. Attentional control, trait anxiety and sleepiness were expected to exert moderating effects on the relationship between condition and performance. A stronger positive effect of doodling on SA and WM was expected in participants with lower attentional control, higher trait anxiety and higher sleepiness. In line with expectations, this study found an increase in HR during the SA (significant) and WM (near significant) tasks under the doodling (vs. non-doodling) condition, indicating that doodling did increase arousal. However, SA performance declined significantly under the doodling condition, with no identified moderating effects. Doodling did not significantly affect WM performance; however, there was a moderating effect of self-reported attentional control that approached significance. Children who reported low attentional control benefitted slightly from doodling, while children who reported high attentional control deteriorated slightly in WM performance (and the reverse was true in the no doodling condition). Changes in HR did not predict changes in performance on either SA or WM tests, indicating that the increased arousal was not associated with performance in either task.

2.4.1 Sustained attention and working memory

This study found a decline in SA performance under the doodling condition. This finding is in line with Tucha et al.'s (2010), report of a detrimental effect of chewing gum on vigilance in TD children and cgdADHD. However, it contradicts much of the previous research, which has reported either positive or no effects of SMA on elements of attention and learning including vigilance, concentration, maths problem solving, literacy skills and standardised maths achievement tests. No overall effect of doodling on WM was found, and this finding is consistent with several previous studies. For example, Fedewa et al. (2015) and Taipalus et al. (2017) found no effect of therapy ball use on measures of maths and literacy.

One possible explanation for the decline in SA performance and the null effect on WM is interference from the doodling intervention. Interference effects have been reported in previous adult doodling research, which found a positive effect of doodling (an activity requiring visual processes) on performance of an auditory recall task (Andrade, 2010), but not a visual recall task (Chan, 2012). The present study was designed to minimise competing task demands by pairing a visual and kinaesthetic intervention with auditory tests of SA and WM; therefore, interference effects were not expected. However, unlike in previous studies, participants were given specific instructions about how to doodle (replicating Andrade's [2010] intervention). It is possible that the way in which the doodling condition was operationalised in the present study introduced a competing demand for cognitive resources that was greater than in other studies and was sufficient to overwhelm any benefits of increased arousal.

This interpretation is particularly relevant as Schott (2011) suggested that individuals typically doodle in a consistent way, for example, always drawing faces or always drawing geometrical patterns. The additional cognitive demand would be especially likely to impact performance on the WM task, which already required participants to work up to capacity to hold and manipulate increasingly large amounts of information at one time. The discrepancy in findings between Andrade's (2010) findings and our findings may be explained by the better-developed attentional control skills of the adult participants, meaning that they were better able to cope with the study demands.

Another possible explanation of our SA and WM findings relates to time. Tänzer et al. (2009), who used a similar outcome measure (concentration), found a poorer performance in participants who chewed gum (compared to controls) for the first 12 minutes of their task. However, during the final 4 minutes, gum-chewing participants outperformed controls. Similar results in adults were reported by Tucha and Simpson (2011), in which gum chewing was associated with poorer performance during the first 10 minutes of a 30-minute SA task, but better performance during later stages, relative to a control condition. Tucha and Simpson (2011) linked their findings to research on exercise, which also reported an initial negative effect on cognitive performance, followed by a beneficial effect after approximately 20 minutes (Lambourne & Tomporowski, 2010). In both studies, an interference effect was proposed to explain the initial negative effect of movement, followed by arousal-induced benefits (Tucha & Simpson, 2011; Lambourne & Tomporowski, 2010). This arousal-interference hypothesis could explain the present SA and WM findings. The SA task used in the current study was 12 minutes long; therefore, it is possible that it was not sufficiently long to demonstrate a positive effect of doodling on SA over time. The WM task was significantly shorter than the SA task, increasing the possibility that the task duration was insufficient to show arousal-based benefits.

2.4.2 Working memory and attentional control

While no overall effect of doodling on WM was found, the near-significant interaction of doodling with levels of attentional control warrants discussion. This finding partially supports optimal arousal theory: children who struggled most with attention – and, therefore, would be expected to have lower levels of arousal – performed better when doodling (vs non-doodling). This finding also concurs with Wu et al.'s (2012) study, which found a specific benefit of therapy ball use on the reaction times of cgdADHD, indicating improved ability to focus and sustain attention. WM has not been specifically investigated in relation to SMA; however, previous studies using maths problem solving tasks are closely related. Most of these were single case studies of fidgeting, involving participants identified as having attention difficulties (Kercood et al., 2007; Emmert et al., 2009; Kercood & Grskovic, 2010). The small positive effects reported in these studies line up with our findings of a slight positive effect of doodling on WM for those with lower self-reported attentional control.

Parallel analyses run using the two measures of attentional control generated different findings in relation to WM performance. A near-significant interaction effect was found between condition and self-reported attentional control (ACS-C); however, no interaction effect was found between condition and teacher-reported inattention/hyperactivity. Our findings support the concurrent validity of both measures: scores from each source were significantly correlated (r_s = .38 p = .004) and they related similarly to other variables (e.g., high scores on both measures were associated with high WM scores). However, the two measures differed slightly in relation to the specific constructs targeted and the level of detail elicited. The ACS-C specifically measured sustained attention and attentional switching, whereas the SDQ measured inattention and hyperactivity. In addition, teacher-completed SDQ responses are based on observable behavioural indicators, whereas the ACS-C allows participants to respond based on internal processes that may not always be obvious to an observer. These differences may explain the disparity in findings relating to WM.

2.4.3 Arousal

Heightened arousal has been reliably shown to exert cognitive benefits (Kahneman, 1973, Andreassi, 1995; Barry et al. 2005). In the present study, SA performance declined and WM performance did not differ in the presence of increased arousal between conditions. As only a small non-significant increase in HR was recorded for the WM task, it is possible that the change in arousal was not sufficient to improve WM performance overall. In addition to interference effects (discussed above), the index of arousal used in this study may have obscured the relationship between arousal and performance on the attention tasks. Arousal can be measured in a number of ways and HR may is a basic index of arousal. It is possible that this measure was not sufficiently sensitive to capture some changes or patterns in arousal, particularly as the changes were small. For example, heart rate variability (HRV), which measures variation in the time between heartbeats. HRV can react to changes more quickly than HR, making it a more sensitive measure of arousal (Appelhans & Luecken, 2006).

2.4.4 Other moderators

Self-reported attentional control was the only identified moderator on task performance between condition, and only in relation to WM. Self-reported sleepiness was significantly associated with WM (but not SA) under both conditions: increased sleepiness was associated with diminished WM performance. This replicates the findings of Lim and Dinges' (2005) meta-analysis, in which WM was found to be significantly impacted by sleep deprivation, with a moderate overall effect size. While simple attention tests (requiring only stimulus detection) were subject to a strong detrimental impact of sleep deprivation, performance on tests of complex attention (a category which would include the current SA test) was only slightly affected by sleep deprivation.

Trait anxiety was related to WM at a near significant level ($p = .076$) under the non doodling condition, consistent with the findings of Moran's (2016) meta-analysis, which highlighted an effect size of $g=-.334$ for the association between anxiety and WM and across 177 studies. Mental efficiency was not measured in this study and may have been more strongly related to trait anxiety, in line with Hadwin et al.'s (2005) findings that efficiency, rather than accuracy, was impacted by anxiety.

2.4.5 Strengths and limitations

This study was well-designed, well powered and highly original. A repeated measures design controlled for participant variables and the doodling condition was standardised by asking all participants to doodle in the same way, reducing variation and increasing validity. The possibility of demand characteristics was minimised by careful choice of wording to participants. Validity was further strengthened by measuring and accounting for potential confounders (state anxiety and fatigue) within the analyses. Dual analyses using two different measures of attentional control addressed the issue of shared method variance. The study contributed novel and useful findings to the evidence base. Specific elements of attentional control were measured using standardised tests with good validity and reliability, allowing the differential effects of doodling on different processes within attention to be investigated. This was the first SMA study to specifically investigate WM in children. The inclusion of a HR measure allowed the effect of doodling to be investigated in relation to optimal arousal theory.

This study was limited in external validity. The doodling intervention, the artificial tests of SA and WM and the one-to-one setting did not reflect participants' typical school experience, limiting generalisation to a classroom setting. There was also some variance in intervention fidelity: despite the instructions, some children drew designs or pictures. This may have increased the extent to which some children were distracted by the doodling, making it more difficult to identify any effects on attention. Although analyses of moderators were exploratory, the absence of expected moderating effects may indicate the need for a larger sample in order to identify moderating effects within statistical models of high complexity.

2.4.6 Further research

Future research should aim to replicate this study in order to confirm the current findings, and using a larger sample, as this may enable the identification of more complex relationships. The current study could be extended by investigating more naturalistic forms of doodling and by partitioning tasks to explore the moderating effect of time. A study that targets children identified as having poor attention might be beneficial and show clearer results. It would also be beneficial to study the impact of SMA on other factors related to learning such as mood and sense of control. This could improve understanding of any indirect effects of SMA interventions on learning.

Another avenue of exploration is children's perceptions of the effectiveness of SMA interventions and how they relate to objective measures of effectiveness. This could relate to cognitive performance or related factors and could inform teachers' use of child perceptions when planning and monitoring interventions.

2.4.7 Ontology, Epistemology and Axiology

This study reflects a particular ontological and epistemological position, which was adopted in line with a pragmatist stance. Pragmatism acknowledges the value of different ontological and epistemological positions in creating positive change (Bishop, 2015). The ultimate aim of this research was to produce information that would help educational professionals to improve attention in children. The current UK school system assumes a critical realist ontology and epistemology in relation to measuring learning in children, categorising assessed work as either 'right' or 'wrong' and using quantitative methods to measure progress.

In order to draw conclusions that can be easily and usefully applied within the current educational system, this study adopted a similar ontological and epistemological stance. The choice to use a quantitative methodology was based on this stance, and informed the selection of objective and quantitative measures of attention, which produced numerical data that could be analysed using quantitative methods and subjected to significance testing. The outcome measures for WM and SA reflect the critical realist acknowledgement of the existence of psychological constructs that can be measured and are shaped, but not fully constructed, by the lens of each individual.

2.4.8 Implications in an educational context

Based on the present findings, doodling as operationalised in this study cannot be recommended to improve SA. However, doodling may exert a small beneficial effect on WM for individuals who report difficulties with attentional control. More naturalistic forms of doodling may affect attention differently. The current findings also support the importance of minimising potential distractions in optimising children's attention.

Appendix A Searches

The following searches were conducted:

PsycInfo

((DE "Attention" OR DE "Attentional Capture" OR DE "Divided Attention" OR DE "Focused Attention" OR DE "Monitoring" OR DE "Selective Attention" OR DE "Sustained Attention" OR DE "Vigilance" OR DE "Visual Attention") OR (DE "Memory" OR DE "Autobiographical Memory" OR DE "Early Memories" OR DE "Eidetic Imagery" OR DE "Episodic Memory" OR DE "Explicit Memory" OR DE "False Memory" OR DE "Implicit Memory" OR DE "Long Term Memory" OR DE "Memory Consolidation" OR DE "Memory Decay" OR DE "Memory Trace" OR DE "Prospective Memory" OR DE "Reminiscence" OR DE "Repressed Memory" OR DE "Retrospective Memory" OR DE "Short Term Memory" OR DE "Spatial Memory" OR DE "Spontaneous Recovery (Learning)" OR DE "Verbal Memory" OR DE "Visual Memory") OR (DE "Learning" OR DE "Adult Learning" OR DE "Animal Learning" OR DE "Cat Learning" OR DE "Cognitive Hypothesis Testing" OR DE "Collaborative Learning" OR DE "Conditioning" OR DE "Cooperative Learning" OR DE "Discrimination Learning" OR DE "Electronic Learning" OR DE "Experiential Learning" OR DE "Extinction (Learning)" OR DE "Foreign Language Learning" OR DE "Generalization (Learning)" OR DE "Generation Effect (Learning)" OR DE "Implicit Learning" OR DE "Incidental Learning" OR DE "Intentional Learning" OR DE "Interference (Learning)" OR DE "Mastery Learning" OR DE "Maze Learning" OR DE "Mnemonic Learning" OR DE "Nonverbal Learning" OR DE "Observational Learning" OR DE "Organizational Learning" OR DE "Overlearning" OR DE "Perceptual Learning" OR DE "Probability Learning" OR DE "Problem Based Learning" OR DE "Rat Learning" OR DE "Relearning" OR DE "School Learning" OR DE "Self-Regulated Learning" OR DE "Sequential Learning" OR DE "Serial Learning" OR DE "Skill Learning" OR DE "Social Learning" OR DE "Spatial Learning" OR DE "Spontaneous Recovery (Learning)" OR DE "State Dependent Learning" OR DE "Transfer (Learning)" OR DE "Trial and Error Learning" OR DE "Verbal Learning") OR (DE "Cognition" OR DE "Animal Cognition" OR DE "Mental Lexicon") OR (DE "Attention Deficit Disorder" OR DE "Attention Deficit Disorder with Hyperactivity") OR (DE "Academic Achievement" OR DE "Academic Overachievement" OR DE "Academic Underachievement" OR DE "Achievement Gap" OR DE "College Academic Achievement" OR DE "Mathematics Achievement" OR DE "Reading Achievement" OR DE "Science Achievement")) AND ((DE "Chewing") OR (DE "Tactual Stimulation"

OR DE "Massage" OR DE "Tactual Displays") OR (DE "Physical Activity" OR DE "Actigraphy" OR DE "Exercise") OR ("fidget*") OR ("doodl*") OR ("exercise ball*") OR ("therapy ball*") OR ("stability ball*")) AND ((DE "Students" OR DE "Business Students" OR DE "Classmates" OR DE "College Students" OR DE "Dental Students" OR DE "Elementary School Students" OR DE "Graduate Students" OR DE "High School Students" OR DE "International Students" OR DE "Junior High School Students" OR DE "Kindergarten Students" OR DE "Law Students" OR DE "Medical Students" OR DE "Postgraduate Students" OR DE "Preschool Students" OR DE "Reentry Students" OR DE "Seminarians" OR DE "Special Education Students" OR DE "Transfer Students" OR DE "Vocational School Students") OR ("infants") OR ("children") OR ("adolescents"))

Medline

((MH "Attention+") OR (MH "Learning+") OR (MH "Cognition+") OR (MH "Memory+") OR (MH "Attention Deficit Disorder with Hyperactivity") OR (MH "Educational Status+")) AND ((MH "Chewing Gum") OR ("fidget*") OR ("doodl*") OR ("physical activity") OR ("tactile stimulation") OR ("exercise ball*") OR ("therapy ball*") OR ("stability ball*")) AND (("students") OR (MH "Child+") OR (MH "Adolescent") OR (MH "Infant+"))

ERIC

((SU.EXACT.EXPLODE("Attention") OR SU.EXACT.EXPLODE("Cognitive Processes") OR SU.EXACT.EXPLODE("Learning") OR SU.EXACT.EXPLODE("Attention Deficit Disorders") OR SU.EXACT.EXPLODE("Academic Achievement")) AND ("doodl*" OR "fidget*" OR SU.EXACT("Stimuli") OR SU.EXACT.EXPLODE("Physical Activity Level") OR "therapy ball*" OR "exercise ball*" OR "stability ball*" OR "chewing") AND (SU.EXACT.EXPLODE("Infants") OR SU.EXACT.EXPLODE("Children") OR SU.EXACT.EXPLODE("Adolescents") OR SU.EXACT.EXPLODE("Students"))) AND (stype.exact("Scholarly Journals") AND la.exact("ENG"))

Web of Science

((Attention) OR (Memory) OR (Learning) OR (Cognition) OR (“Attention Deficit Disorder”) OR (“Attention Deficit Hyperactivity Disorder”) OR (“Academic achievement”)) AND ((Fidget*) OR (Doodl*) OR (Chewing) OR (“Tactile Stimulation”) OR (“Exercise ball*”) OR (“Therapy ball*”) OR (“Stability ball*”) OR (“Physical activity”)) AND ((Infants) OR (Children) OR (Adolescents) OR (Students))

Appendix B Record of Category Filtering in Web of Science

Results were filtered by category in Web of Science due to the large number of irrelevant results. The category names, along with the number of results excluded under each category, are presented below. A total of 2030 results were excluded through this process.

Category	**Number of Results**
Public environmental occupational health	477
Sport sciences	309
Nutrition dietetics	174
Hospitality leisure sport tourism	116
Rehabilitation	94
Medicine general internal	91
Health care sciences services	81
Physiology	65
Endocrinology metabolism	65
Health policy services	41
Nursing	39
Medicine research experimental	32
Pharmacology pharmacy	29
Environmental sciences	28
Orthopedics	16
Biology	16
Family studies	15
Anthropology	14
Substance abuse	13
Obstetrics gynecology	13

Cardiac cardiovascular systems	13
Genetics heredity	12
Environmental studies	11
Sociology	10
Medical informatics	10
Gerontology	10
Urban studies	9
Transportation	9
Oncology	9
Food science technology	8
Computer science interdisciplinary applications	8
Social work	7
Communication	7
Information science library science	6
Economics	6
Developmental biology	6
Computer science information systems	6
Women s studies	5
Surgery	5
Respiratory system	5
Radiology nuclear medicine medical imaging	5
Engineering biomedical	5
Dentistry oral surgery medicine	5
Anesthesiology	5
Toxicology	4

Social issues	4
Rheumatology	4
Geriatrics gerontology	4
Forestry	4
Ergonomics	4
Computer science cybernetics	4
Biophysics	4
Transportation science technology	3
Plant sciences	3
Peripheral vascular disease	3
Otorhinolaryngology	3
Integrative complementary medicine	3
Instruments instrumentation	3
Immunology	3
Geography	3
Gastroenterology hepatology	3
Engineering civil	3
Electrochemistry	3
Critical care medicine	3
Computer science theory methods	3
Chemical analytical	3
Business	3
Biotechnology applied microbiology	3
Biochemistry molecular biology	3
Allergy	3
Hematology	2
Ethics	2

Engineering industrial	2
Ecology	2
Dance	2
Computer science software engineering	2
Computer science artificial intelligence	2
Cell biology	2
Andrology	2
Zoology	2
Veterinary sciences	2
Reproductive biology	1
Political science	1
PAthology	1
Ophthalmology	1
Music	1
Management	1
Humanities multidisciplinary	1
Horticulture	1
Engineering multidisciplinary	1
Business finance	1
Art	1
Architecture	1

Appendix C Downs and Black (1998) Checklist for Measuring Study Quality (Adapted)

Question and guidance	Scoring
Reporting	
1. Is the hypothesis/aim/objective of the study clearly described?	(Yes = 1, No = 0)
2. Are the main outcomes to be measured clearly described in the Introduction or Methods section? *If the main outcomes are first mentioned in the Results section, the question should be answered no.*	(Yes = 1, No = 0)
3. Are the characteristics of the patients included in the study clearly described? *In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given.*	(Yes = 1, No = 0)
4. Are the interventions of interest clearly described? *Treatments and placebo (where relevant) that are to be compared should be clearly described.*	(Yes = 1, No = 0)
5. Are the distributions of principal confounders in each group of subjects to be compared clearly described? *A list of principal confounders is provided.*	(Yes = 2, Partially = 1, No = 0)
6. Are the main findings of the study clearly described? *Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).*	(Yes = 1, No = 0)
8. Does the study provide estimates of the random variability in the data for the main outcomes? *In non-normally distributed data the inter-quartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.*	(Yes = 1, No = 0)

8. Have the characteristics of patients lost to follow-up been described? 9. *This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered 'no' where a study does not report the number of patients lost to follow-up.*	(Yes = 1, No = 0)
10. Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	(Yes = 1, No = 0)
External validity All the following criteria attempt to address the representativeness of the findings of the study and whether they may be generalised to the population from which the study subjects were derived.	
11. Were the subjects asked to participate in the study representative of the entire population from which they were recruited? *The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.*	(Yes = 1, No = 0, Unable to determine = 0)
12. Were those subjects who were prepared to participate representative of the entire population from which they were recruited? *The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.*	(Yes = 1, No = 0, Unable to determine = 0)

13. Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive? *For the question to be answered yes the study should demonstrate that the intervention was representative of that in use in the source population. The question should be answered no if, for example, the intervention was undertaken in a specialist centre unrepresentative of the hospitals most of the source population would attend. Additional notes: answer yes for typical school setting. Answer partially when set in a school with some deviations from norm (e.g. testing in empty classroom). Answer no for non-school setting.*	(Yes = 2, Partially = 1, No = 0, Unable to determine = 0)
Internal validity – bias	
14. a) Was an attempt made to blind study subjects to the intervention they have received? *For studies where the patients would have no way of knowing which intervention they received, this should be answered yes.*	(Yes = 1, No = 0, Unable to determine = 0)
14. b) Was an attempt made to blind study subjects to the study hypotheses?	(Yes = 1, No = 0, Unable to determine = 0)
15. a) Was an attempt made to blind those measuring the main outcomes of the intervention?	(Yes = 1, No = 0, Unable to determine = 0)
16. If any of the results of the study were based on “data dredging”, was this made clear? *Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.*	(Yes = 1, No = 0, Unable to determine = 0)
17. In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls? *Where follow-up was the same for all study patients the answer should yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.*	(Yes = 1, No = 0, Unable to determine = 0)

18. Were the statistical tests/methods of analysis used to assess the main outcomes appropriate? *The statistical techniques used must be appropriate to the data. For example non- parametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes. Additional note: visual inspection of graphs is considered appropriate in studies using single case experimental designs.*	(Yes = 1, No = 0, Unable to determine = 0)
19. Was compliance with the intervention/s reliable? *Where there was noncompliance with the allocated treatment or where there was contamination of one group, the question should be answered no. For studies where the effect of any misclassification was likely to bias any association to the null, the question should be answered yes.*	(Yes = 1, No = 0, Unable to determine = 0)
20. Were the main outcome measures used accurate (valid and reliable)? *For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.*	(Yes = 1, No = 0, Unable to determine = 0)
Internal validity - confounding (selection bias)	
21. Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population? *For example, patients for all comparison groups should be selected from the same hospital. The question should be answered unable to determine for cohort and case- control studies where there is no information concerning the source of patients included in the study*.	(Yes = 1, No = 0, Unable to determine = 0)
22. Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time? *For a study which does not specify the time period over which patients were recruited, the question should be answered as unable to determine.*	(Yes = 1, No = 0, Unable to determine = 0)

23. a) *Were study subjects randomised to intervention groups?* *Studies which state that subjects were randomised should be answered yes except where method of randomisation would not ensure random allocation. For example alternate allocation would score no because it is predictable. Additional note: applicable to studies using between-group designs in which each group only participates under one condition (not crossover designs).*	(Yes [individual participants] = 2, Yes [whole classes] = 1, No = 0, Unable to determine = 0)
23. b) For studies including within-group factors, were study subjects randomised to starting conditions?	(Yes = 1, No = 0, Unable to determine = 0)
23. c) Was the order of conditions counterbalanced?	(Yes = 1, No = 0, Unable to determine = 0)
24. Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable? *All non-randomised studies should be answered no. If assignment was concealed from patients but not from staff, it should be answered no.*	(Yes = 1, No = 0, Unable to determine = 0)
25. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn? *This question should be answered no for trials if: the main conclusions of the study were based on analyses of treatment rather than intention to treat; the distribution of known confounders in the different treatment groups was not described; or the distribution of known confounders differed between the treatment groups but was not taken into account in the analyses. In non-randomised studies if the effect of the main confounders was not investigated or con- founding was demonstrated but no adjustment was made in the final analyses the question should be answered as no.*	(Yes = 1, No = 0, Unable to determine = 0)
26. Were losses of patients to follow-up taken into account? *If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.*	(Yes = 1, No = 0, Unable to determine = 0)
Power	
27. a) Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?	(Yes = 1, No = 0, Unable to determine = 0)

27. b) For single case experimental designs, was there a minimum of three data points at baseline and three data points in each experimental condition?	(Yes = 1, No = 0, Unable to determine = 0)

Appendix D Quality Assessment

Question number (total points available)	Schilling, Washington, Billingsley & Deitz (2003)	Kercood, Grskovic, Lee & Emmert (2007)	Tänzer, von Fintel & Eikermann (2009)	Emmert et al. (2009)	Kercood & Grskovic (2010)	Tucha, Simpson, Evans, Birrel, Sontag, Lange & Tucha (2010)	Johnston, Tyler, Stansberry, Moreno & Foreyt (2012)	Kercood & Banda (2012)	Wu, Wang, Chen, Lai, Yang & Guo (2012)	Goodmon, Leverett, Royer, Hillard, Tedder & Rakes (2014)	Merritt (2014)	Fedewa, Davis & Ahn (2015)	Mead, Scibora, Gardner & Dunn (2016)	Tadayon & Afhami (2016)	Taipalus, Hixson, Kanouse, Wyse & Fursa (2017)
1 (1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2 (1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3 (1)	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1
4 (1)	1	1	1	1	1	1	1	0	1	1	0	0	1	1	1
5 (2)	–	–	0	–	–	2	2	–	2	1	1	1	1	0	–
6 (1)	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1
7 (1)	–	–	0	–	–	1	1	–	1	1	1	1	1	1	–
9 (1)	–	–	–	–	–	1	1	–	–	0	0	1	1	0	1

10 (1)	–	–	1	–	–	1	1	–	1	1	0	1	1	1	–
11 (1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12 (1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 (2)	2	1	1	1	1	0	2	1	0	2	2	2	2	2	2
14 a (1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 b (1)	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
15 (1)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
16 (1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17 (1)	–	–	–	–	–	1	1	–	1	1	1	1	1	1	–
18 (1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19 (1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20 (1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21 (1)	–	–	1	–	–	0	1	–	0	1	1	1	1	1	–
22 (1)	–	–	1	–	–	0	1	–	0	1	1	1	1	1	–
23 a (2)	–	–	1	–	–	–	1	–	–	–	0	1	1	0	–
23 b (1)	0	0	–	0	0 (study 1)	1	–	0	1	1	–	–	–	–	1

23 c (1)	0	0	–	0	1	1	–	0	–	0	–	–	–	–	0
24 (1)	–	–	0	–	–	–	0	–	–	–	0	0	0	0	–
25 (1)	–	–	0	–	–	1	1	–	0	1	1	0	1	0	–
26 (1)	–	–	–	–	–	–	1	–	–	0	0	1	1	0	–
27 a (1)	–	–	1	–	–	1	1	–	0	0	0	1	0	0	–
27 b (1)	1	1	–	1	1	–	–	1	–	–	–	–	–	–	1
No. applicable questions (total possible score)	18 (19)	18 (19)	24 (27)	18 (19)	18 (19)	26 (28)	27 (30)	18 (19)	24 (26)	27 (29)	27 (30)	27 (30)	27 (30)	27 (30)	19 (20)
Total score	13	11	15	11	12	19	24	9	15	19	14	19	21	15	14
Proportion score (2 d.p.)	0.68	0.58	0.56	0.58	0.63	0.68	0.8	0.47	0.58	0.66	0.47	0.63	0.7	0.5	0.7

Appendix E Participant Characteristics from SDQ

	Possible Range	Min	Max	M	SD
Total difficulties	40	0	36	9.02	8.84
Internalising	20	0	18	4.35	4.89
Externalising	20	0	18	4.67	5.03
Emotional	10	0	10	2.64	2.82
Conduct	10	0	8	1.55	2.43
Hyperactivity	10	0	10	3.13	3.11
Peer problems	10	0	9	1.71	2.43
Prosocial	10	1	10	8.07	2.57

Note. N = 55

	Number (percentage) of participants		
	Normal	Borderline	Abnormal
Total difficulties	38 (69.1%)	6 (10.9%)	11 (20.0%)
Emotional	42 (76.4%)	6 (10.9%)	7 (12.7%)
Conduct	45 (81.8%)	1 (1.8%)	9 (16.3%)
Hyperactivity	41 (74.5%)	5 (9.1%)	9 (16.3%)
Peer problems	45 (81.8%)	3 (5.5%)	7 (12.7%)
Prosocial	47 (85.5%)	2 (3.6%)	6 (10.9)

Appendix F Teacher information letter and consent form

Teacher Information Sheet (Version 1, 30/05/17)

How is doodling linked to children's attention?

We would like to invite you to take part in a research project.

It is important for you to know why the research is being done and what it will involve. Please read this information carefully and discuss it with others if you wish. If there is anything that is not clear, or if you would like more information or to ask any questions, please do not hesitate to contact Helen Jones at hmj1g14@soton.ac.uk.

The aim of the study
The aim of the study is to find out about the links between doodling and children's attention. The study will investigate links between doodling, levels of physiological arousal and performance on attention tasks.

Why is the study being done?
Being able to pay attention is important for children to learn at school. Regulation of attention is linked to regulation of physiological arousal (i.e. how calm or excited someone is), and there is some evidence that small movements such as doodling or fidgeting can affect physiological arousal and attention. Learning more about the links between doodling and attention may help schools to support children with their attention and learning.

Why have I been chosen?
All children currently in Year 4 at [insert name of school] and their class teachers for the next academic year (Year 5) are invited to take part.

What will happen if I take part?
If you agree to take part in this research, children in your class will be invited to participate in the research project:

Children who agree to take part will be asked to attend a short group session in which the main researcher (Helen) will introduce the research, explain what it will involve and answer any questions. Each child who agrees to take part in the research will sign an assent form. Each child will then be asked to take part in two sessions, each lasting approximately 30 minutes. These will take place during school time in the school. In each session, the main researcher (Helen) will work with each child individually and will ask each child to do two tasks to assess their attention. Each child will also be asked to complete some short questionnaires to indicate their levels of anxiety and fatigue. In one of the sessions, children will also be asked to doodle while performing the tasks. During both sessions, each child will wear a small machine clipped around one finger (called a fingertip pulse oximeter) to measure their heart rate.

After both sessions, at a time decided with you, children will be asked to complete three further questionnaires to indicate their general levels of attention, anxiety and sleepiness. These will be given out by the researcher to groups of children and should take no longer than 30 minutes to complete altogether.

What will my role be?
If you agree to take part in this research, you will be consulted about the research schedule to ensure that the children in your class do not miss any lessons that you feel are important for them to attend.

You will also be asked to complete a short questionnaire about each child and to tell us each child's current levels in literacy and maths, whether he/she has any identified special educational needs and how many school days he/she has been at school this year. This should take approximately 5 minutes per child.

Are there any risks involved?
Children who choose to participate will miss some lesson time – approximately 90-100 minutes in total. This will include a short group session to explain the research and gain assent, two individual sessions of approximately 30 minutes and one group session of approximately 20-30 minutes to complete questionnaires. The main researcher (Helen) will liaise with you to ensure that no child misses a lesson that you consider to be important for them to attend.

Depending on the number of children in your class who choose to take part, the time taken to provide information about the children may impact on your planning time. To compensate for this, your school will be given funding for supply cover, allocated according to the number of participating children.

Are there any benefits in taking part?
Through taking part in this research, you will contribute to knowledge about how to improve children's attention in school, which may be used to benefit you and your school.

Will my participation be confidential?
Yes, all information collected from you, the children in your class and their parents/carers during the course of this research will be kept strictly confidential and in a manner which complies with the data protection act and university policies. Identification numbers will be used in place of names and any identifying information (e.g. consent forms) will kept securely in a locked cabinet or on a password protected encrypted memory stick,

What happens if I change my mind?
If you decide that you do not wish to participate you are free to withdraw at any time.

What happens if something goes wrong?
If you have questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the Chair of the Ethics Committee, Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: +44 (0)23 8059 3856, email fshs-rso@soton.ac.uk

Where can I get more information?
If you have any questions or would like more information about this study please contact Helen Jones at hmj1g14@soton.ac.uk.

THANK YOU FOR TAKING THE TIME TO READ THIS INFORMATION

UNIVERSITY OF Southampton

CONSENT FORM (Version 1, 30/05/17)

How is doodling linked to children's attention?

Researcher name: Helen Jones
ERGO Study ID number:
RGO reference number:

Please initial the boxes if you agree with the statements:

I have read and understood the information sheet (30/05/17/version 1) and have had the opportunity to ask questions about the study	☐
I agree to take part in this research project and agree for the data I provide to be used for the purpose of this study	☐
I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected	☐

Name of teacher (print name)…………………………………………………

Signature of teacher…………………………………………………………….

Date…………………………………………………………………………………………….

Name of researcher (print name)…………………………………………………

Signature of researcher…………………………………………………………….

Date…………………………………………………………………………………………….

Appendix G Parent information letter and consent form

Parent Information Sheet (Version 2, 22/05/17)

How is doodling linked to children's attention?

Your child is being invited to take part in a research study. It is important for you to know why the research is being done and what it will involve. Please read this information carefully and discuss it with others if you wish. If there is anything that is not clear, or if you would like more information or to ask any questions, please do not hesitate to contact Helen Jones at hmj1g14@soton.ac.uk.

The aim of the study
The aim of the study is to find out about the links between doodling and children's attention. The study will investigate links between doodling, levels of physiological arousal and performance on attention tasks.

Why is the study being done?
Being able to pay attention is important for children to learn at school. Regulation of attention is linked to regulation of physiological arousal (i.e. how calm or excited someone is), and there is some evidence that small movements such as doodling or fidgeting can affect physiological arousal and attention. Learning more about the links between doodling and attention may help schools to support children with their attention and learning.

Why has my child been chosen?
All children currently in Year 4 at [insert name of school] have been invited to take part.

What will happen if my child takes part?
If you agree for your child to take part in this research, your child will be asked to attend a short group session in which the main researcher (Helen) will introduce the research, explain what it will involve and answer any questions. If your child agrees to take part in the research they will sign an assent form. Your child will then be asked to take part in two sessions, each lasting approximately 30 minutes. These will take place during school time in the school. In each session, the main researcher (Helen) will work with your child individually and will ask your child to do two tasks to assess their attention. Your child will also be asked to complete some short questionnaires to indicate their levels of anxiety and fatigue. In one of the sessions, your child will also be asked to doodle while performing the tasks. During both sessions, your child will wear a small machine clipped around one finger (called a fingertip pulse oximeter) to measure their heart rate.

After both sessions, at a time decided with your child's teacher, your child will be asked to complete three further questionnaires to indicate their general levels of attention, anxiety and sleepiness. These will be given out by the researcher to groups of children and should take no longer than 30 minutes to complete altogether. Your child's teacher will be asked to complete a short questionnaire about your child and also to tell us your child's current levels in literacy and maths, whether he/she has any identified special educational needs and how many school days he/she has been at school this year.

Are there any risks involved?

It is possible that your child may feel worried about taking part in the individual session or about their performance on the attention tasks. They will be reassured that it is normal to find the tasks challenging and that no one other than the researchers will know their individual scores. It is also possible that the content of the questionnaires may give rise to some worries. Your child will be informed that they can speak to their teacher or the researcher if they have any concerns.
You child will not miss any break times as a result of taking part and we will liaise with your child's class teacher to ensure that your child does not miss any lesson that the teacher believes is important for the child to attend.

Are there any benefits in my child taking part?
Your child will receive a £5 book token to thank them for their participation. Through taking part in this research, there may also be general benefits as your child will contribute to knowledge about how to improve children's attention in school.

Will my child's participation be confidential?
Yes, all information collected from you, your child and your child's teacher during the course of this research will be kept strictly confidential and in a manner which complies with the data protection act and university policies. Identification numbers will be used in place of names and any identifying information (e.g. consent forms) will kept securely in a locked cabinet or on a password protected encrypted memory stick,

What happens if I change my mind?
If you or your child decide that you do not wish to participate you are free to withdraw at any time.

What happens if something goes wrong?
If you have questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the Chair of the Ethics Committee, Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: +44 (0)23 8059 3856, email fshs-rso@soton.ac.uk

Where can I get more information?
If you have any questions or would like more information about this study please contact Helen Jones at hmj1g14@soton.ac.uk.

We will talk through the study with your child and ask whether or not they would like to take part. Even if you are happy for your child to take part, they will still be asked to decide for themselves on the day and children will only take part if both they and their parents have given informed consent. **If you consent for your child to take part, please return the enclosed form to your child's teacher.**

THANK YOU FOR TAKING THE TIME TO READ THIS INFORMATION

UNIVERSITY OF Southampton

CONSENT FORM (Version 2, 25/09/17)

How is doodling linked to children's attention?

Researcher name: Helen Jones
ERGO Study ID number:
RGO reference number:

*Please **initial** the boxes if you agree with the statements:*

I have read and understood the information sheet (22/05/17/version 2) and have had the opportunity to ask questions about the study	☐
I agree for my child to take part in this research project and agree for his/her data to be used for the purpose of this study	☐
I understand my child's participation is voluntary and he/she may withdraw at any time without my legal rights being affected	☐

Name of child (print name)……………………………………………………………….

Name of parent/guardian (print name)…………………………………………………

Signature of parent/guardian………………………………………………………….

Date……………………………………………………………………………………….

Appendix H Child information letter and assent form

Information sheet for young people (Version 2, 22/5/17)

How is doodling linked to children's attention?

We would like to invite you to take part in a research project.

You should only take part if you want to. If you do not want to take part that is OK and it will not be a problem. Before you decide whether you want to take part, it is important for you to know why the research is being done and what it will involve. I am going to read the following information to you, which will explain more about the research. There will be time at the end to ask me if there is anything that is not clear or you would like more information.

Who is doing the research?
My name is Helen and I am a trainee Educational Psychologist studying at the University of Southampton. I am working with two supervisors at that university. My university contact details are on a letter, which has already been sent to your parents. Your teachers also have the contact details.

What is the study about?
We would like to learn more about the links between doodling and children's attention.

Who is being invited to take part?
We are asking children in Year 5 to take part.

What will I be asked to do?
There will be two research sessions, each lasting about half an hour. During these sessions, I (Helen) will work with you and ask you to do two tasks that measure attention. There will also be some short questionnaires to fill in to show your level of tiredness and anxiety. During one of the sessions, I will ask you to doodle while doing the tasks. During both sessions, you will have a small machine clipped around one finger to measure your heart rate.

After both sessions have happened, I will meet with you in a group and ask you to fill in three more questionnaires to show what you think about your attention, anxiety and sleepiness. This should take less than half an hour. We will also ask your teachers to tell us about your learning, including your current level in literacy and maths, and how many school days you have been at school this year.

What will the information be used for?

Your information will be used to understand more about how doodling and children's attention are linked.

The information you and your teacher gives is confidential (private). This means it is between you and us. We make sure your information is kept private by using identification numbers in place of your name.

Are there any risks from taking part?
We hope that you will not feel any discomfort from taking part; however, you may be nervous or excited about doing some new tasks in school, having your heart rate measured and working with me. It is normal to find the attention tasks difficult and no one other than the researchers will know how you do. It is also possible that you might feel worried after filling in the questionnaires. If you need any advice or feel worried about anything related to this research you can talk to a number of different people. This could be someone you know, like your parent or guardian.

Or you can speak to your class teacher or the Emotional Literacy Support Assistant (ELSA): name and room [*if school does not have an ELSA, details of equivalent person or nominated member of staff here*].

You can also get support from outside school by phoning a helpline, such as Childline: People on Childline will talk to you about any worries you might have and they will keep every conversation you have with them confidential (private). You can speak to someone on Childline by calling 0800 1111. There are other ways of contacting Childline. You can find out more online at http://www.childline.org.uk.

You will not miss any break times and we will work with your teacher to make sure you do not miss any lesson that your teacher thinks is important for you to attend.

Are there any benefits from taking part?
You will receive a £5 book token to thank you for taking part. By taking part in this research, there may also be general benefits as you will help us learn about how to improve children's attention in school.

Do you want to know anything else?
If you have any questions, please ask me or your teacher. You can also contact me at hmj1g14@soton.ac.uk.

Thank you for reading this information. This copy is for you to keep.

UNIVERSITY OF Southampton

Appendix H

ASSENT FORM FOR YOUNG PEOPLE (Version 1, 23/01/17)

How is doodling linked to children's attention?

Researcher name: Helen Jones
ERGO Study ID number:
RGO reference number:

Please circle your answer to the questions below:

Have you read (or had read to you) the information sheet for Children and Young People?	Yes	No
Do you understand what this project is about?	Yes	No
Have you asked all the questions you want?	Yes	No
Have you had your questions answered in a way you understand?	Yes	No
Do you understand it's OK to stop taking part at any time?	Yes	No
Are you happy to take part?	Yes	No
If <u>any</u> answers are 'no' or you **don't** want to take part, **don't** sign your name!		
If you would like to take part……please write your name and today's date		
Your name	**Date**	**Signature**
The researcher who explained this project to you needs to sign too		
Researcher	**Date**	**Signature**

Appendix I Debrief sheets for teachers and children

Debriefing Statement *(written or verbal)* (Version 1, 30/05/17)

How is doodling linked to children's attention?

Thank you for taking part in this research.

The aim of this research was to investigate the links between doodling and children's attention. There is some evidence that doodling may help children to concentrate by increasing their physiological arousal (how calm or excited they are).

We expect that when doodling (compared to not doodling):

- children will score higher on tasks measuring attention
- children's average heart rates will be slightly higher

The information you have provided will help us to understand how doodling affects children's control of their attention. Once again, the results of this study will not include your name or any information that could identify you.

This sheet is yours to keep. When the research is finished we will tell you the results.

If anything in this research has made you feel worried please talk to a senior member of staff. You can also contact the researcher (Helen Jones) at hmj1g14@soton.ac.uk if you have any more questions.

If you have questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the Chair of the Ethics Committee, Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: +44 (0)23 8059 3856, email fshs-rso@soton.ac.uk

UNIVERSITY OF Southampton

Debriefing Statement *(written or verbal)* (Version 1, 10/02/17)

How is doodling linked to children's attention?

Thank you for taking part in this research.

The aim of this research was to investigate the links between doodling and children's attention. There is some evidence that doodling may help children to concentrate by increasing their physiological arousal (how calm or excited they are).

We expect that when doodling (compared to not doodling):

- children will score higher on tasks measuring attention
- children's average heart rates will be slightly higher

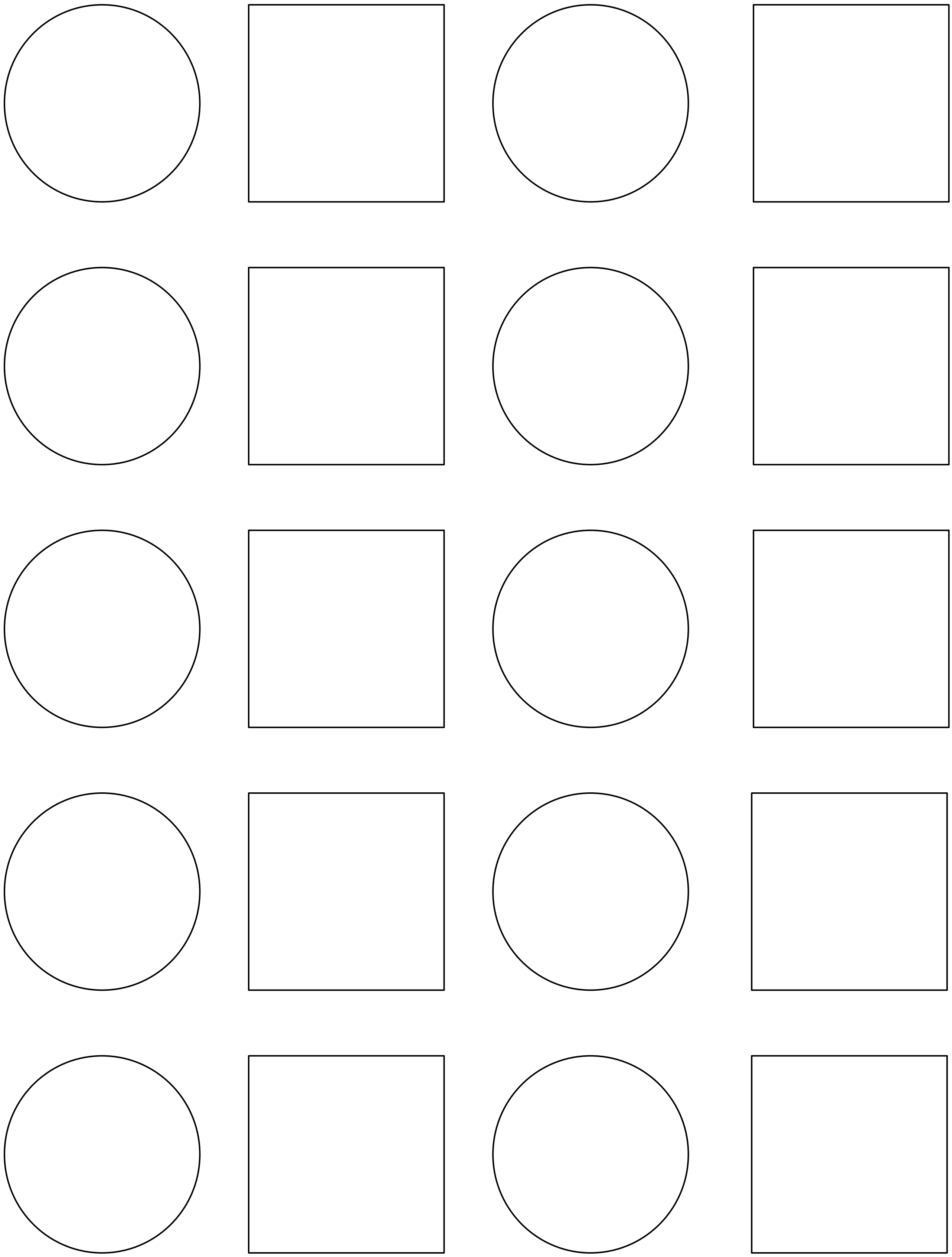
Your information will help us to understand how doodling affects children's control of their attention. Once again, the results of this study will not include your name or any information that could identify you.

This sheet is yours to keep. When the research is finished a letter will be sent home explaining the results.

If anything in this research has made you feel worried please talk to your teacher or another member of staff. You can also contact the researcher (Helen Jones) at hmj1g14@soton.ac.uk if you have any more questions.

If you have questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the Chair of the Ethics Committee, Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: +44 (0)23 8059 3856, email fshs-rso@soton.ac.uk

Appendix J Doodling Sheet



Appendix K Assessment of Normality

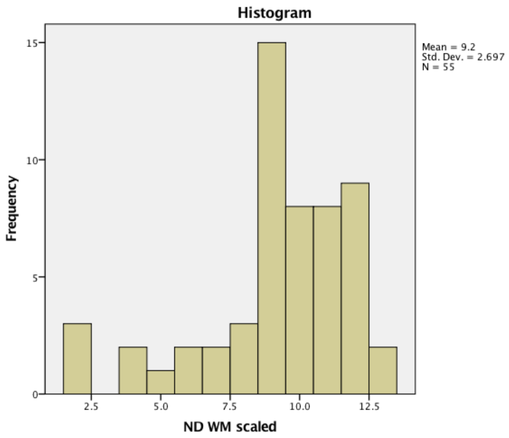
K.1 Skewness and Kurtosis Calculations

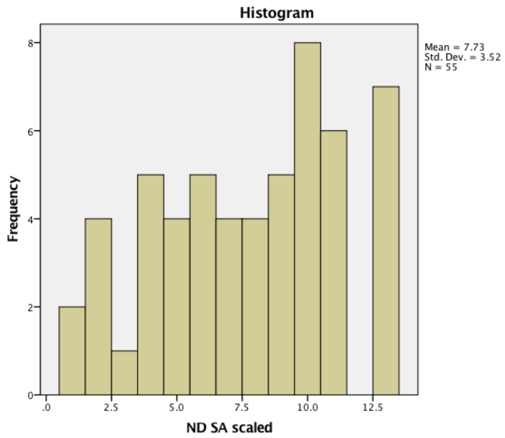
Non doodling	Skewness	Std error	Z score	Kurtosis	Std error	Z score	Significant at p<.05 if Z> 1.96
WM	-1.184	0.322	-3.68	1.189	0.634	1.88	S
SA	-0.217	0.322	-0.67	-0.955	0.634	-1.51	-
WM HR	1.096	0.322	3.40	3.805	0.634	6.00	S & K
SA HR	-0.262	0.322	-0.81	-0.046	0.634	-0.07	-
Mean anxiety	1.01	0.322	3.14	-0.062	0.634	-0.10	S
Mean fatigue	0.721	0.322	2.24	0.214	0.634	0.34	S

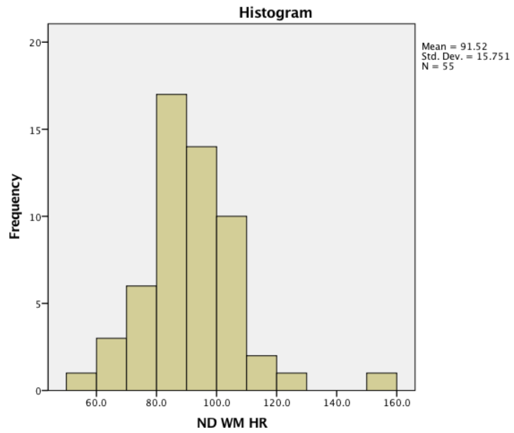
Doodling	Skewness	Std error	Z score	Kurtosis	Std error	Z score	Significant at p<.05 if Z> 1.96
WM	-0.766	0.322	-2.38	-0.247	0.634	-0.39	S
SA	0.163	0.322	0.51	-1.214	0.634	-1.91	-
WM HR	1.77	0.322	5.50	6.371	0.634	10.05	S & K
SA HR	0.172	0.322	0.53	-0.448	0.634	-0.71	-
Mean anxiety	1.185	0.322	3.68	0.885	0.634	1.40	S
Mean fatigue	0.746	0.322	2.32	-0.027	0.634	-0.04	S

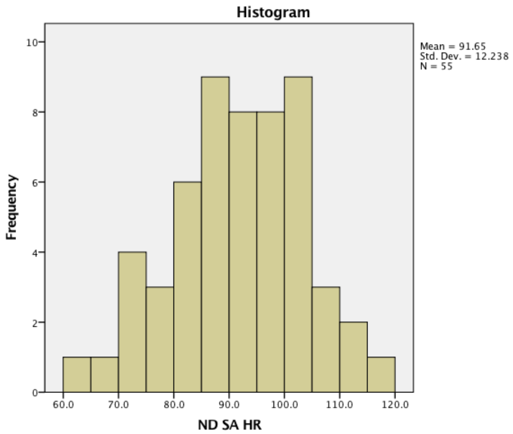
	Skewness	Std error	Z score	Kurtosis	Std error	Z score	Significant at p<.05 if Z> 1.96
ASC total	-0.212	0.322	-0.66	0.719	0.634	1.13	-
ASC focusing	0.399	0.322	1.24	0.275	0.634	0.43	-
ASC shifting	-0.303	0.322	-0.94	-0.246	0.634	-0.39	-
RCMAS-2 total	0.055	0.322	0.17	-0.839	0.634	-1.32	-
RCMAS-2 physical	0.63	0.322	1.96	-0.565	0.634	-0.89	-
RCMAS-2 worry	-0.007	0.322	-0.02	-0.883	0.634	-1.39	-
RCMAS-2 social	0.252	0.322	0.78	0.176	0.634	0.28	-
ESS	0.647	0.322	2.01	-0.103	0.634	-0.16	S
SDQ inattention-hyperactivity	0.732	0.322	2.27	-0.561	0.634	-0.88	S

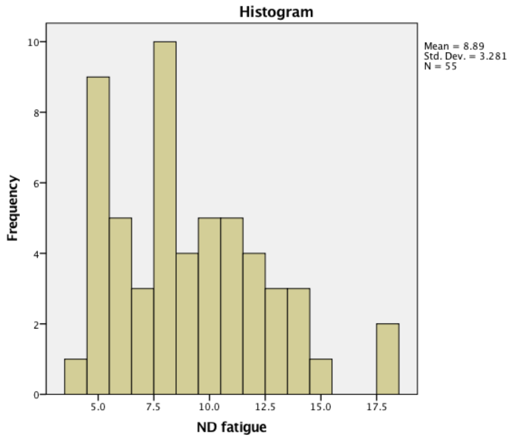
K.2 Histograms

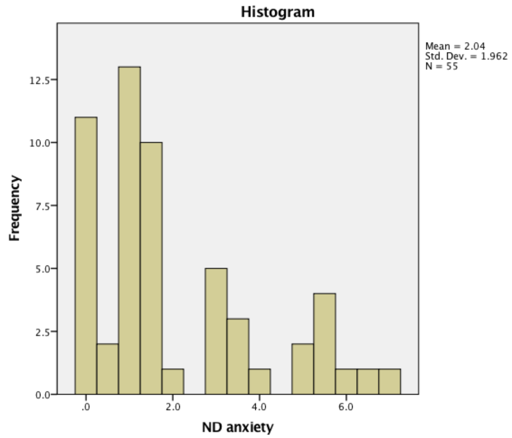


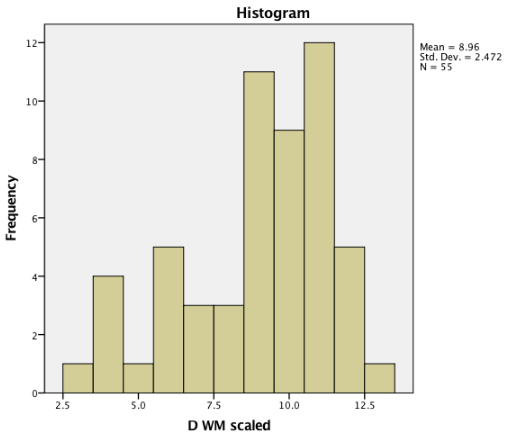


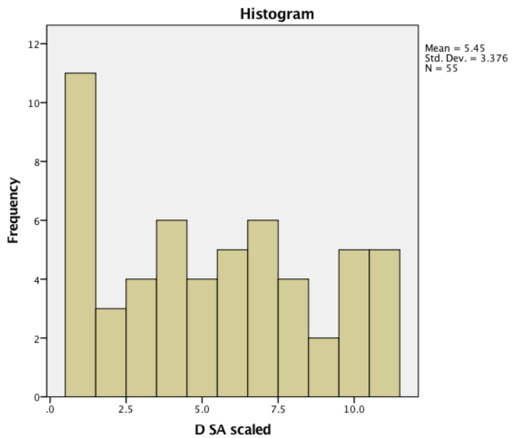


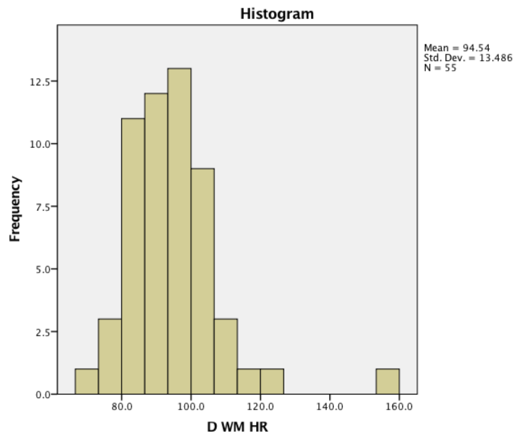

Histogram
Mean = 91.65
Std. Dev. = 12.238
N = 55
Frequency
ND SA HR


Histogram
Mean = 8.89
Std. Dev. = 3.281
N = 55
Frequency
ND fatigue

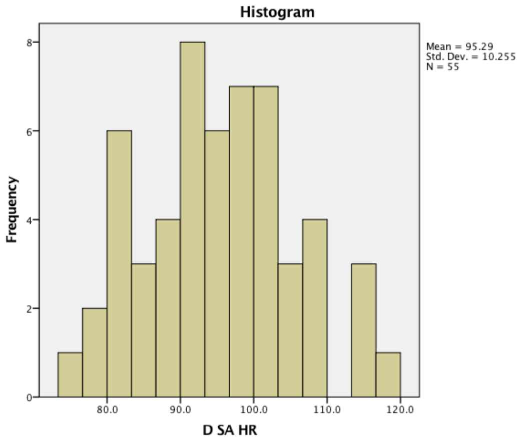

Histogram
Mean = 2.04
Std. Dev. = 1.962
N = 55
Frequency
ND anxiety

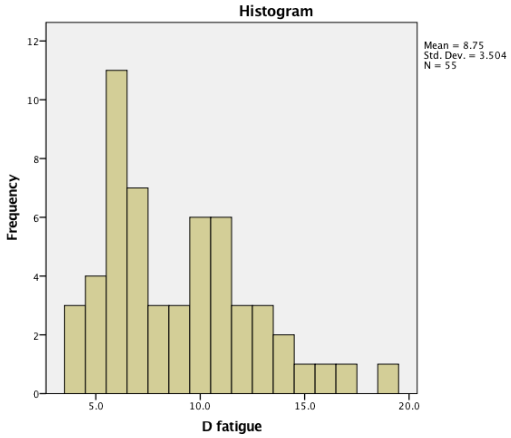

Histogram
Mean = 8.96
Std. Dev. = 2.472
N = 55
Frequency
D WM scaled

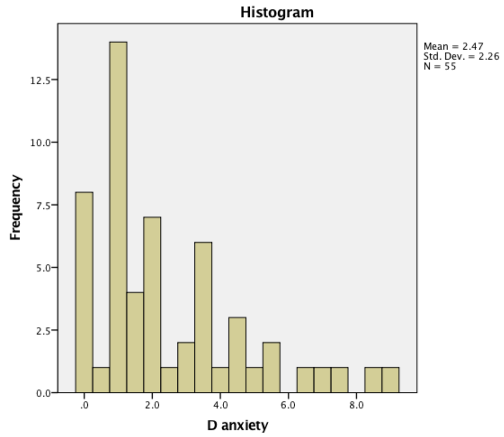

Histogram
Mean = 5.45
Std. Dev. = 3.376
N = 55
Frequency
D SA scaled

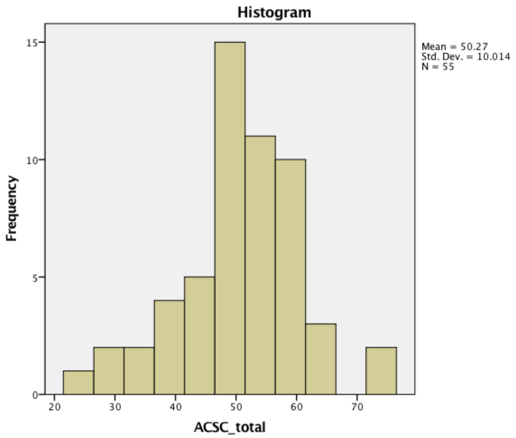

Histogram
Mean = 94.54
Std. Dev. = 13.486
N = 55
Frequency
D WM HR

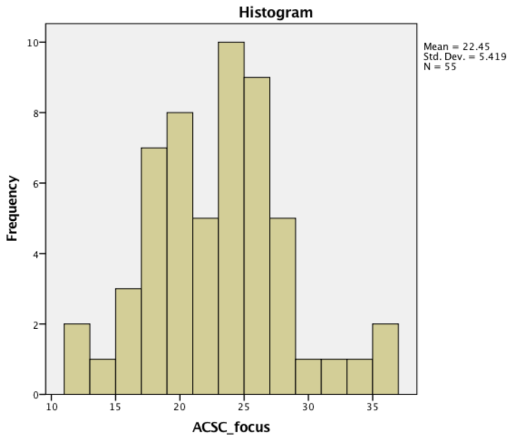
Appendix K

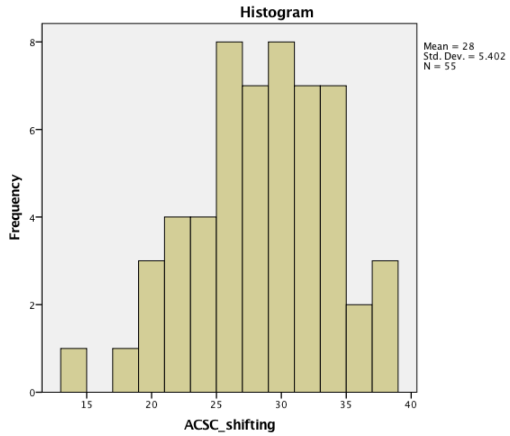

Histogram
Mean = 95.29
Std. Dev. = 10.255
N = 55
Frequency
D SA HR

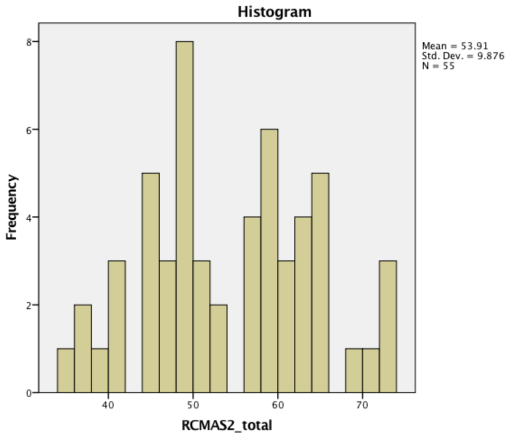

Histogram
Mean = 8.75
Std. Dev. = 3.504
N = 55
Frequency
D fatigue

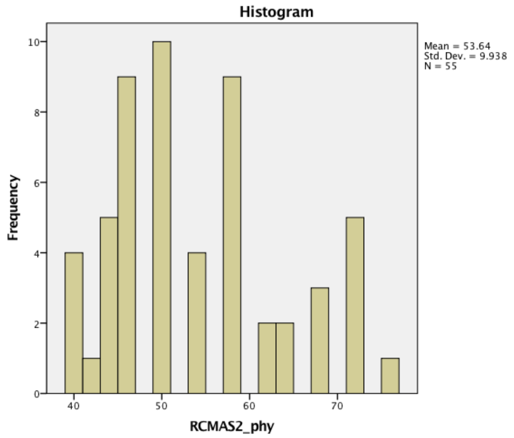

Histogram
Mean = 2.47
Std. Dev. = 2.26
N = 55
Frequency
D anxiety

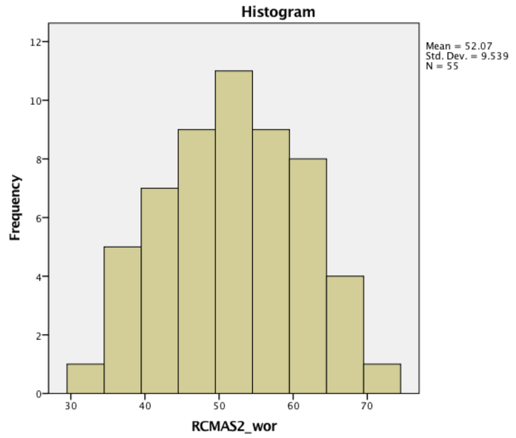

Histogram
Mean = 50.27
Std. Dev. = 10.014
N = 55
Frequency
ACSC_total

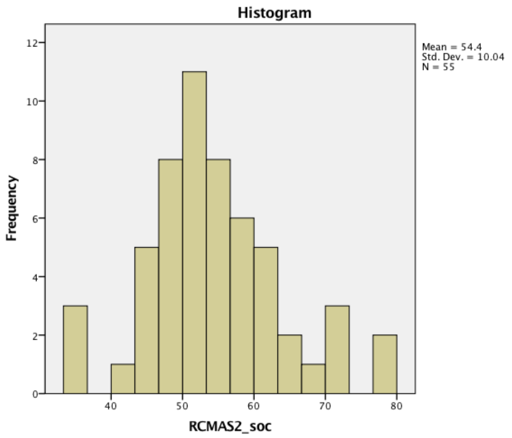

Histogram
Mean = 22.45
Std. Dev. = 5.419
N = 55
Frequency
ACSC_focus

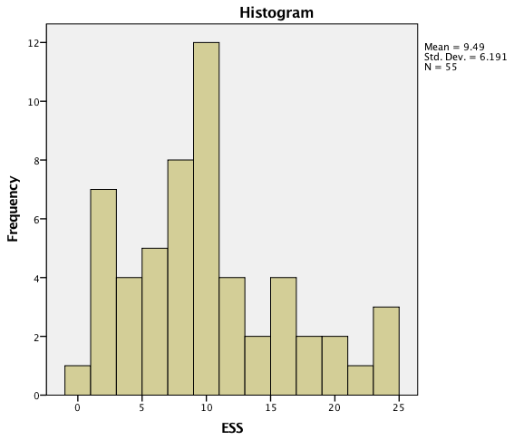

Histogram
Mean = 28
Std. Dev. = 5.402
N = 55
Frequency
ACSC_shifting

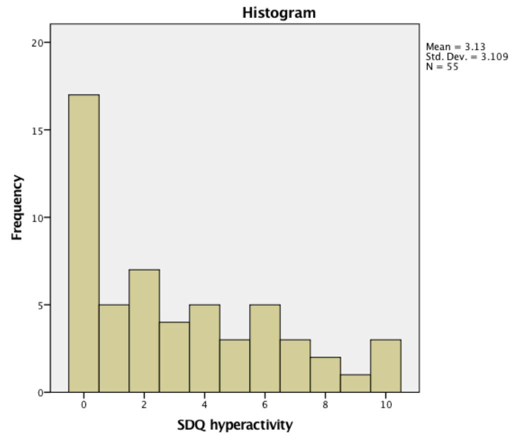

Histogram
Mean = 53.91
Std. Dev. = 9.876
N = 55
Frequency
RCMAS2_total


Histogram
Mean = 53.64
Std. Dev. = 9.938
N = 55
Frequency
RCMAS2_phy

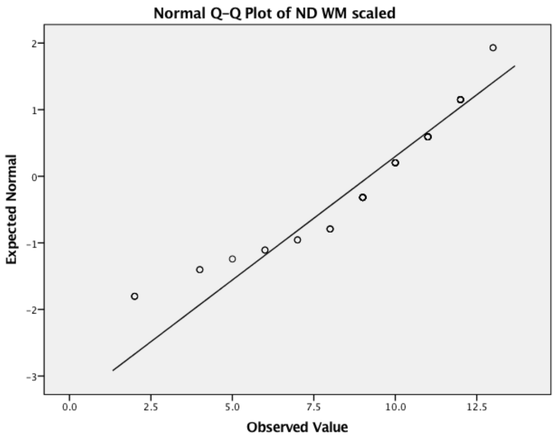

Histogram
Mean = 52.07
Std. Dev. = 9.539
N = 55
Frequency
RCMAS2_wor

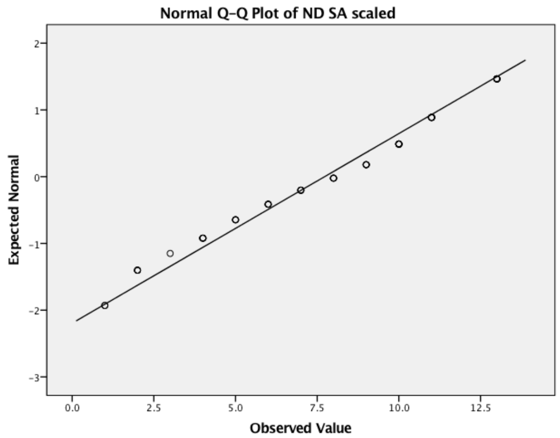

Histogram
Mean = 54.4
Std. Dev. = 10.04
N = 55
Frequency
RCMAS2_soc

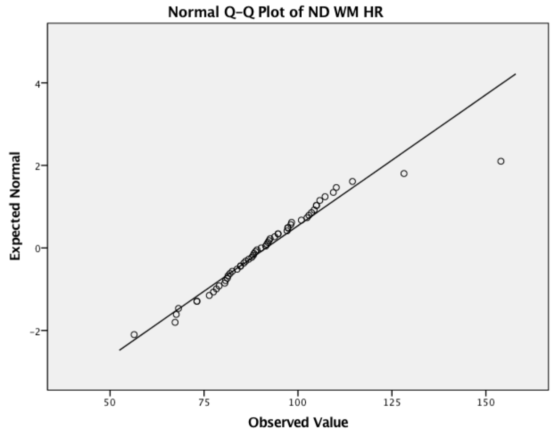

Histogram
Mean = 9.49
Std. Dev. = 6.191
N = 55
Frequency
ESS

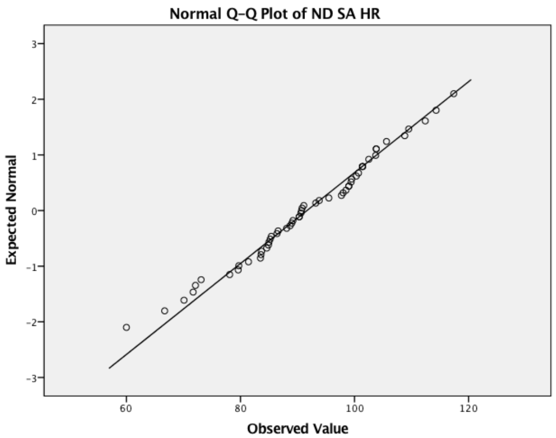

Histogram
Mean = 3.13
Std. Dev. = 3.109
N = 55
Frequency
SDQ hyperactivity

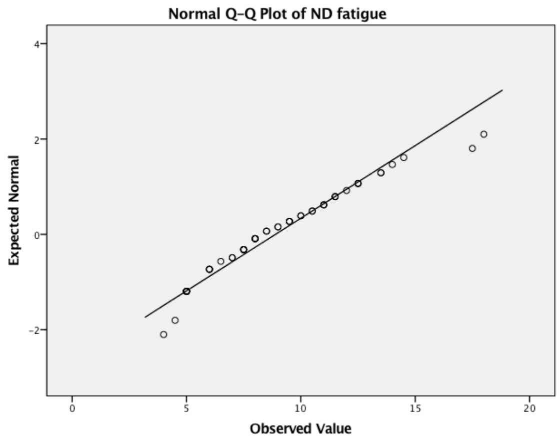
K.3 Normal Q-Q Plots

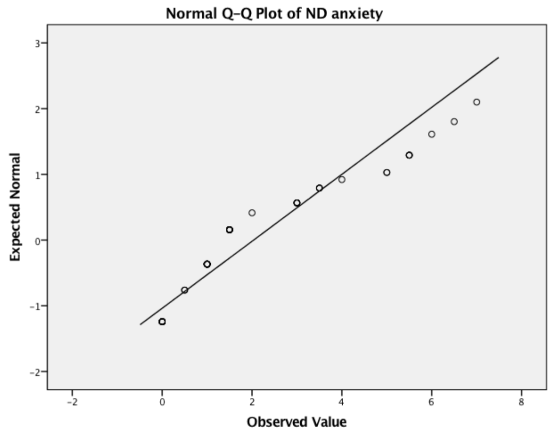


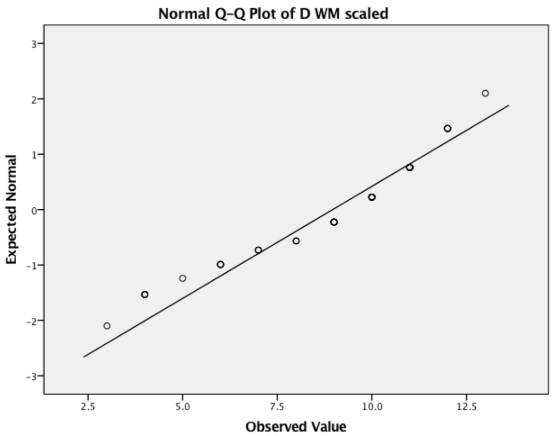


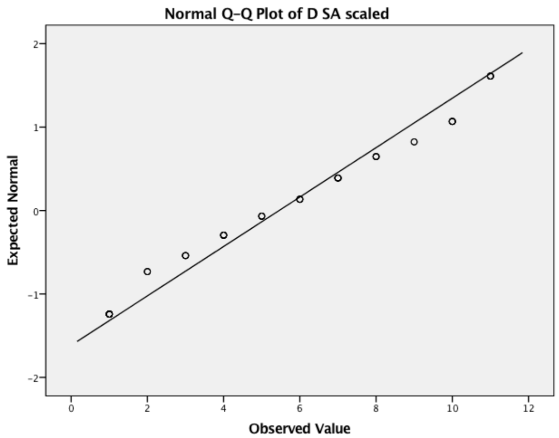


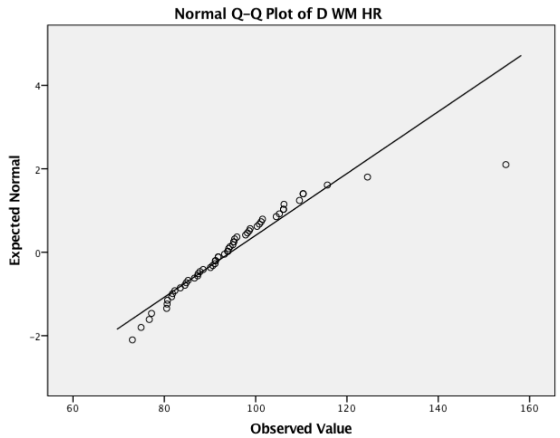


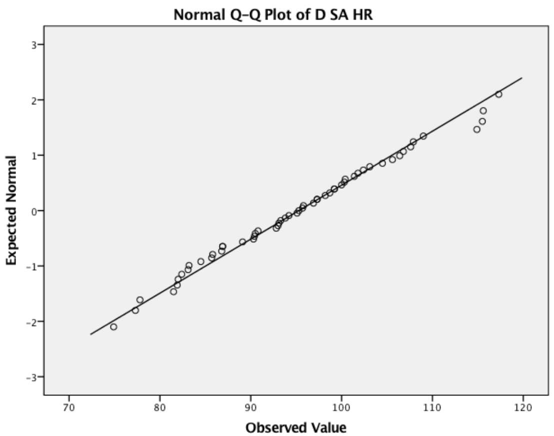


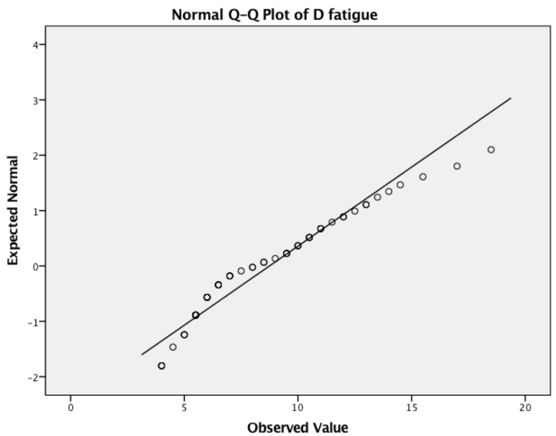


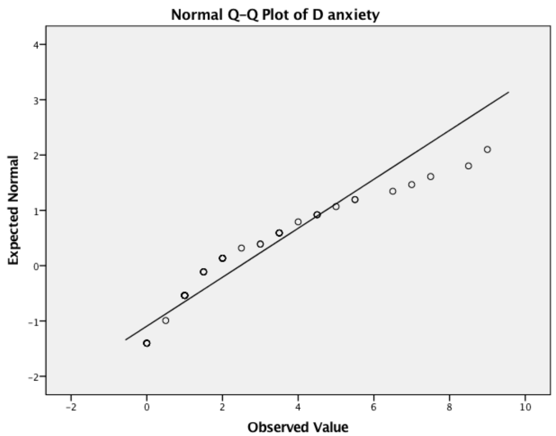

Normal Q–Q Plot of D WM scaled
Expected Normal
Observed Value


Normal Q–Q Plot of D SA scaled
Expected Normal
Observed Value

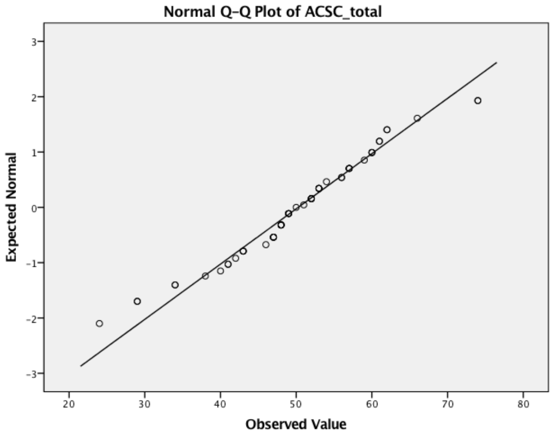

Normal Q–Q Plot of D WM HR
Expected Normal
Observed Value


Normal Q–Q Plot of D SA HR
Expected Normal
Observed Value

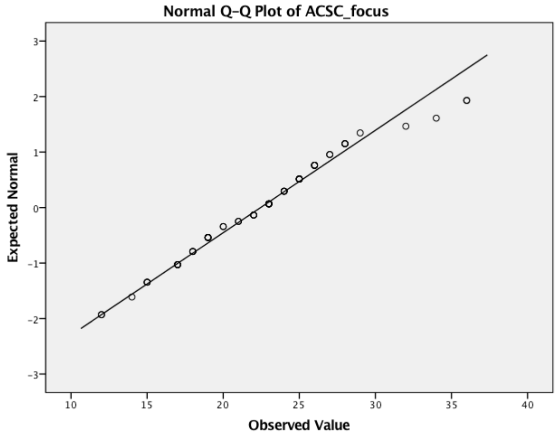

Normal Q–Q Plot of D fatigue
Expected Normal
Observed Value


Normal Q–Q Plot of D anxiety
Expected Normal
Observed Value

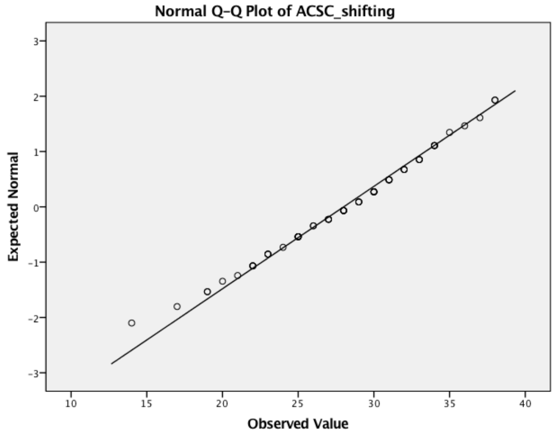
Appendix K



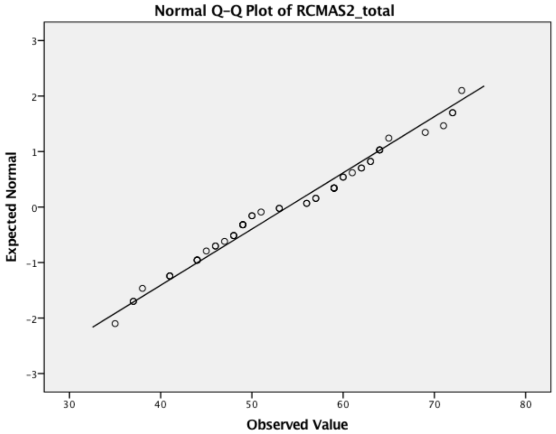
Normal Q-Q Plot of ACSC_total
Expected Normal
Observed Value



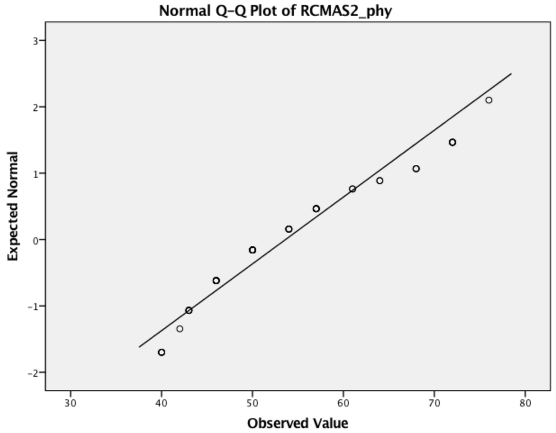
Normal Q-Q Plot of ACSC_focus
Expected Normal
Observed Value



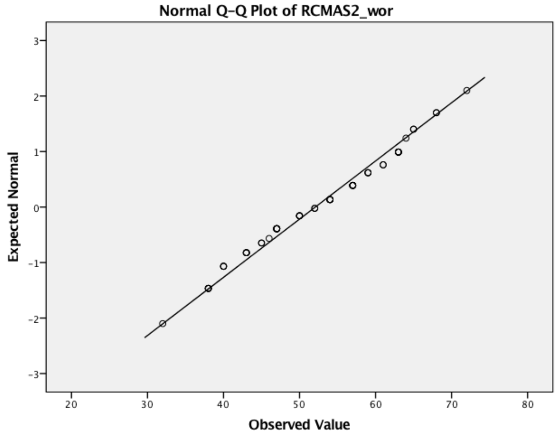
Normal Q-Q Plot of ACSC_shifting
Expected Normal
Observed Value



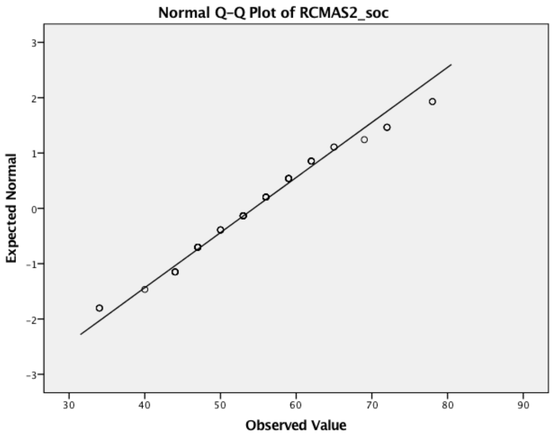
Normal Q-Q Plot of RCMAS2_total
Expected Normal
Observed Value

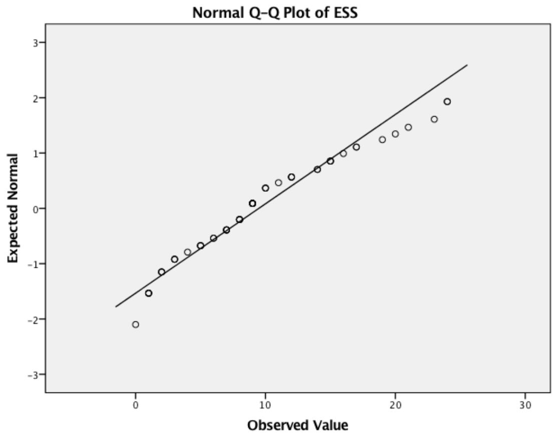


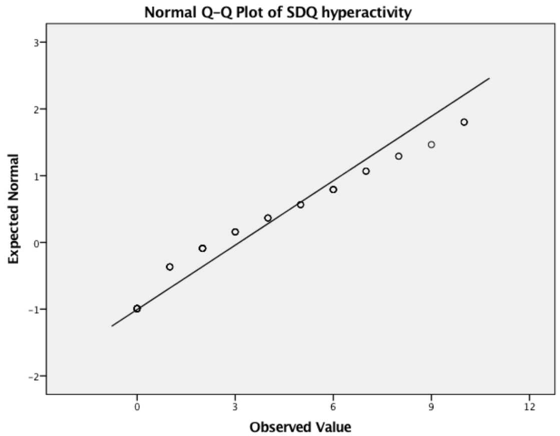
Normal Q-Q Plot of RCMAS2_phy
Expected Normal
Observed Value



Normal Q-Q Plot of RCMAS2_wor
Expected Normal
Observed Value


Normal Q-Q Plot of RCMAS2_soc
Expected Normal
Observed Value
3
2
1
0
-1
-2
-3
30
40
50
60
70
80
90


Normal Q-Q Plot of ESS
Expected Normal
Observed Value
3
2
1
0
-1
-2
-3
0
10
20
30

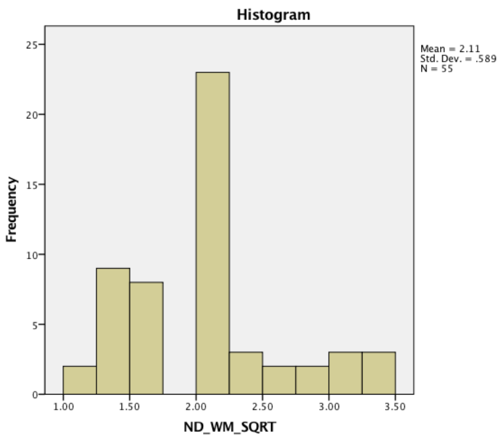

Normal Q-Q Plot of SDQ hyperactivity
Expected Normal
Observed Value
3
2
1
0
-1
-2
0
3
6
9
12

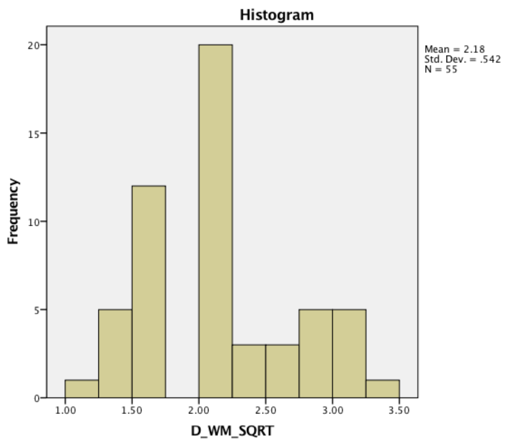
Appendix L Assessment of Normality and Outliers for Transformed variables

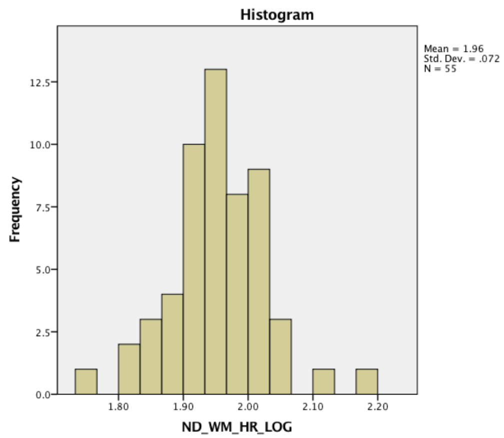
L.1 Skewness and Kurtosis

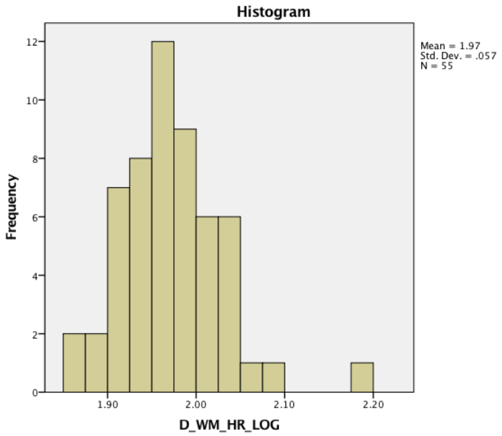
	Skewness	Std error	z	Kurtosis	Std error	z	Significant at p<.05 if Z> 1.96
ND WM SQRT	0.505	0.322	1.57	0.115	0.634	0.18	
D WM SQRT	0.31	0.322	0.96	-0.522	0.634	-0.82	
ND WM HR LOG	0.149	0.322	0.46	1.735	0.634	2.74	K
D WM HR LOG	0.967	0.322	3.00	2.753	0.634	4.34	S & K
ND fatigue SQRT	0.34	0.322	1.06	-0.476	0.634	-0.75	
D fatigue SQRT	0.401	0.322	1.25	-0.66	0.634	-1.04	
ND anxiety SQRT	-0.049	0.322	-0.15	-0.779	0.634	-1.23	
D anxiety SQRT	-0.061	0.322	-0.19	-0.383	0.634	-0.60	
ESS SQRT	-0.297	0.322	-0.92	-0.11	0.634	-0.17	

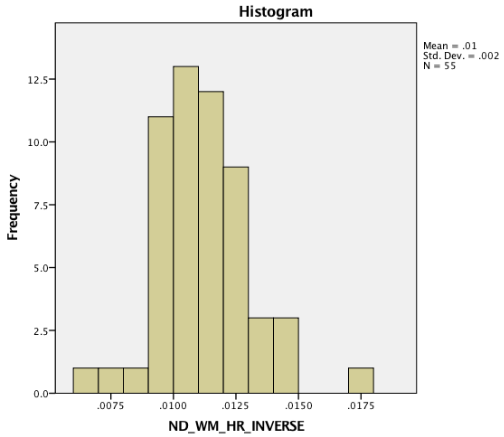
L.2 Histograms

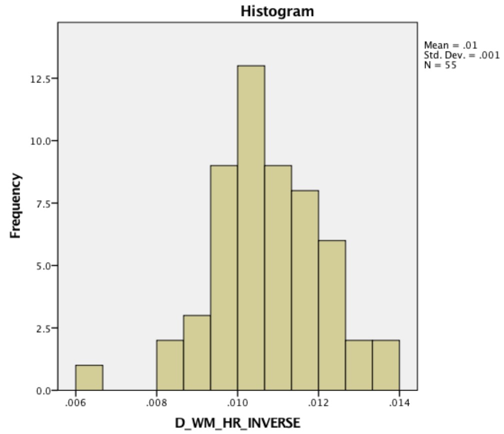


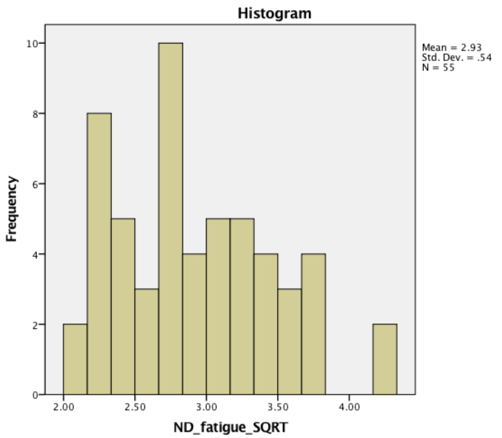


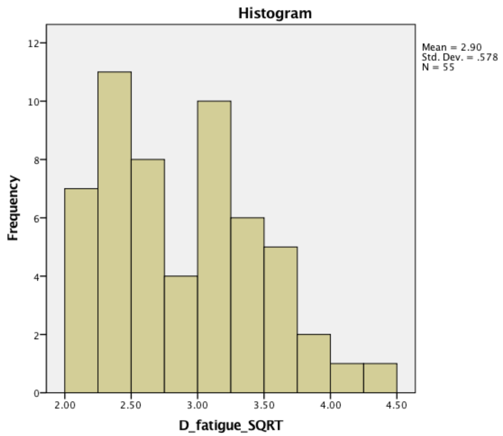


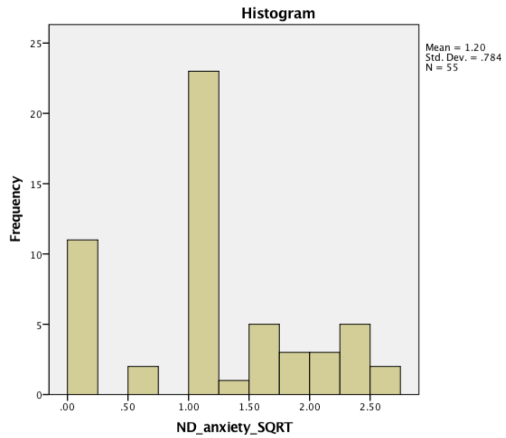

Histogram
Mean = 1.97
Std. Dev. = .057
N = 55
Frequency
D_WM_HR_LOG


Histogram
Mean = .01
Std. Dev. = .002
N = 55
Frequency
ND_WM_HR_INVERSE

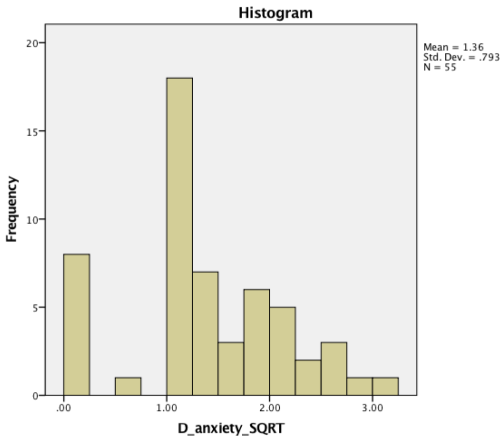

Histogram
Mean = .01
Std. Dev. = .001
N = 55
Frequency
D_WM_HR_INVERSE


Histogram
Mean = 2.93
Std. Dev. = .54
N = 55
Frequency
ND_fatigue_SQRT

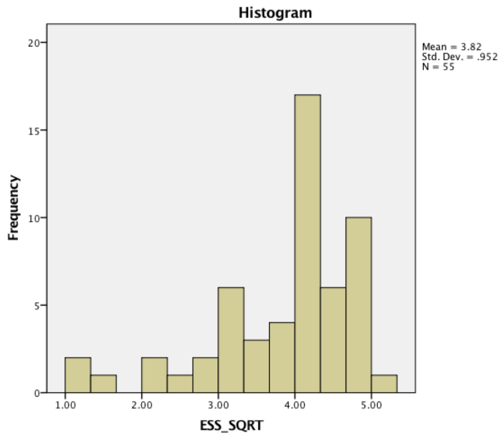

Histogram
Mean = 2.90
Std. Dev. = .578
N = 55
Frequency
D_fatigue_SQRT


Histogram
Mean = 1.20
Std. Dev. = .784
N = 55
Frequency
ND_anxiety_SQRT

Appendix L

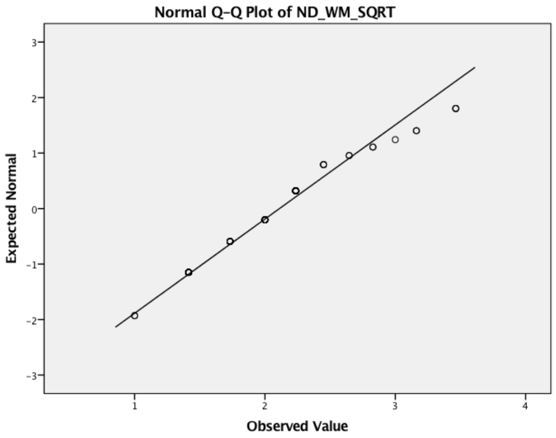


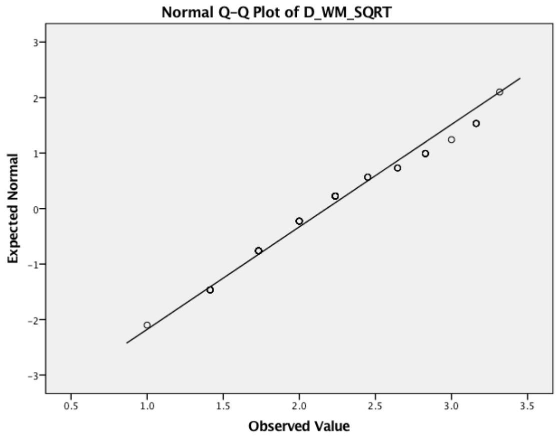
Histogram
Mean = 1.36
Std. Dev. = .793
N = 55
Frequency
D_anxiety_SQRT

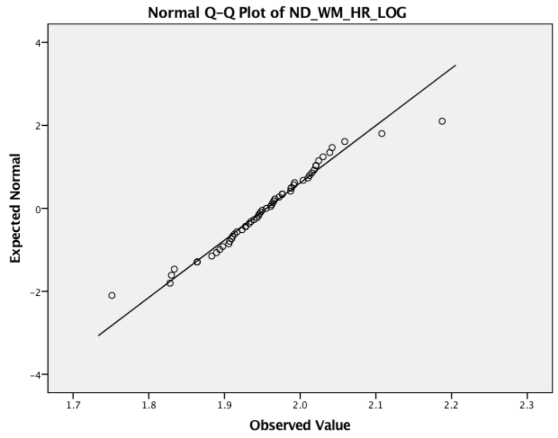


Histogram
Mean = 3.82
Std. Dev. = .952
N = 55
Frequency
ESS_SQRT

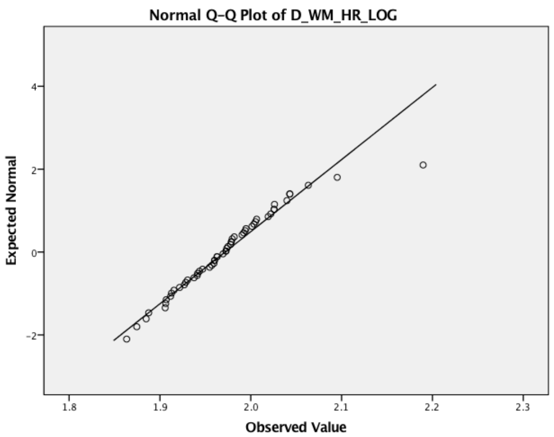
L.3 Normal Q-Q Plots

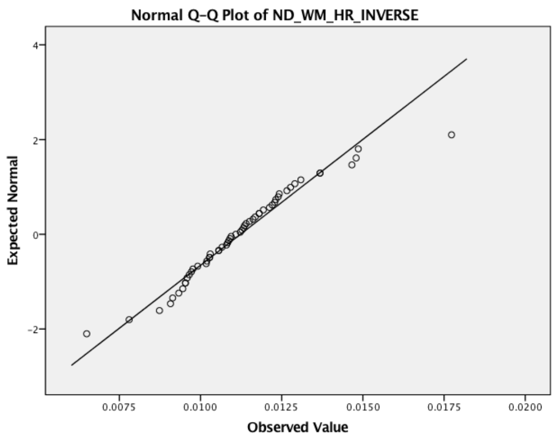


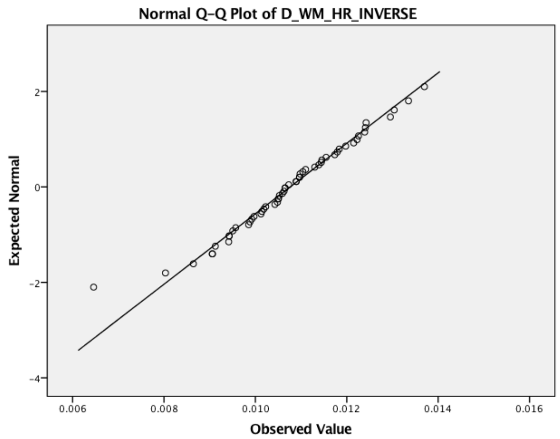


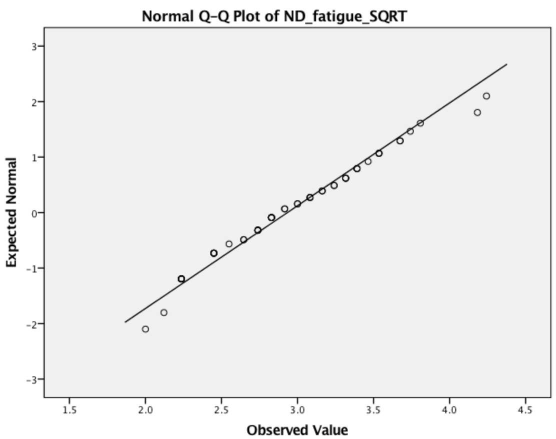


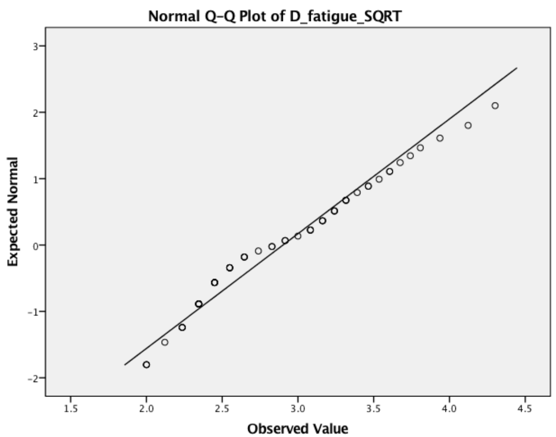
Appendix L

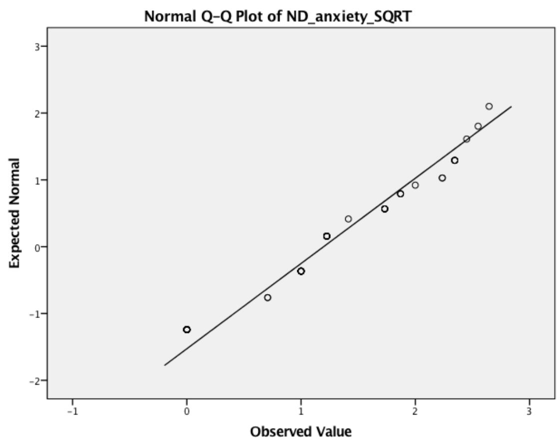

Normal Q-Q Plot of D_WM_HR_LOG
Expected Normal
Observed Value

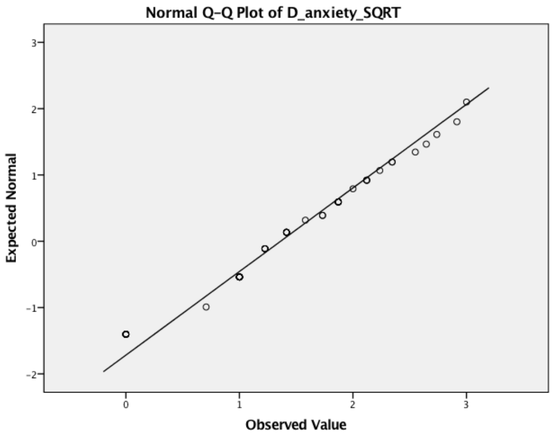

Normal Q-Q Plot of ND_WM_HR_INVERSE
Expected Normal
Observed Value


Normal Q-Q Plot of D_WM_HR_INVERSE
Expected Normal
Observed Value

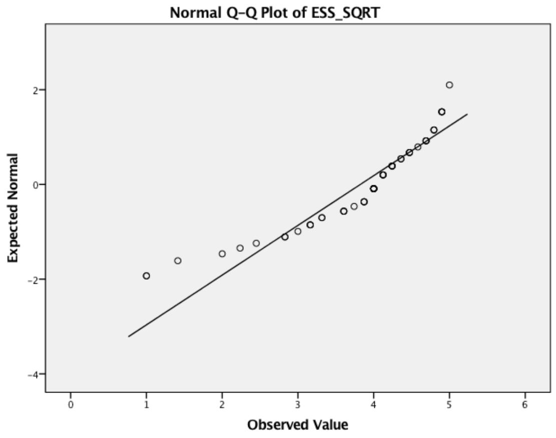

Normal Q-Q Plot of ND_fatigue_SQRT
Expected Normal
Observed Value


Normal Q-Q Plot of D_fatigue_SQRT
Expected Normal
Observed Value


Normal Q-Q Plot of ND_anxiety_SQRT
Expected Normal
Observed Value

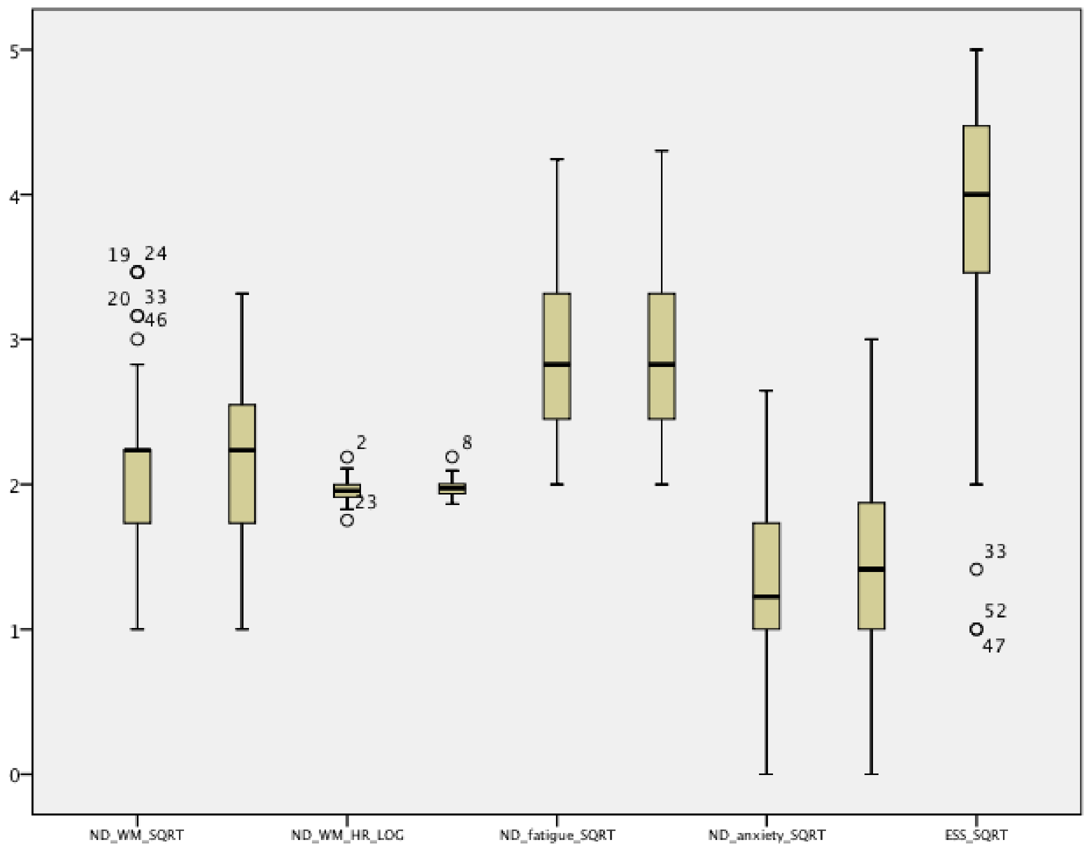


Normal Q-Q Plot of D_anxiety_SQRT
Expected Normal
Observed Value



Normal Q-Q Plot of ESS_SQRT
Expected Normal
Observed Value

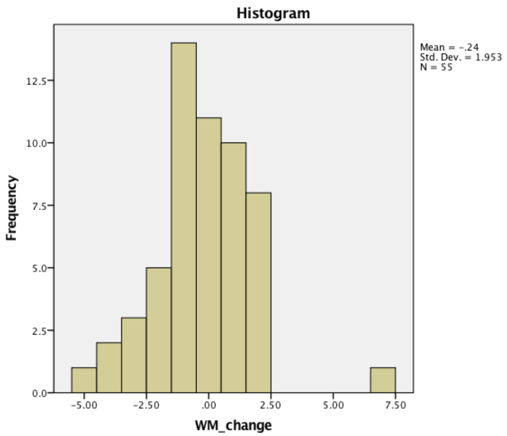
L.4 Boxplots

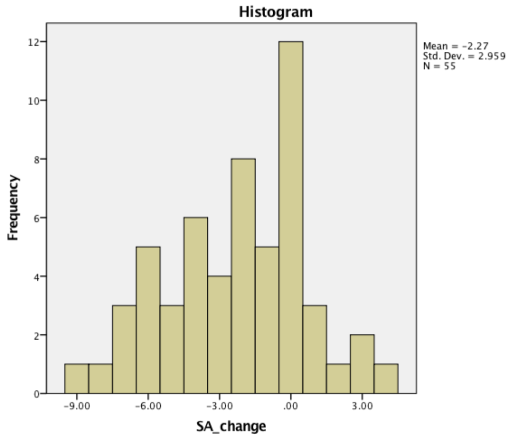

5
4
3
2
1
0
19 24
20 33
46
2
23
8
33
52
47
ND_WM_SQRT
ND_WM_HR_LOG
ND_fatigue_SQRT
ND_anxiety_SQRT
ESS_SQRT

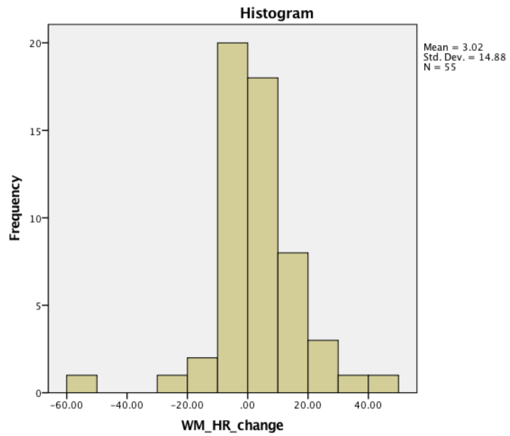
Appendix M Descriptive Statistics for Change Scores

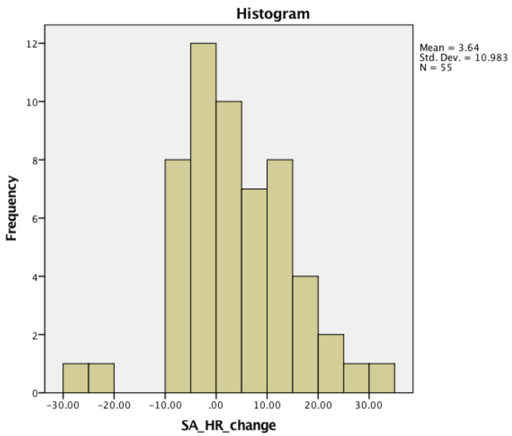
	K-S Sig.	Skewness	Std error	z	Kurtosis	Std error	z	Significant at p<.05 if Z> 1.96
WM change	.004	0.45	0.322	1.40	2.68	0.634	4.23	K
WM HR change	.037	-.54	0.322	-1.68	6.05	0.634	9.54	K
SA change	.034	-.21	0.322	-.65	-.50	0.634	-.79	
SA HR change	.200	-.13	0.322	-.40	1.07	0.634	1.69	
Fatigue change	.053	-.02	0.322	-.06	1.40	0.634	2.21	K
State anxiety change	.000	.94	0.322	2.92	-.15	0.634	-.24	S

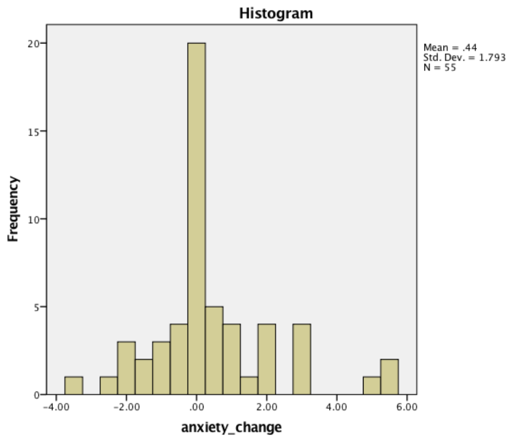
Appendix M

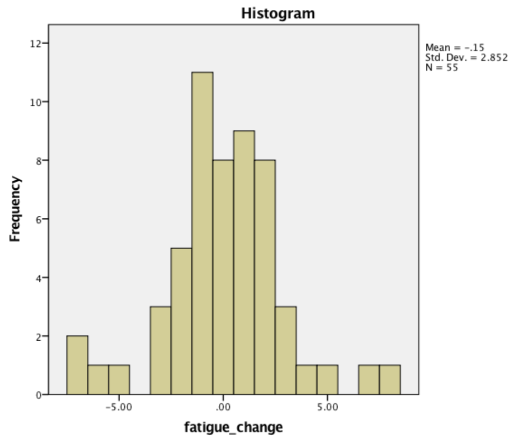

Histogram
Frequency
WM_change
Mean = -.24
Std. Dev. = 1.953
N = 55

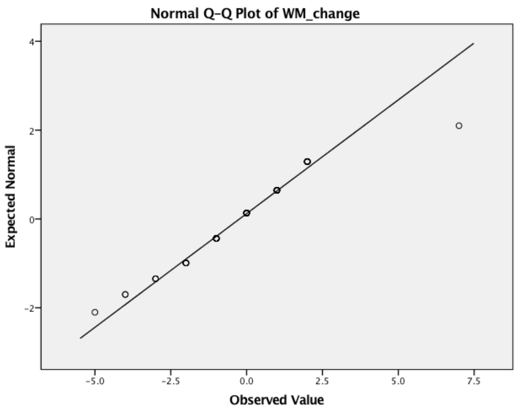

Histogram
Frequency
SA_change
Mean = -2.27
Std. Dev. = 2.959
N = 55

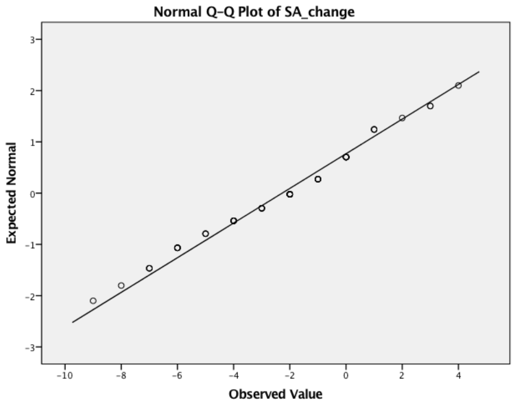

Histogram
Frequency
WM_HR_change
Mean = 3.02
Std. Dev. = 14.88
N = 55

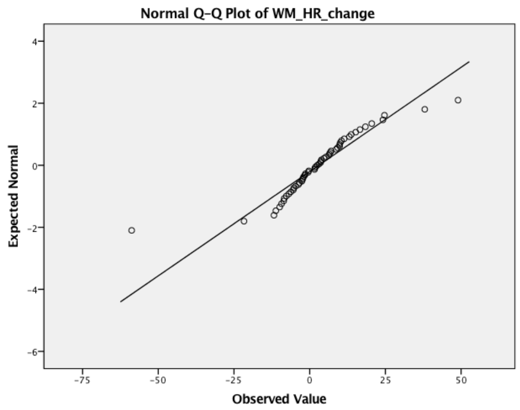

Histogram
Frequency
SA_HR_change
Mean = 3.64
Std. Dev. = 10.983
N = 55

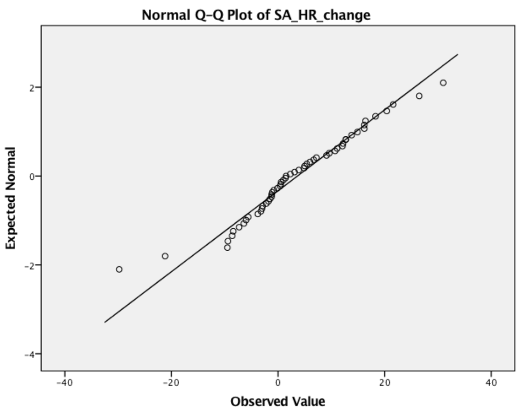

Histogram
Frequency
anxiety_change
Mean = .44
Std. Dev. = 1.793
N = 55

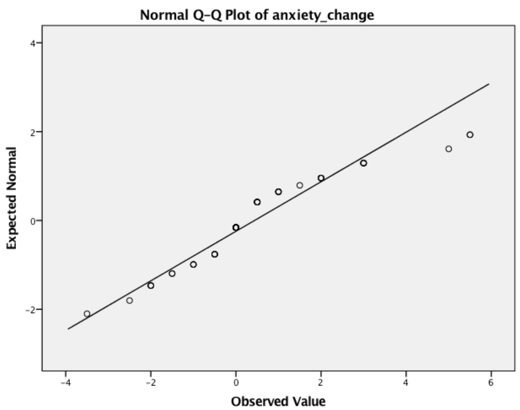

Histogram
Frequency
fatigue_change
Mean = -.15
Std. Dev. = 2.852
N = 55

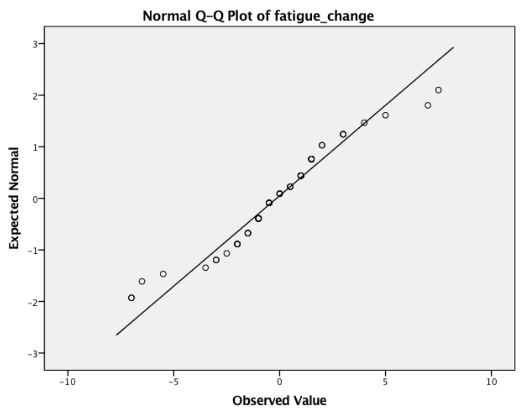

Normal Q-Q Plot of WM_change
Expected Normal
Observed Value


Normal Q-Q Plot of SA_change
Expected Normal
Observed Value

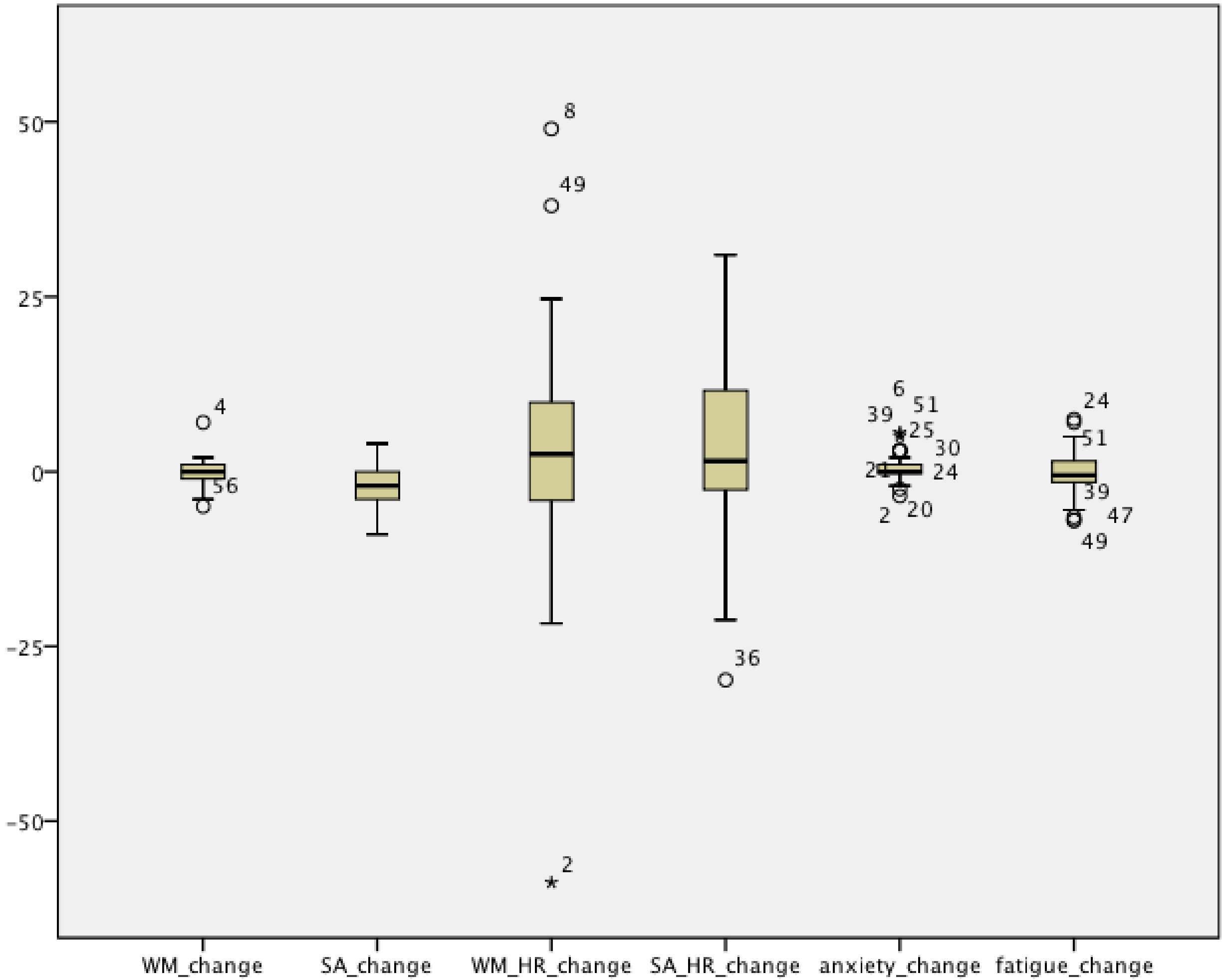

Normal Q-Q Plot of WM_HR_change
Expected Normal
Observed Value


Normal Q-Q Plot of SA_HR_change
Expected Normal
Observed Value


Normal Q-Q Plot of anxiety_change
Expected Normal
Observed Value


Normal Q-Q Plot of fatigue_change
Expected Normal
Observed Value

Appendix M


50
25
0
-25
-50
8
49
2
4
56
36
6
39
51
25
30
24
2
20
24
51
39
47
49
WM_change
SA_change
WM_HR_change
SA_HR_change
anxiety_change
fatigue_change

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