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An absence of attentional bias: Statistics anxiety is unique among anxieties

Thesis submitted by

Peter K. H. Chew BPsych (Hons Class I)

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Statement of the Contribution of Others

This thesis was undertaken by the author under the supervision of Denise Dillon and Anne Swinbourne. Both supervisors provided academic and editorial advice. The thesis also benefited from the editorial advice of George Jacobs and Nimrod Delante (Learning Advisors in JCU Singapore). Lastly, Daniel Lindsay and Alison Sheaves assisted with data collection in JCU Australia while Cherie Sim Sze Min and Danica Lim assisted with data collection in JCU Singapore.

The following chapters of the thesis were written as individual papers for publication. Chapters 2 and 5 have already been published. Chew wrote the paper whereas Dillon and Swinbourne provided academic and editorial advice.

Chapter	Publication Status
1	Introduction to thesis; Not applicable for publication.
2	Chew, P. K. H., & Dillon, D. B. (2014). Statistics anxiety update: Refining the construct and recommendations for a new research agenda. *Perspectives on Psychological Science, 9*(2), 196–208. doi:10.1177/1745691613518077
3	Chew, P. K. H., Dillon, D. B., & Swinbourne, A. (Under Review). A study of the Statistical Anxiety Rating Scale (STARS) among psychology majors in Singapore and Australia. *Applied Psychological Measurement*
4	Chew, P. K. H., & Dillon, D. B. (Under Review). Attentional Bias: A Methodological Review. *Education Sciences and Psychology*
5	Chew, P. K. H., Swinbourne, A., & Dillon, D. B. (2014). No evidence of attentional bias in statistics anxiety. *The European Journal of Social & Behavioural Sciences*, *10*(3), 1451–1465. doi:10.15405/ejsbs.131
6 7 8	Chew, P. K. H., Swinbourne, A., & Dillon, D. B. (Under Review). An absence of attentional bias: Statistics anxiety is unique among anxieties. *SAGE Open*

Declaration on Ethics

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council (NHMRC) National Statement on Ethical Conduct in Human Research, 2007. The proposed research studies received human research ethics approval from the JCU Human Research Ethics Committee Approval Number #H4761 and #H5008.

Abstract

The first purpose of the project was to examine the internal consistency and structure of the English version of the Statistical Anxiety Rating Scale (STARS). Participants were 202 (79% females) psychology undergraduates at James Cook University. Participants completed the STARS, the Statistical Anxiety Scale, and the Attitudes toward Statistics scale. Acceptable internal consistency reliabilities, ranging from .81 to .94, were found in this sample. Approximate fit indices suggest that a correlated six first-order factor model best describes the data in contrast to theoretical considerations suggesting that a six factor model with two correlated superordinate factors (i.e., statistics anxiety and attitudes toward statistics) best describes the data. The second purpose of the project was to examine the role of attentional bias in statistics anxiety in three experiments. Participants were 94 (73% females), 99 (68% females), and 104 (67% females) psychology undergraduates at James Cook University, respectively. These participants had either never taken a statistics course before but expected to enrol in one in the future, were currently enrolled in a statistics course, or had successfully completed at least one statistics course but were not currently enrolled in a statistics course. Participants completed the emotional Stroop task and the dot probe task, the STARS, the Social Desirability Scale, and the State-Trait Anxiety Inventory. No statistically significant differences were found across the experiments, indicating an absence of attentional bias in statistics anxiety. Implications include a reconsideration of the cognitive mechanisms underlying statistics anxiety. Specifically, individuals with statistics anxiety might be interpreting danger based on the absence of safety indicators instead of the presence of danger indicators. Alternatively, another form of cognitive bias, such as an interpretation bias might underlie statistics anxiety. Future research should be conducted to compare the plausibility of these two explanations.

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Typographic Conventions

Although APA formatting has been used throughout this thesis manuscript, the following variations have been applied to enhance readability.

1) Single line spacing was used for Tables and Figures instead of double line spacing.
2) Tables and Figures are placed within the text instead of at the end of the manuscript.
3) Headings and sub-headings are numbered (e.g., 1.1, then 1.1.1 and 1.1.2).

Chapter 1: Introduction

The American Psychological Association (APA) presented five learning goals in their guidelines for the undergraduate psychology major (APA, 2013). These goals were: (a) a knowledge base in psychology, (b) scientific inquiry and critical thinking, (c) ethical and social responsibility in a diverse world, (d) communication, and (e) professional development. Because statistics courses[1] help students achieve the goal of scientific inquiry and critical thinking and, to a lesser extent, communication (e.g., the ability to interpret and communicate quantitative data), these courses have become a staple in most psychology programs (Stoloff et al., 2009).

According to Stoloff et al. (2009), the statistics course is one of the two courses (the other being the introductory psychology course) that serve as the foundation for undergraduate psychology programs. Out of 374 universities surveyed in North America, 100% of them offer at least one statistics course, with some of these universities offering up to three (17%), four (16%), or more than four (2%) statistics courses in their program (Stoloff et al., 2009). Furthermore, up to 98% of these universities require students to complete as least one statistics course as a necessary part of their degree program.

Similar results have been found among universities in Singapore and Australia (see Appendix 1.1). Out of 38 universities, 100% of them offer at least one statistics course, with some of these universities offering up to three (45%), four (18%), or five (8%) statistics courses in their psychology program. Consistent with the APA (2013) guidelines, all of these universities require students to complete as least one statistics course as a necessary part of their degree program. James Cook University (JCU) is one such university. At JCU,

[1] Note on terminology: The curricula of most statistics courses in the social sciences are not limited to statistics per se; rather, these courses often incorporate elements of research design and methods. Furthermore, although universities in Australia refer to the degree and module as ‘psychology course’ and ‘statistics subjects’, respectively, universities in the USA use the terms ‘psychology program’ and ‘statistics courses’, respectively. Since most of the statistics anxiety literature is based in the USA, this thesis adopts the latter naming convention.

students enrolled in the Bachelor of Psychology program are required to complete three statistics courses in a developmental sequence across levels: (a) Introductory, (b) Intermediate, and (c) Advanced (see Appendix 1.2 for course description). The studies reported in this thesis recruited participants from JCU's Singapore and Australia campuses.

Statistics courses are high-stakes courses. All universities in Singapore and Australia use scores on statistics courses, among other criteria, to determine students' entry into their Psychology Honours program. For example, at JCU, students are required to achieve a Credit[2] average across the level-two courses: Introductory and Intermediate statistics. Students are also required to achieve a Distinction average across five level-three courses including the advanced level statistics course. The situation is exacerbated by the fact that most graduate-level psychology programs require (or at least prefer) students with an Honours degree.

Given the mandatory and high-stakes nature of statistics courses, it is not surprising that students experience anxiety when they undertake these courses (Onwuegbuzie & Wilson, 2003). Originally named 'statiscophobia'(Heemskerk, 1975), the field attracted research interest with the renaming of the construct as 'statistics anxiety' and the development of an instrument to assess it (Cruise, Cash, & Bolton, 1985). Situated in this context of statistics education, this thesis contributes to the statistics anxiety literature by providing two literature reviews (Chapters 2 and 4), one psychometric study (Chapter 3) and three experimental studies (Chapters 5, 6, and 7). A conceptual diagram of the thesis is presented in Figure 1.1. This diagram is repeated at the start of each chapter. Although chapters were written as individual papers for publication, overlapping material such as definitions of constructs or descriptions of measures have been minimized. These chapters are described next.

[2] At JCU, students are awarded a Credit for scoring between 65 and 74 (inclusive) and a Distinction for scoring between 75 and 84 (inclusive).

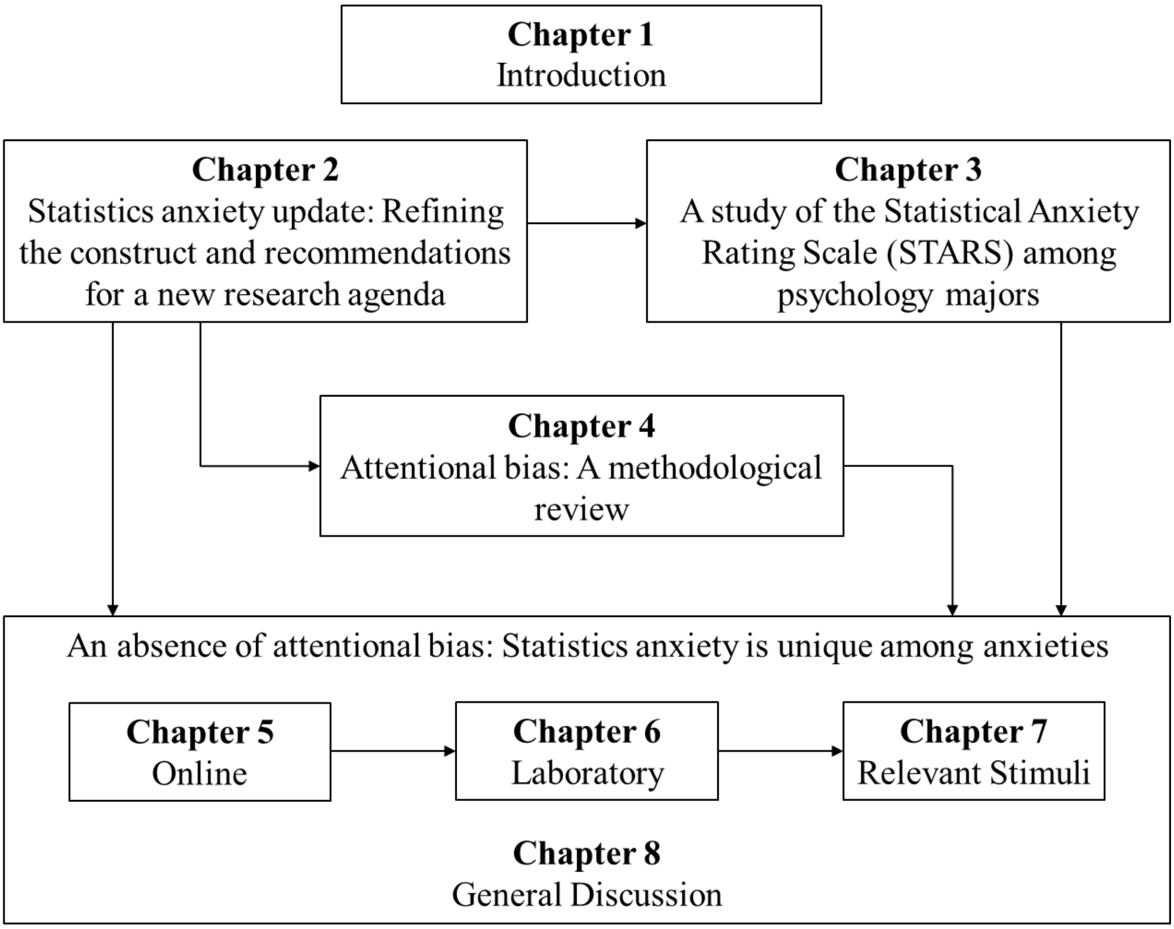


Figure 1.1. Conceptual diagram of the thesis.

Chapter 2 reviews the statistics anxiety literature and provides a rationale and conceptual framework for the remaining chapters. The paper advocates refining the statistics anxiety construct by (a) distinguishing it from related variables such as mathematics anxiety and attitudes toward statistics, (b) redefining statistics anxiety, and (c) selecting appropriate measures of statistics anxiety. Furthermore, the antecedents, effects, and interventions of statistics anxiety are evaluated to provide recommendations for a new research agenda. In particular, researchers are recommended to adopt an information processing perspective and examine the role of attentional bias in statistics anxiety (e.g., Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van IJzendoorn, 2007).

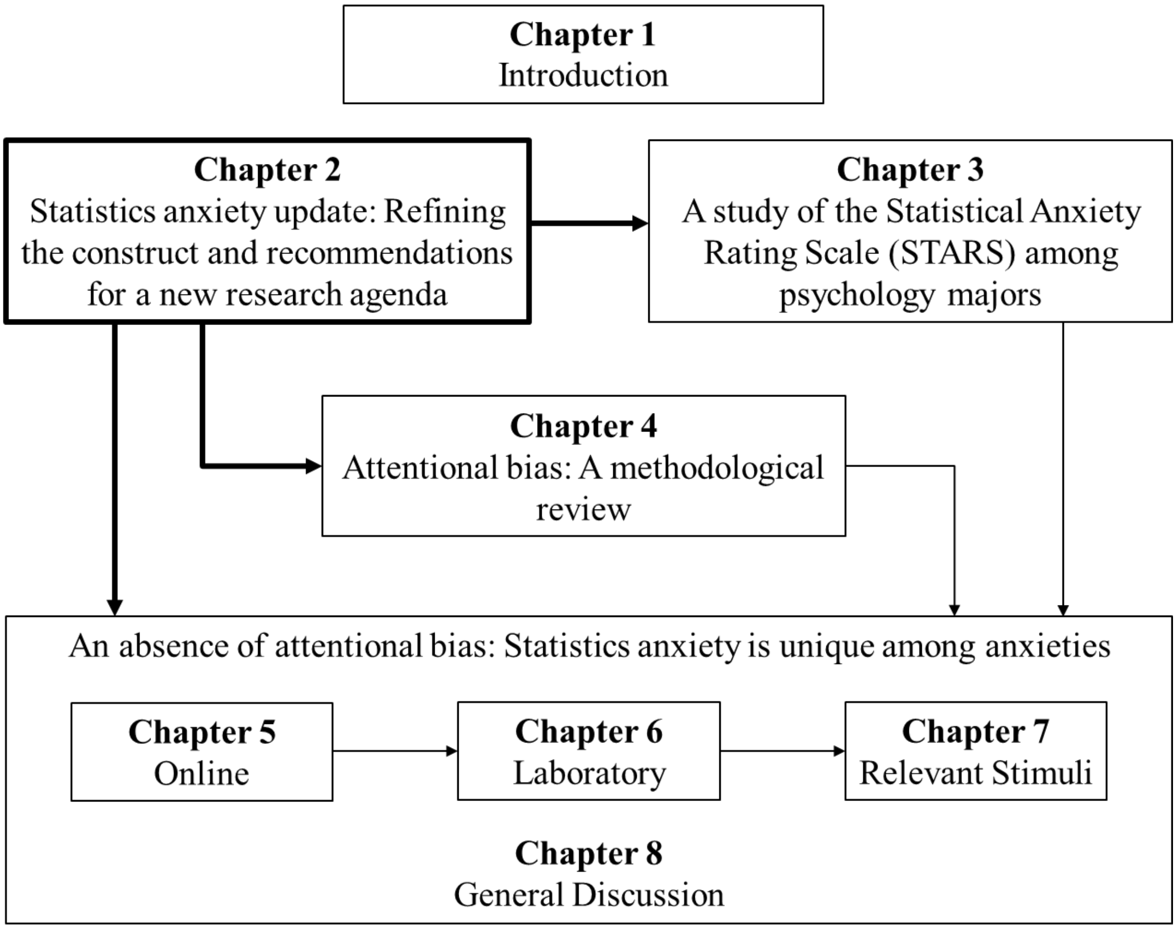
Chapter 3 examines the psychometric properties of the Statistical Anxiety Rating Scale (STARS) for its use in Chapters 5, 6 and 7 (Cruise et al., 1985). Previous research suggested that the STARS assesses both statistics anxiety and attitudes toward statistics rather than only statistics anxiety (Hanna, Shevlin, & Dempster, 2008; Papousek et al., 2012). Consistent with previous research, the paper found that the first three subscales of the STARS (Interpretation Anxiety, Test and Class Anxiety, Fear of Asking for Help) assess statistics anxiety, whereas the remaining three subscales of the STARS (Worth of Statistics, Computation Self-Concept, Fear of Statistics Teachers) assess attitudes toward statistics.

Chapter 4 reviews the attentional bias literature and provides a methodological guide to Chapters 5, 6, and 7. The paper describes common reaction time (RT) tasks and reviews the evidence for attentional bias among anxious individuals. The paper also makes recommendations to address the following methodological limitations of attentional bias studies: the (a) seemingly poor psychometric properties of RT tasks, (b) inappropriate practice of dichotomizing continuous variables, (c) improper handling of RT distributions, and (d) use of the mean as a summary statistic.

Chapters 5, 6, and 7 examine the role of attentional bias in statistics anxiety in three experiments. Experiment 1 was conducted online, Experiment 2 in a laboratory, and Experiment 3 used stimuli relevant to each factor of the STARS (Cruise et al., 1985). The evidence of attentional bias has been well-documented among clinical and non-clinical populations (e.g., Bar-Haim et al., 2007). However, contrary to previous research, the three experiments found no evidence of attentional bias in statistics anxiety. The results suggest that statistics anxiety is unique due to the complete absence of attentional bias on both a global level and on the individual factors level.

Chapter 8 summarizes the main findings from Chapters 5, 6, and 7, and discusses their implications for future research. The four-stage theoretical model of attentional bias (Bar-Haim et al., 2007) was modified to accommodate the results of the three experiments. This modification suggests that the absence of attentional bias could be due to individuals with statistics anxiety interpreting danger based on the absence of safety indicators instead of the presence of danger indicators. Alternatively, another form of cognitive bias, such as an interpretation bias, might underlie statistics anxiety. Future research should identify the cognitive mechanism underlying statistics anxiety to inform the development of effective, theory-based interventions.

Chapter 2: Statistics anxiety update: Refining the construct and recommendations for a new research agenda



This chapter reviews the statistics anxiety literature to provide a rationale and conceptual framework for the remaining chapters. An earlier version of this chapter has been published in a journal:

Chew, P. K. H., & Dillon, D. B. (2014). Statistics anxiety update: Refining the construct and recommendations for a new research agenda. *Perspectives on Psychological Science, 9*(2), 196–208. doi:10.1177/1745691613518077

Chapter 2: Statistics anxiety update: Refining the construct and recommendations for a new research agenda

The importance of statistics to society cannot be denied. Newspapers often use statistics to portray trends such as “crime rate, population growth, spread of diseases, industrial production, educational achievement, or employment trends” (Gal, 2002, p. 3). Government policy decisions are often based on statistics. Hence, the knowledge of statistics is a prerequisite for individuals to play their part as well-informed citizens of a democracy. Unfortunately, most citizens lack the necessary skills to read and to evaluate statistics (Utts, 2003). The American Statistical Association (ASA) has long recognized this problem. For instance, in her presidential address to the ASA, Wallman (1993) emphasized the importance of statistical literacy and defined it as:

> the ability to understand and critically evaluate statistical results that permeate our daily lives – coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions. (p. 1)

Consequently, with statistical literacy as a goal, an increasing number of degree programs are making statistics courses mandatory for university students (Gould, 2010). Unfortunately, taking a statistics course is often a negative experience for students in non-mathematical disciplines (e.g., social sciences) (Onwuegbuzie & Wilson, 2003). Students enrolled in undergraduate psychology programs expect to study psychology-related topics, often without realizing the relevance of statistics to the science of psychology. Indeed, only 46.7% of such students were aware of the statistics element in a psychology program (Ruggeri, Dempster, Hanna, & Cleary, 2008). The lack of awareness is further compounded by the importance assigned to statistics courses in psychology.

Out of 374 universities surveyed in North America, 98% of them require students to complete at least one statistics course – with most of those requiring students to complete two – as a requirement for their psychology degree program (Stoloff et al., 2009). Furthermore, statistics courses are often used to determine entry into an Honours program which, in turn, is often essential for entry into postgraduate studies. Given the mandatory and high-stakes nature of statistics courses, it is not surprising that students regard them as the most anxiety-inducing course in their degree programs.

Although at least two literature reviews exist for statistics anxiety (Baloğlu & Zelhart, 2003; Onwuegbuzie & Wilson, 2003), they were done over a decade ago, and newer studies have since added findings for consideration. Therefore, the purpose of this chapter is to provide a current review of the statistics anxiety literature in order to offer directions for future research and ideas for statistics education.

A comprehensive search was conducted on databases PsycARTICLES, PsycINFO, and Google Scholar to identify studies on statistics anxiety that were published from 2003 to 2015. Key search terms included "anxiety", "statistics anxiety", "mathematics anxiety", and "attitudes toward statistics". Subsequently, reference lists of relevant publications were scrutinized for other relevant studies that were not found in the databases. The search terms "mathematics anxiety" and "attitudes toward statistics" were included in order to source articles to provide a comparison to statistics anxiety. Hence, studies on mathematics anxiety and attitudes toward statistics are not reviewed in this chapter.

A total of 65 studies on statistics anxiety are cited in this chapter. Among these studies, 58 (89.2%) are quantitative in nature while 7 (10.8%) are descriptive or qualitative in nature. The 65 studies are summarized and classified in Appendix 2.1. They appear in alphabetical order by the first author of the respective studies. The majority of the quantitative studies were conducted in the USA on both undergraduates and graduates in the social sciences (mainly psychology and education majors). Additionally, most of the studies have an overwhelmingly high percentage of females (up to 100%) in their samples. Finally, the STARS (Cruise et al., 1985) was used in 46 (79.3%) quantitative studies, making it the most popular measure of statistics anxiety in this sample of studies.

2.1 Refining the Statistics Anxiety Construct

Currently, research on statistics anxiety has been hampered by the lack of distinction between statistics anxiety and related variables such as mathematics anxiety and attitudes toward statistics. Therefore, for research on statistics anxiety to flourish, researchers need to (a) distinguish statistics anxiety from related variables, (b) redefine statistics anxiety, and (c) select appropriate measures of statistics anxiety.

2.1.1 Distinguishing Statistics Anxiety from Related Variables

2.1.1.1 Mathematics anxiety. Mathematics anxiety rose to prominence in the early 1970s with Richardson and Suinn's (1972) classic article on the Mathematics Anxiety Rating Scale (MARS). According to Richardson and Suinn, "mathematics anxiety involves feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (p. 551). Initially, mathematics anxiety was conceptualized as a unidimensional construct (Richardson & Suinn, 1972); however, subsequent studies suggested it was a multidimensional construct (e.g., Baloglu & Zelhart, 2007; Kazelskis, 1998). The availability of the MARS has resulted in constant, if not growing, research attention to the field of mathematics anxiety, and many books have been written to help instructors and students overcome it (e.g., Arem, 2009; Burns, 1998; Kogelman & Warren, 1978; Tobias, 1978).

When statistics anxiety was first identified, researchers conceived the construct to be similar to mathematics anxiety. For example, the MARS was used to evaluate the use of humour as an intervention for statistics anxiety (Schact & Stewart, 1990). The lack of distinction could be due to several reasons. First, researchers cannot agree on the definition of statistics. Although there is a lack of more recent reviews, an article more than 70 years ago documented more than a hundred definitions of statistics (Willcox, 1936). One of these definitions asserts that "statistics is [simply] higher mathematics" (E. B. Wilson, 1927, p. 586). Researchers who defined statistics in this manner might be inclined to view statistics anxiety to be similar to mathematics anxiety. Second, although the emphasis on mathematics can differ from one introductory statistics course to another (Papousek et al., 2012), the importance of mathematics is made prominent to researchers by the numerous mathematical formulas found in introductory statistics textbooks (e.g., Gravetter & Wallnau, 2007). Lastly, mathematics anxiety has been extensively studied and is better understood than statistics anxiety. Thus, the similarities between them (Baloğlu, 1999) may have prompted researchers to assimilate the latter under the former.

Cruise, Cash, and Bolton (1985) were the first to advocate for a distinction between statistics anxiety and mathematics anxiety. The authors argued that the existing measures of mathematics anxiety did not adequately assess all aspects of statistics anxiety, and they developed the Statistical Anxiety Rating Scale (STARS) to address this need. Furthermore, statistics learning has often been conceptualized as second language learning (Lalonde & Gardner, 1993; Onwuegbuzie, 2003) rather than mathematics learning. This notion was supported by findings that linguistic intelligence, in addition to mathematical intelligence, is related to lower statistics anxiety (Daley & Onwuegbuzie, 1997).

Subsequently, similarities and differences between statistics anxiety and mathematics anxiety in terms of definitions, nature, antecedents, effects, and interventions were documented (Baloğlu, 1999, 2004). More importantly, although many studies found a significant positive relationship between statistics anxiety and mathematics anxiety, the relationship is moderate and mathematics anxiety, at a maximum, explained less than 50% of the variance in statistics anxiety (Baloğlu, 2004). More recently, one study reported that students with dyslexia had higher mathematics anxiety, but similar levels of statistics anxiety, than those without dyslexia (Jordan, McGladdery, & Dyer, 2014). Taken together, these reports suggest that statistics anxiety is related to, but distinct from, mathematics anxiety (Baloğlu, 1999; Onwuegbuzie & Wilson, 2003).

2.1.1.2 Attitude toward statistics. Similar to the lack of distinction between statistics anxiety and mathematics anxiety, "the literature makes little if any distinction between the concepts of attitudes and anxiety and the terms are often used interchangeably" (Nasser, 2004, p. 3). A literature review reveals two possible reasons for this confusion.

First, although statistics anxiety has been clearly defined as an affective construct (Cruise et al., 1985; Onwuegbuzie, Da Ros, & Ryan, 1997; Zeidner, 1991), there is a lack of consensus among researchers regarding the definition of attitudes (Gal & Ginsburg, 1994; Schau, 2003). Most researchers define attitudes as a purely affective construct (Evans, 2007; Gal & Ginsburg, 1994; Mills, 2004; Rhoads & Hubele, 2000; Roberts & Bilderback, 1980), whereas others define it as consisting of affective, cognitive, and behavioural components (Chiesi & Primi, 2009; Olson & Zanna, 1993). The former definition assumes both anxiety and attitude to be non-cognitive (i.e., affective) constructs, while the latter assumes attitude to be the overarching construct, with anxiety subsumed under it as an affective component (e.g., Schau, 2003).

Second, the widespread use of the STARS (Cruise et al., 1985) may have exacerbated the situation. A recent study suggests that the measure assesses both statistics anxiety and attitudes toward statistics rather than only statistics anxiety (Papousek et al., 2012). Specifically, it has been suggested that the first three subscales of the STARS assess statistics anxiety (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help subscales), whereas the last three subscales (Worth of statistics, Computation Self-Concept, and Fear of Statistics Teachers subscales) assess attitudes toward statistics. Earlier researchers tended to use all six subscales as a measure of statistics anxiety. This procedure likely resulted in high negative correlations between the STARS and measures of attitudes toward statistics. Consequently, researchers might conclude that they are measuring the same construct (e.g., see Perepiczka, Chandler, & Becerra, 2011; Watson, Lang, et al., 2003) and remove one of the variables from their study (Nasser, 2004)[3].

Table 2.1 summarizes the data from Nasser (2004) based on the factor structure of the STARS as suggested by Papousek et al. (2012). The correlations between the statistics anxiety subscales and the Survey of Attitude toward Statistics Scale (SATS) were mostly small with some moderate correlations (ranging from -.19 to -.49). In contrast, the correlations between the attitudes toward statistics subscales and the SATS were mostly moderate with some large correlations (ranging from -.26 to -.76). Hence, researchers should make a distinction between statistics anxiety and attitudes toward statistics and should only use the first three subscales of the STARS to measure statistics anxiety (see Chiesi & Primi, 2010).

Among researchers who distinguished between statistics anxiety and attitudes toward statistics, the general consensus is that negative attitudes toward statistics leads to higher statistics anxiety (Chiesi & Primi, 2010; Mji & Onwuegbuzie, 2004; Onwuegbuzie, 2000; Watson, Kromrey, & Hess, 2003; Watson, Lang, & Kromrey, 2002; Zanakis & Valenzi, 1997). This distinction affords researchers more insights into their data. For example, when the STARS was administered 4 months before an oral examination, the statistics anxiety subscales, but not the attitudes toward statistics subscales, significantly predicted subjectively rated stress and anxiety. On the other hand, attitudes toward statistics, but not statistics

[3] Nasser (2004) investigated the effects of cognitive and affective factors on statistics achievement using Structural Equation Modeling. Statistics anxiety was assessed using the STARS (Cruise, Cash, & Bolton, 1985), and attitudes toward statistics was assessed using the Survey of Attitude toward Statistics Scale (SATS; Schau, Stevens, Dauphinee, & Vecchio, 1995). Statistics anxiety was eventually removed from the model due to its large structural coefficient with attitudes toward statistics (b = -.99).

anxiety, significantly predicted physiological responses (i.e., diastolic blood pressure) to the task (Papousek et al., 2012). These results underscored the importance and potential advantage of distinguishing between statistics anxiety and attitudes toward statistics.

Table 2.1

Correlations between the Subscales of the STARS and the SATS

	SATS			
STARS	Cognitive	Value	Difficulty	Affect
Statistics Anxiety subscales:				
(a) Interpretation anxiety	-.19*	-.21*	-.06	-.06
(b) Test and class anxiety	-.28*	-.35*	-.22*	-.49*
(c) Fear of asking for help	-.22*	-.24*	.01	-.33*
Attitudes toward Statistics subscales:				
(d) Worth of statistics	-.34*	-.76*	-.26*	-.48*
(e) Computation self-concept	-.63*	-.33*	-.34*	-.50*
(f) Fear of statistics teachers	-.36*	-.33*	-.33*	-.35*

Note. Data summarized from Nasser (2004) based on the factor structure of the STARS as suggested by Papousek et al. (2012).
* $p < .05$.

Currently, the critical question is whether the construct of statistics anxiety offers additional advantages for researchers and instructors compared to mathematics anxiety and attitudes toward statistics. Literature suggests that a reliable and valid measure of statistics anxiety allows researchers to identify students who are high in statistics anxiety, to predict scores on a statistics examination, and to evaluate the relative effectiveness of interventions designed to reduce statistics anxiety. Therefore, future research should examine the utility and predictive ability of statistics anxiety, mathematics anxiety, and attitudes toward statistics concurrently. For example, a point can be made for the distinctiveness of statistics anxiety if it predicts scores on statistics examinations better than the other two variables. However, before such research can be conducted, statistics anxiety needs to be redefined.

2.1.2 Redefining Statistics Anxiety

Statistics anxiety may be narrowly defined "as the feelings of anxiety encountered when taking a statistics course or doing statistical analyses" (Cruise et al., 1985, p. 92).

Offering a broader perspective, statistics anxiety is anxiety that occurs as a result of encountering statistics in any form and at any level (Onwuegbuzie et al., 1997). Thus, it may also be defined as:

> a performance characterized by extensive worry, intrusive thoughts, mental disorganization, tension, and physiological arousal … when exposed to statistics content, problems, instructional situations, or evaluative contexts, and is commonly claimed to debilitate performance in a wide variety of academic situations by interfering with the manipulation of statistics data and solution of statistics problems. (Zeidner, 1991, p. 319)

However, none of the definitions addresses its relationship with mathematics anxiety and attitudes toward statistics. Additionally, although there is some evidence for the positive effects of statistics anxiety on statistics achievement (Keeley, Zayac, & Correia, 2008), the majority of the literature focuses on the negative effects of statistics anxiety. Therefore, one recommendation is to extend the definition of statistics anxiety (Onwuegbuzie et al., 1997) and redefine it as:

> a negative state of emotional arousal experienced by individuals as a result of encountering statistics in any form and at any level; this emotional state is preceded by negative attitudes toward statistics and is related to but distinct from mathematics anxiety.

This definition should distinguish statistics anxiety from mathematics anxiety and attitudes toward statistics and serve as a guide in the selection of measures.

2.1.3 Selecting Appropriate Measures of Statistics Anxiety

A literature review revealed six measures purported to assess statistics anxiety. They are the STARS (Cruise et al., 1985), the Statistics Anxiety Inventory (Zeidner, 1991), the Statistics Anxiety Scale (Pretorius & Norman, 1992), an unnamed instrument (Zanakis &

Valenzi, 1997), the Statistics Anxiety Measure (Earp, 2007), and the Statistical Anxiety Scale (Vigil-Colet, Lorenzo-Seva, & Condon, 2008). These measures and their subscales are summarized in Table 2.2.

Table 2.2

Measures and Subscales of Statistics Anxiety (By Date of Publication)

Measures	Subscales
51-item STARS (Cruise et al., 1985)	(a) Interpretation anxiety (b) Test and class anxiety (c) Fear of asking for help (d) Worth of statistics (e) Computation self-concept (f) Fear of statistics teachers
40-item Statistics Anxiety Inventory (Zeidner, 1991)	(a) Statistics test anxiety (b) Statistics content anxiety
10-item Statistics Anxiety Scale (Pretorius & Norman, 1992)	Unidimensional
36-item Unnamed instrument (Zanakis & Valenzi, 1997)	(a) Student interest in and perceived worth of statistics (b) Anxiety when seeking help for interpretation (c) Computer usefulness and experience (d) Math anxiety (e) Understanding (f) Test anxiety
44-item Statistics Anxiety Measure (Earp, 2007)	(a) Anxiety (b) Attitude towards class (c) Fearful behaviour (d) Attitude towards math (e) Performance
24-item Statistical Anxiety Scale (Vigil-Colet et al., 2008)	(a) Examination anxiety (b) Asking for help anxiety (c) Interpretation anxiety

Two of these measures assume statistics anxiety to be similar to mathematics anxiety. Both the Statistics Anxiety Inventory (Zeidner, 1991) and the Statistics Anxiety Scale (Pretorius & Norman, 1992) were developed by replacing words related to mathematics with words related to statistics in the 40-item version of the Mathematics Anxiety Rating Scale (Richardson & Woolfolk, 1980) and the 10-item version of the Mathematics Anxiety Scale (Betz, 1978), respectively. Another two measures make no distinction between statistics anxiety and attitudes toward statistics. The unnamed instrument (Zanakis & Valenzi, 1997) and the Statistics Anxiety Measure (Earp, 2007) assess both statistics anxiety and attitude toward statistics. Using any of these four measures might result in high correlations between statistics anxiety, mathematics anxiety, and attitudes toward statistics. Consequently, researchers might assume the constructs to be similar or even identical.

Therefore, researchers who wish to measure statistics anxiety are recommended to use either the STARS (Cruise et al., 1985) or the Statistical Anxiety Scale (Vigil-Colet et al., 2008). Currently, the STARS has been extensively utilized by researchers due to the superiority of its reliability and validity data compared with that of other measures (Baloğlu, 2002; Hanna et al., 2008; Liu, Onwuegbuzie, & Meng, 2011; Mji & Onwuegbuzie, 2004; Papousek et al., 2012). However, as mentioned earlier, researchers should use only the first three subscales of the STARS as a measure of statistics anxiety. A second option is to use the Statistical Anxiety Scale, a promising instrument that affords researchers a specific measure of statistics anxiety. Nevertheless, the measure seems to be in its infancy with only two validity studies conducted (Chew & Dillon, 2014a; Chiesi, Primi, & Carmona, 2011). Thus, future research is needed to confirm its factor structure with diverse samples.

With the lack of distinction between statistics anxiety and related variables addressed, the next section of this paper reviews and evaluates the antecedents, effects, and interventions of statistics anxiety in order to provide recommendations for statistics instructors and for a new research agenda.

2.2 Antecedents of Statistics Anxiety[4]

The antecedents of statistics anxiety are classified as situational, dispositional, and environmental (Onwuegbuzie & Wilson, 2003). Situational antecedents refer to factors that surround the stimulus object or event, whereas dispositional antecedents refer to the

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[4] This section should be named ‘Correlates of Statistics Anxiety' given the correlational nature of most of the studies reported here. However, past literature reviews on statistics anxiety (Onwuegbuzie & Wilson, 2003), mathematics anxiety (Baloğlu, 1999), and general anxiety (Lazarus & Averill, 1972) have used the term ‘Antecedents’ along with its classification as situational, dispositional, and environmental. Accordingly, this chapter adopts the same naming convention to maintain consistency and ease of interpretation.

personality characteristics of an individual, and environmental antecedents refer to events which occurred in the past.

2.2.1 Situational Antecedents of Statistics Anxiety

Given the relationship between mathematics and statistics, a number of mathematics-related variables have been implicated in statistics anxiety. For example, statistics anxiety was found to be positively related to mathematics anxiety, number anxiety, mathematics course anxiety, and mathematics exam anxiety (Baloğlu, 2004).

Some characteristics of statistics courses have been implicated in statistics anxiety. In general, students taking accelerated courses experience higher levels of statistics anxiety than students taking regular courses (Bell, 2005). In addition, students taking an online statistics course report higher levels of statistics anxiety than their counterparts taking a statistics course on campus (DeVaney, 2010). However, students were not randomly assigned and a major limitation of DeVaney's study was the different characteristics of the groups. For example, students in the on-campus group (n = 27) were predominantly Black (66.7%), whereas students in the online group (n = 93) were predominantly White (74.2%).

The probabilistic nature of statistics has also been implicated in statistics anxiety. In statistics courses, students often have to deal with ambiguous scenarios in their learning. For example, when the null hypothesis is rejected, students have to accept that there is a 5% chance of making a Type I error (i.e., rejecting the null hypothesis when it is true). Students who are uncomfortable with such ambiguity might be more prone to experience statistics anxiety. Indeed, intolerance of uncertainty and students' tendency to worry (a dispositional antecedent) were found to be positively correlated with one another and with statistics anxiety (A. S. Williams, 2013).

2.2.2 Dispositional Antecedents of Statistics Anxiety

Procrastination has been found to be related to statistics anxiety. Students who procrastinated due to fear of failure and task aversiveness tended to experience higher levels of statistics anxiety (Dunn, 2013; Onwuegbuzie, 2004). However, procrastination and statistics anxiety might affect each other in a bi-directional manner. Students who procrastinate might experience higher statistics anxiety due to the increasing difficulty and workload of the course. Conversely, students with high levels of statistics anxiety might procrastinate due to task aversiveness (Onwuegbuzie, 2004).

Reading ability, learning strategies, and preference for numerical information have also been implicated in statistics anxiety. Students with poor reading ability tend to experience higher levels of statistics anxiety (Collins & Onwuegbuzie, 2007). The results provided support for the notion that a well-written statistics textbook might help meet the needs of students and alleviate statistics anxiety (Schact, 1990). With regard to learning strategies, students who used rehearsal, elaboration, organization, critical thinking, and effort regulation strategies experienced lower levels of statistics anxiety (Kesici, Baloğlu, & Deniz, 2011). Lastly, students with a higher preference for numerical information tend to experience lower levels of statistics anxiety (A. S. Williams, 2014).

The Big Five personality factors have also been found to be related to statistics anxiety (Chew & Dillon, 2014b). Neuroticism and Extraversion were positively correlated with statistics anxiety whereas Openness to Experience and Agreeableness were negatively correlated with statistics anxiety. Finally, although Conscientiousness positively predicts statistics examination grades (Furnham & Chamorro-Premuzic, 2004), the factor was not correlated with statistics anxiety. The authors suggest that "…conscientiousness students are able to circumvent, but not alleviate, statistics anxiety to do well in statistics examinations" (Chew & Dillon, 2014b, p. 1184).

2.2.3 Environmental Antecedents of Statistics Anxiety

The research on the relationship between age and gender and statistics anxiety has yielded mixed results. Although some studies reported that older students (e.g., age 25 years and above) had higher statistics anxiety than younger students (Baloğlu, 2003; Bell, 2003), a more recent study found no age differences (Bui & Alfaro, 2011). With regard to gender differences, although some studies reported that females experience higher statistics anxiety than males (Baloğlu, Deniz, & Kesici, 2011; Beurze, Donders, Zielhuis, de Vegt, & Verbeek, 2013; Rodarte-Luna & Sherry, 2008), at least one study found that males had higher statistics anxiety than females (Koh & Zawi, 2014), and other studies reported no gender differences (Baloğlu, 2003; Bui & Alfaro, 2011; Hsiao & Chiang, 2011). The mixed results could be due to various sources of inconsistencies, such as type of analysis (e.g., *t*-tests, discriminant function analysis, or MANOVA), country (e.g., USA, Turkey, or Taiwan), and the inclusion of other variables in the analysis (e.g., controlling for GPA or previous mathematics experience). Nevertheless, among studies that reported age or gender differences, the effect sizes were mostly small to moderate (e.g., Rodarte-Luna & Sherry, 2008). This suggests that the practical significance of the differences might be negligible. For example, although females reported higher statistics anxiety than males, there were no differences in statistics achievement (D. R. Bradley & Wygant, 1998). In addition, gender was not related to statistics examination grades (Furnham & Chamorro-Premuzic, 2004). Thus, future research should assess statistics achievement in conjunction with statistics anxiety. Specifically, researchers should examine whether age and gender differences in statistics anxiety affect statistics achievement.

Cross-cultural and ethnic differences have also been implicated in statistics anxiety. International students in the USA showed higher statistics anxiety than domestic students (Bell, 2008). In addition, American college students in the United States showed higher statistics anxiety than Turkish college students in Turkey (Baloğlu et al., 2011). With regard to ethnicity, although no significant differences in statistics anxiety were found between Latino/Hispanics and Caucasians (Bui & Alfaro, 2011), African Americans were found to have higher levels of statistics anxiety than their Caucasian American counterparts (Onwuegbuzie, 1999).

2.2.4 Evaluation of Antecedents of Statistics Anxiety

Most of the research examining antecedents has assessed statistics anxiety and another variable (e.g., reading ability) concurrently in a semester. Subsequently, due to the multidimensional nature of the variables, canonical correlation analysis or MANOVA was used to analyse the data. It should be acknowledged that the non-experimental design of the studies did not afford assessments of causality. Nevertheless, most of the antecedents cannot be manipulated due to their nature (e.g., gender, age, ethnicity, etc.) or due to ethical concerns (e.g., procrastination). Hence, researchers should recognize these limitations and use these research as a source of ideas for the development of interventions (e.g., a program designed to improve reading ability). Subsequently, the effectiveness of the interventions should be evaluated in an experimentally-designed study.

2.3 Effects of Statistics Anxiety

A consistent negative relationship has been found between statistics anxiety and statistics achievement in a variety of studies (Bell, 2001; Hanna & Dempster, 2009; Onwuegbuzie & Seaman, 1995; Onwuegbuzie, 1995, 2003; Tremblay, Gardner, & Heipel, 2000; Zanakis & Valenzi, 1997). In other words, students who experience higher levels of statistics anxiety tend to have lower performance on a statistics examination.

A study assessing the relationship between statistics anxiety and the difficulty of passing a statistics course measured statistics anxiety in a sample of psychology students enrolled in an introductory statistics course in the first semester of 2005 (Galli, Ciancaleoni, Chiesi, & Primi, 2008). Their course failures (if any) were recorded from June 2005 to February 2007. Out of 442 students, 99 (22%) students failed once, 42 (9.5%) failed twice, and 21 (5.1%) failed three times, leading to a total of 162 (37%) students who failed the course at least once. These 162 students had higher levels of statistics anxiety than the 280 students who passed the course at the first attempt. Because statistics anxiety was assessed in the first semester, students could not have been reporting higher statistics anxiety due to failing the statistics course previously.

Despite the numerous studies that found a negative relationship between statistics anxiety and statistics achievement, it has been suggested that statistics anxiety may have a facilitative component (Onwuegbuzie & Wilson, 2003). Indeed, high and low levels of statistics anxiety were related to lower performance, whereas mid-level anxiety corresponded to higher performance (Keeley et al., 2008; also see Yerkes & Dodson, 1908). This has important implications for the implementation of statistics anxiety interventions. It should be cautioned that “anxiety is not a fire that needs to be stamped out for students to be successful . . . some anxiety is acceptable” (Keeley et al., 2008, p. 13).

2.3.1 Evaluation of Effects of Statistics Anxiety

Current research on the effects of statistics anxiety is limited due to the lack of cut-off scores for anxiety levels. For example, although moderate statistics anxiety facilitates performance (Keeley et al., 2008), it is unclear at which point statistics anxiety may change from being debilitative to facilitative, and finally to debilitative again (Onwuegbuzie & Wilson, 2003). Most clinical instruments have a set of cut-off scores to identify individuals most likely to benefit from interventions. For example, on the Beck’s Anxiety Inventory, a total score of 0-7 indicates minimal anxiety, 8-15 mild anxiety, 16-25 moderate anxiety, and 26-63 indicates severe anxiety (Beck & Steer, 1993). From a practical point of view, statistics instructors are better served by knowing the various percentages of students experiencing low, medium, and high statistics anxiety rather than knowing the mean anxiety levels of the class. For instance, instructors could employ interventions for students who report high levels of statistics anxiety. Therefore, future research should determine a set of cut-off scores that could differentiate students in need for intervention from those who do not.

2.4 Interventions for Statistics Anxiety

Given the negative effects of statistics anxiety, studies have explored how innovative instructional methods might reduce that anxiety. One method involves presenting 17 graduate students with nine short “sleuthing” stories and asking them to use statistical analyses to “solve” the puzzle (D’Andrea & Waters, 2002). A pretest-posttest design showed a significant decrease in statistics anxiety scores in the posttest. Another method requires statistics instructors to employ application-oriented teaching methods (applying statistics to real-world problems, critiquing of journal articles, etc.), while being attentive to students’ anxiety (humorous teaching style, providing coping strategies, etc.) in class (Pan & Tang, 2004). Similarly, a pretest-posttest design showed a significant decrease in statistics anxiety scores among 21 graduate students in the posttest. The latter method has been successfully replicated. Specifically, 28 graduate students reported a significant decrease in statistics anxiety scores and an increase in statistics self-efficacy scores (i.e., higher confidence to learn statistics) in the posttest (McGrath, Ferns, Greiner, Wanamaker, & Brown, 2015).

The effectiveness of a gender-sensitive and culture-sensitive statistics course in alleviating statistics anxiety has been examined (Davis, 2003) because some research showed that women and minorities reported higher statistics anxiety (e.g., Baloğlu et al., 2011). Davis (2003) designed a statistics course around the six factors of statistics anxiety (Cruise et al., 1985). For example, the Fear of Asking for Help factor was addressed by discussing statistics anxiety with students. More importantly, participants had weekly discussions on the role of women and minorities in research. A pretest-posttest design revealed significant reductions in statistics anxiety among 41 graduate students at posttest.

Lastly, the role of instructor immediacy in reducing students' levels of statistics anxiety was examined (A. S. Williams, 2010). Immediacy refers to a set of behaviours communicated by the instructors to influence the perception of psychological and physical distance. The first 38 graduate students to enrol in the introductory statistics course was allocated to the experimental group (taught by A. S. Williams) whereas the remaining 38 graduate students were allocated to the control group (taught by other instructors). Throughout the semester, A. S. Williams exhibited both verbal (e.g., addresses students by name) and nonverbal (e.g., looks at the class while talking) immediacy behaviours. A pretest-posttest control group design revealed a significant decrease in statistics anxiety scores for the experimental group.

2.4.1 Evaluation of Interventions for Statistics Anxiety

Although since the previous, most recent literature review (i.e., Onwuegbuzie & Wilson, 2003), there has been an increase in the use of experimental designs to evaluate interventions, the design of the studies can be further improved. Only one included a control group design (A. S. Williams, 2010); the others used a one group pretest-posttest design (D'Andrea & Waters, 2002; Davis, 2003; McGrath et al., 2015; Pan & Tang, 2004). A common argument for this design is the ethical issue of withholding a potentially beneficial intervention from the control group (Pan & Tang, 2004). Nevertheless, the lack of a control group is problematic, because it does not take into account several alternative competing explanations for improvement such as history, maturation, testing, and regression to the mean (Campbell & Stanley, 1963). For example, there is some evidence that statistics anxiety decreases over time in the absence of interventions (Chew & Dillon, 2012; Keeley et al., 2008). Hence, the effectiveness of the interventions in these studies is in question.

In education research, it is often impractical or impossible to randomly assign students to groups. Consequently, most research uses pre-existing groups, such as students from two comparable classes. Therefore, future research should use the Non-Equivalent Control Group Design, a commonly used quasi-experimental design, to evaluate interventions for statistics anxiety. The Non-Equivalent Control Group Design is essentially a pretest-posttest control group design without random assignment. While the design has its limitations, it is vastly superior to the one group pretest-posttest design in terms of interpretation (Campbell & Stanley, 1963). Subsequently, researchers are recommended to run both ANOVA (on the change scores–posttest minus pretest) and ANCOVA (with pretest as covariate and posttest as outcome) to increase their confidence in the conclusions (Van Breukelen, 2006).

2.5 Recommendations for Statistics Instructors

This chapter makes five recommendations for statistics instructors based on statistics anxiety literature. First, the emphasis on mathematics in statistics courses should be reduced. Although formulas and calculations might help students understand statistics (however, see Rumsey, 2002), they might aggravate the situation because students have to deal with mathematics anxiety in addition to statistics anxiety. Furthermore, with the plethora of commercial and free statistical software, the need for manual calculations should be diminished. Thus, instructors should devote most of their time to helping students understand the assumptions and the appropriate uses of statistical tests.

Second, given the relationship between academic procrastination and statistics anxiety (Dunn, 2013; Onwuegbuzie, 2004), instructors should structure the statistics course to discourage procrastination. Similar to student procrastination in enrolling in the statistics course until their last semester (Roberts & Bilderback, 1980), anecdotal evidence suggests that students procrastinate on studying for statistics until the last week or two before their examinations. Therefore, instructors can introduce weekly quizzes to encourage students to keep up with their required readings. Furthermore, incorrect answers on these quizzes help instructors identify areas the students are having problems with. In addition, instructors should award marks to students for participation rather than for correct answers. The idea is to encourage students to be consistent in studying for statistics instead of experiencing statistics anxiety or test anxiety due to the potentially evaluative nature of the quizzes.

Third, a system should be in place to allow for anonymous questions, because some students experience anxieties related to Fear of Asking for Help and Fear of Statistics Teachers (Cruise et al., 1985). For example, the commonly used BlackBoard Learning Management System allows instructors to set up forums for students to post questions anonymously. Subsequently, instructors can either answer the questions on the forums or collate the questions and address them in class.

Fourth, humour should be integrated into statistics courses through the inclusion of cartoons on lecture slides (Schact & Stewart, 1990) or by adopting a humorous teaching style (Pan & Tang, 2004). The Consortium for the Advancement of Undergraduate Statistics Education (CAUSE, 2013) website contains a wide array of materials ranging from cartoons to videos to make the learning of statistics fun and engaging. More recommendations and resources on the use of humour in statistics teaching can be found in Lesser and Pearl (2008). However, instructors should only include materials related to the topic being taught instead of random humour. For example, a cartoon that illustrates the importance of labelling the axes of a graph would be appropriate in contrast to one that makes fun of a politician. In addition, care should be taken to ensure that the materials are gender and culture sensitive (Davis, 2003).

Lastly, instructors could try to exhibit certain anxiety-reducing behaviours in class. A recent study found that female teachers' mathematics anxiety negatively affects elementary school girls' mathematics achievement (Beilock, Gunderson, Ramirez, & Levine, 2010). Although no similar studies have been done on statistics anxiety, instructors should manage their own anxieties (if any) to appear confident and composed to students. In addition, instructors should exhibit immediacy behaviours to increase psychological and physical closeness and to reduce statistics anxiety (A. S. Williams, 2010). Lists of such behaviours are found in the verbal immediacy scale (Gorham, 1988) and the revised nonverbal immediacy scale (McCroskey, Richmond, Sallinen, Fayer, & Barraclough, 1995). For example, instructors can address students by name (verbal) and move around the classroom while teaching (nonverbal).

2.6 Recommendations for a New Research Agenda

Current research on statistics anxiety is limited in several ways. First, antecedent research is not being used to inform interventions. For example, despite procrastination being an antecedent of statistics anxiety (Onwuegbuzie, 2004), no research has evaluated the effect of reducing procrastination as an intervention for statistics anxiety. In this instance, antecedent research has served no purpose other than informing researchers about the correlates of statistics anxiety. Secondly, although research on the effects of statistics anxiety clearly emphasizes the need for instructors to be aware of this anxiety and for researchers to develop interventions for it, the research does not explain how statistics anxiety negatively affects statistics achievement. Lastly, most of the intervention research has been instructor-centred. These studies assume, perhaps incorrectly in certain instances, that instructors have the autonomy, ability, and time to implement these interventions in class.

In view of these limitations, there is a need for the field of statistics anxiety to move toward a new research agenda. Specifically, researchers could adopt an information processing perspective on statistics anxiety. According to cognitive theories (Beck, 1976; Bower, 1981), individuals with anxiety have an attentional bias to process information congruent with their anxiety. Furthermore, these theories assert that this bias plays an important role in the aetiology and maintenance of anxiety in individuals. Evidence of this bias has been documented using experimental paradigms, such as the emotional Stroop task and the dot probe task (MacLeod, Mathews, & Tata, 1986). More recently, researchers have modified the dot probe task and applied it successfully as an intervention (commonly known as Attentional Bias Modification) for nonclinical populations, such as high trait anxious students, and for clinical populations, such as patients with Generalized Anxiety Disorder, social phobia, or alcohol dependence (Bar-Haim, 2010; Browning, Holmes, & Harmer, 2010; Schoenmakers et al., 2010). The intervention is remarkable considering the absence of a therapist in its implementation.

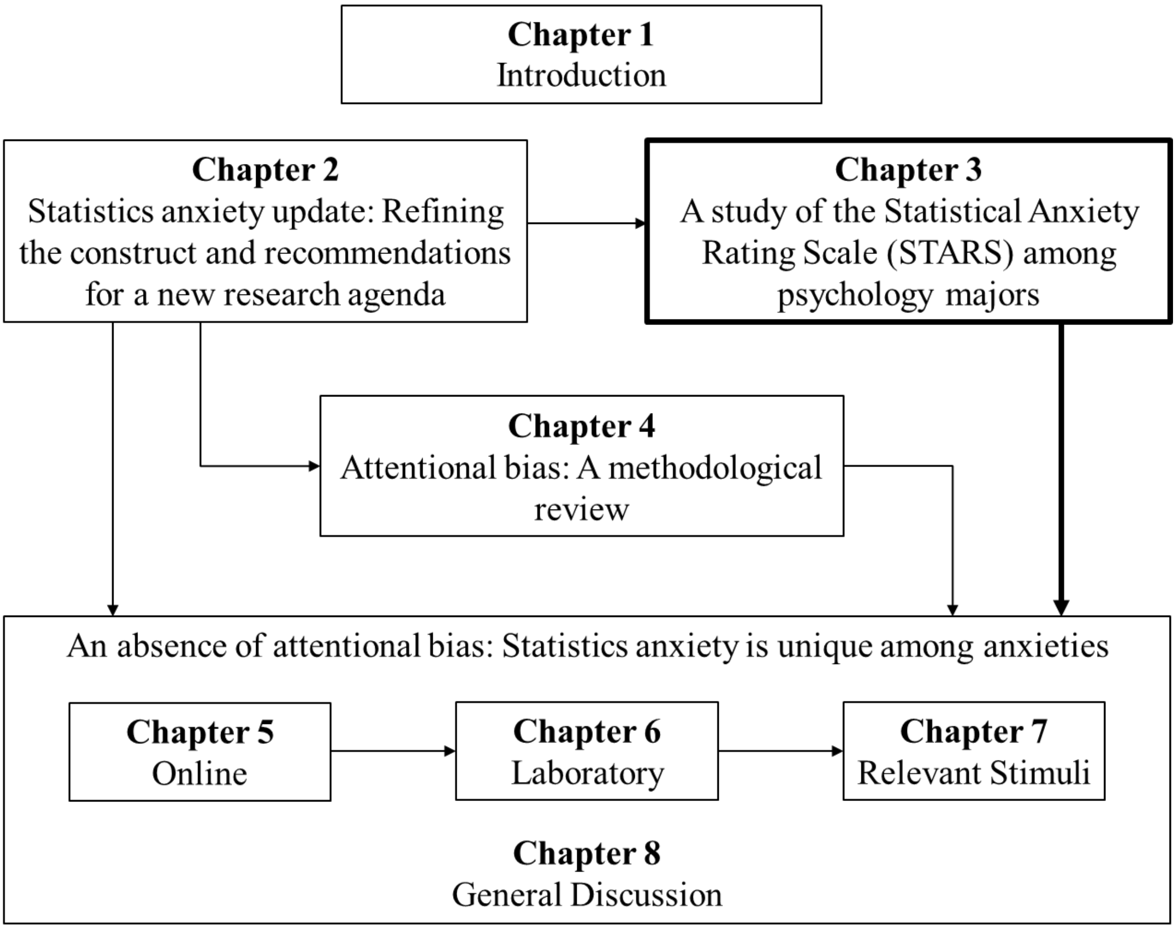
An information processing perspective is appropriate due to the similarity between statistics anxiety and specific phobias. In fact, statistics anxiety can be considered a form of specific phobia, because the symptoms only emerge when students are learning or applying statistics (Onwuegbuzie, 1999). An information processing perspective suggests that an attentional bias toward threatening stimuli might characterize students who are high in statistics anxiety. For example, these students should be faster in responding to a dot that replaces a statistics-related threatening word (e.g., mode) than a neutral word (e.g., deck) on the dot probe task (MacLeod et al., 1986). Hence, the role of attentional bias as an antecedent and effect of statistics anxiety should be explored. The presence of an attentional bias provides hints as to the mechanisms by which statistics anxiety operates. For example, students high in statistics anxiety might be allocating a disproportionate amount of cognitive resources (attention) in processing threatening words. This leads to poor concentration and impaired learning (Beck & Clark, 1997), which eventually results in poor statistics achievement.

More importantly, the presence of an attentional bias informs possible interventions. For example, future research can explore the effectiveness of Attentional Bias Modification as a student-centred intervention for statistics anxiety. The program can be completed online (MacLeod, Soong, Rutherford, & Campbell, 2007) with minimal participation from instructors, allowing students to assume at least part of the responsibility for their anxiety.

2.7 Summary

The purpose of this paper is to provide a current review of the statistics anxiety literature with the goal of refining the statistics anxiety construct and providing recommendations for statistics instructors and for a new research agenda. Statistics anxiety can be refined by redefining it, which will inform the selection of appropriate measures. Recommendations for statistics instructors include: (a) reducing the emphasis on mathematics, (b) using humour, (c) discouraging student procrastination, (d) allowing anonymous questions, and (e) using immediacy behaviours. Lastly, the adoption of an information processing perspective to motivate a new research agenda addresses several limitations in the statistics anxiety literature and suggests a potentially effective, student-centred intervention for statistics anxiety. In particular, with statistics courses being a compulsory component of psychology degree programs (Stoloff et al., 2009) and a well-documented prevalence of anxiety about such courses, there is a pressing need for well-evaluated interventions to be documented and shared with both researchers, instructors, and students. The goal of promoting statistics literacy for citizens of a democracy might eventually come to fruition when the negative effects of statistics anxiety are attenuated from the process of statistics learning.

Chapter 3: A study of the Statistical Anxiety Rating Scale (STARS) among psychology majors in Singapore and Australia



This chapter examines the psychometric properties of the Statistical Anxiety Rating Scale (STARS) for its use in Chapters 5, 6 and 7. An earlier version of this chapter is currently under review in a journal:

Chew, P. K. H., Dillon, D. B., & Swinbourne, A. (Under Review). A study of the Statistical Anxiety Rating Scale (STARS) among psychology majors in Singapore and Australia. *Applied Psychological Measurement*

Chapter 3: A study of the Statistical Anxiety Rating Scale (STARS) among psychology majors in Singapore and Australia

Cruise et al. (1985) developed the STARS to measure statistics anxiety. An initial 89-item pilot instrument was completed by 1150 participants in the USA and the data subjected to factor analysis using the Principal Components Method with varimax rotation. Results indicated that the rotation of 51 items on six factors yielded the most interpretable structure. The six factors were: (a) Interpretation Anxiety, (b) Test and Class Anxiety, (c) Fear of Asking for Help, (d) Worth of Statistics, (e) Computation Self-Concept, and (f) Fear of Statistics Teachers.

Interpretation Anxiety refers to the feelings of anxiety encountered when interpreting statistical data. The Test and Class Anxiety factor encompasses the anxiety involved when attending a statistics class or when taking a statistics test. Fear of Asking for Help assesses the anxiety experienced when seeking help. Worth of Statistics relates to an individual's perception of the relevance of statistics to the individual. Computation Self-Concept relates to an individual's self-perception of his or her ability to understand and calculate statistics. Lastly, Fear of Statistics Teachers refers to an individual's perception of the statistics teacher.

The 51-item STARS consists of two parts (Cruise et al., 1985). Part one consists of 23 items which assess statistics anxiety associated with situations where students have contact with statistics and it includes the following factors: (a) Interpretation Anxiety, (b) Test and Class Anxiety, and (c) Fear of Asking for Help. Individuals respond on a 5-point Likert scale that ranges from 1 = *No Anxiety* to 5 = *Strong Anxiety*. Part two consists of 28 items that measure the level of agreement with various statements about statistics and statistics teachers and it includes the following factors: (d) Worth of Statistics, (e) Computation Self-Concept, and (f) Fear of Statistics Teachers. Responses are made on a 5-point Likert scale that ranges from 1 = *Strongly Disagree* to 5 = *Strongly Agree*.

Despite the existence of newer measures of statistics anxiety, such as the Statistical Anxiety Scale (Vigil-Colet et al., 2008), the STARS (Cruise et al., 1985) has been used extensively by researchers due to the superiority of its reliability and validity data as compared with other measures (Onwuegbuzie & Wilson, 2003). The psychometric properties of the STARS have been examined and the six-factor structure confirmed in several studies using student populations in the USA (Baloğlu, 2002), South Africa (Mji & Onwuegbuzie, 2004), the United Kingdom (Hanna et al., 2008), China (Liu et al., 2011), and Austria (Papousek et al., 2012). The internal consistency of the STARS reported by these studies is summarized in Table 3.1. Furthermore, Keeley et al. (2008) reported two-week test-retest reliabilities that ranged from .76 to .87 and four-months test-retest reliabilities that ranged from .41 to .74 (n = 83). More recently, Papousek et al. (2012) reported five-month test-retest reliabilities that ranged from .49 to .78 (n = 89). With regards to validity, despite confirming the six-factor structure, several researchers have argued that the STARS assesses both statistics anxiety and attitudes toward statistics rather than only statistics anxiety (Hanna et al., 2008; Papousek et al., 2012).

Hanna et al. (2008) examined the structure of the STARS with a sample of 650 undergraduate psychology students in the United Kingdom and reported that a correlated six first-order factor model explained the data better than a six factor model with one superordinate factor. The results were unexpected because the latter model should be a better model if all six factors of the STARS assess statistics anxiety alone. For example, all six factors should load on a single superordinate factor (i.e., statistics anxiety) if the STARS assesses statistics anxiety only. Instead, the results suggest that while the six factors are correlated, they might assess a construct more multifaceted than statistics anxiety. Furthermore, Hanna et al. noted that many items and factors of the STARS appear to assess related concepts of statistics anxiety, such as attitudes toward statistics. Based on these findings, Hanna et al. suggested replacing the term “statistics anxiety” with a more appropriate label such as “statistical attitudes and anxiety”.

Table 3.1

Internal Consistency Reliability Coefficients (Cronbach’s alpha) of the STARS among Six Studies

Factors	(Cruise et al., 1985) (*n* = 1150)	(Baloğlu, 2002) (*n* = 221)	(Mji & Onwuegbuzie, 2004) (*n* = 169)	(Hanna et al., 2008) (*n* = 650)	(Liu et al., 2011) (*n* = 201)	(Papousek et al., 2012) (*n* = 400)
Interpretation	.89	.89	.77	.87	.86	.88
Test	.91	.91	.77	.87	.85	.87
Fear	.85	.62	.68	.83	.72	.86
Worth	.94	.94	.86	.94	.91	.94
Self-Concept	.88	.85	.81	.87	.74	.86
Teachers	.80	.79	.74	.83	.69	.80
Total Scale	-	.96	.92	-	.94	.96

Note. Interpretation = Interpretation Anxiety; Test = Test and Class Anxiety; Fear = Fear of Asking for Help; Worth = Worth of Statistics; Self-Concept = Computation Self-Concept; Teachers = Fear of Statistics Teachers.

Subsequently, Papousek et al. (2012) translated the STARS to German and examined its structure with a sample of 400 undergraduate students in Austria. Papousek et al. argued that the two-part nature of the STARS, as well as the different labels assigned to the Likert scales (anxiety vs. agreement), suggests that part one of the STARS assesses statistics anxiety and part two assesses attitudes toward statistics. Papousek et al. extended the work of Hanna et al. (2008) by including a six-factor model with two superordinate factors representing three factors each: statistics anxiety (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help) and attitudes toward statistics (Worth of Statistics, Computation Self-Concept, and Fear of Statistics Teachers). Due to the use of multiple fit indices, two models were found to be equally acceptable: a modified correlated six first-order factor model (13 error correlations were specified and item 47 was reassigned to load on another factor) and the modified six factor model with two superordinate factors. However, Papousek et al. provided support for the latter model by demonstrating differential validity between statistics anxiety and attitudes toward statistics in subsequent validation studies. Nevertheless, it should be noted that the conclusions made by Papousek et al. were based on the German adaptation of the STARS. Therefore, a research gap exists with regards to the structure of the English version of the STARS.

Given the popularity of the STARS (Cruise et al., 1985), it is important that researchers be aware of the constructs assessed by the instrument. A clarification of the structure of the STARS and a distinction between statistics anxiety and attitudes toward statistics offers researchers more insights into their data. For example, Bell (2003) reported that non-traditional university students (defined as students aged 25 years and above) scored higher on the Test and Class Anxiety factor whereas traditional university students (below the age of 25 years) scored higher on the Worth of Statistics factor of the STARS. As high scores indicate higher anxiety, the results suggest that both groups of students experience statistics anxiety, but that anxiety appears to be associated with different factors. However, if the STARS assesses both anxiety and attitudes (with high scores on Worth of Statistics indicating more negative attitudes), this finding could be reinterpreted to mean that non-traditional students had higher statistics anxiety but understood the importance of statistics than did traditional students.

Hence, the purpose of the current study is to bridge the research gap by examining the internal consistency and structure of the original English version of the STARS (Cruise et al., 1985). Three models are specified and evaluated based on prior research (Hanna et al., 2008; Papousek et al., 2012): a correlated six first-order factor model (Model 1), a six factor model with one superordinate factor (i.e., statistics anxiety only) (Model 2), and a six factor model with two correlated superordinate factors (Model 3). For Model 3, it is hypothesized that part one of the STARS (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help factors) will load on one superordinate factor (i.e., statistics anxiety) and part two of the STARS (Worth of statistics, Computation Self-Concept, and Fear of Statistics Teachers factors) will load on another superordinate factor (i.e., negative attitudes toward statistics). It is hypothesized that Model 3 will best represent the data from the current sample.

3.1 Method

3.1.1 Participants

A convenience sample of 202 (79% females) psychology undergraduates was recruited from James Cook University's Singapore (71%) and Australia (29%) campuses. Their ages ranged from 17 to 54 years (M = 23.72, SD = 7.18). The predominantly female sample was consistent with the gender distribution of the psychology undergraduate population in Singapore and Australia. Participants were either currently enrolled in a statistics course (74%) or had completed at least one statistics course but were not currently enrolled in a statistics course (26%). Barrett (2007) recommends a minimum sample size of 200 for Confirmatory Factor Analysis/Structural Equation Modelling.

3.1.2 Instruments

3.1.2.1 The Background Information Form. The Background Information Form was developed by the authors for the purpose of the current study. The form was designed to assess basic demographic information such as age, gender, and statistics course enrolled. The form is presented in Appendix 3.1.

3.1.2.2 The STARS. The basic structure and response format of the STARS have been described earlier. The current study used a revised version of the STARS. Hanna et al. (2008) revised six items to facilitate understanding by students in the UK. The revised version was chosen due to the relative similarity in language use between the Singapore sample and the UK sample. For example, the word "car" is used in Singapore, Australia, and the UK instead of the word "automobile". Appropriate item scores are summed for each factor, with higher scores indicating higher levels of statistics anxiety. The instrument is presented in Appendix 3.2.

3.1.2.3 The Statistical Anxiety Scale. The Statistical Anxiety Scale is a 24-item instrument designed to assess three factors of statistics anxiety: (a) Examination Anxiety, (b) Asking for Help Anxiety, and (c) Interpretation (Vigil-Colet et al., 2008). Individuals respond on a 5-point Likert scale that ranges from 1 = *No Anxiety* to 5 = *Considerable Anxiety*. Appropriate item scores are summed for each factor and for the total scale, with higher scores indicating higher levels of statistics anxiety. Vigil-Colet et al. (2008) reported internal consistency ranging from.82 to .92 for the subscales and .91 for the total scale (n = 159). The three-factor structure has been confirmed in two psychometric studies (Chew & Dillon, 2014a; Chiesi et al., 2011). The current study found internal consistencies that ranged from .89 to .95. The instrument is presented in Appendix 3.3.

3.1.2.4 The Attitudes toward Statistics scale. The Attitudes toward Statistics scale is a 29-item instrument designed to assess two aspects of an individual's attitudes toward statistics: (a) Attitudes toward Field and (b) Attitudes toward Course (Wise, 1985). Responses are made on a 5-point Likert scale that ranges from 1 = *Strongly Disagree* to 5 = *Strongly Agree*. Fourteen negatively worded items are reverse scored and the appropriate item scores are summed for each factor and for the total scale. Higher scores indicate higher levels of positive attitudes toward statistics. Wise (1985) reported internal consistency of .92 and .90, and two week test-retest reliability of .82 and .91, for the Attitudes toward Field subscale and the Attitudes toward Course subscale, respectively (n = 92). The two-factor structure has been confirmed in other factor-analytic studies (Shultz & Koshino, 1998; Waters, Martelli, Zakrajsek, & Popovich, 1988). The current study found internal consistencies that ranged from .91 to .93. The instrument is presented in Appendix 3.4.

3.1.3 Procedure

Participants were invited to complete the Background Information Form, the STARS (Cruise et al., 1985), the Statistical Anxiety Scale (Vigil-Colet et al., 2008), and the Attitudes toward Statistics scale (Wise, 1985). Each instrument took about 10 minutes to complete. Both the STARS and the Statistical Anxiety Scale are measures of statistics anxiety while the Attitudes toward Statistics scale is a measure of attitudes toward statistics. All instruments were administered online using SurveyGizmo (2015) and counterbalanced to control for order effects. Although the STARS was developed as a paper-and-pencil instrument, subsequent psychometric studies on the instrument have yielded similar results despite the different mode of administration (online; Hanna et al., 2008; paper-and-pencil; Papousek et al., 2012). Online surveys also increase self-disclosure and reduce social desirability (Duffy, Smith, Terhanian, & Bremer, 2005; Locke & Gilbert, 1995; Turner et al., 1998; Wright, 2005). Participants either received extra course credit or were entered into a lucky draw for a chance to win an iPod shuffle. This procedure was approved by the James Cook University Human Research Ethics Committee (see Appendix 3.5).

3.1.4 Data Analysis

There are three scenarios in the general strategic framework for testing structural equation models: (a) strictly confirmatory, (b) alternative models, and (c) model generating (Jöreskog, 1993). The model generating scenario is currently the most common approach (Byrne, 2010). In this scenario, an initial model is specified and evaluated against a set of fit indices. If the model represents a poor fit to the data, the researcher identifies the source of misfit and modifies the model. For example, Papousek et al. (2012) specified 13 error correlations and reassigned an item to another factor to improve model fit. Nevertheless, criticisms have been directed at some aspects of the model generating scenario (Barrett, 2007; MacCallum, Roznowski, & Necowitz, 1992; Marsh, Hau, & Wen, 2004).

Approximate fit indices were originally developed to indicate degree of model fit to data. However, recommended cut-off values of these indices have been elevated to golden rules, resulting in a binary decision (fit/no fit) of model fit (Marsh et al., 2004). For example, the recommended cut-off value of the Comparative Fit Index (CFI) is .95 (Hu & Bentler, 1999), and models with a value of more than .95 are considered a good fit. Consequently, Barrett (2007) recommends banning the use of such fit indices (however, see Markland, 2007). Another criticism deals with the non-generalizability of modifications (MacCallum et al., 1992). Because modifications (e.g., error correlations) are data driven, the modifications might not generalize to samples in other studies or to the population. Therefore, the current study uses the alternative models scenario to test structural equation models (Jöreskog, 1993; MacCallum et al., 1992; MacCallum, Wegener, Uchino, & Fabrigar, 1993).

In the alternative models scenario, several competing models, grounded in theory, are specified and evaluated (Byrne, 2010). Based on fit indices, one model would be selected as the best model to represent the data. As recommended by the AMOS 16 User's Guide (Arbuckle, 2007), the Linhart and Zucchini's (1986) bootstrap approach to model comparison is used in this study. The bootstrap approach is summarized in four steps: (a) generate multiple bootstrap samples from the current sample, (b) fit every model to every bootstrap sample and calculate the discrepancy of the implied moments between the sample and population, (c) calculate the average discrepancy across bootstrap samples for each model, and (d) select the model with the lowest average discrepancy (Arbuckle, 2007).

Additionally, several fit indices were used to aid interpretation. These indices are the Browne-Cudeck Criterion (BCC), the Expected Cross-Validation Index (ECVI) (Browne & Cudeck, 1989), and the Consistent Akaike's Information Criterion (CAIC) (Bozdogan, 1987). These indices do not have recommended cut-off values; instead, they are compared across models, with lower values indicating better model fit relative to other competing models.

Lastly, the theoretical appropriateness of the models was considered (Arbuckle, 2007). Indeed, "the assessment of model adequacy should be a multifaceted enterprise comprising consideration of model fit, empirical adequacy and substantive meaningfulness"

(Markland, 2007, p. 858). Theoretical appropriateness of the models was in this instance evaluated by examining convergent and divergent validity using the Statistical Anxiety Scale (Vigil-Colet et al., 2008) and the Attitudes toward Statistics scale (Wise, 1985).

3.2 Results

All results were analysed using SPSS and AMOS version 16.0 with the alpha level set at .05. Preliminary analyses suggest that females had higher scores on the Computation Self-Concept factor than males. Additionally, participants from the Singapore campus had higher scores on the Interpretation Anxiety factor than their counterparts from the Australian campuses. However, the sample size was not large enough to permit separate investigations. Thus, the results were collapsed across gender and campuses. Internal consistencies, means, and standard deviations of the six factors of the STARS (Cruise et al., 1985) are presented in Table 3.2. Cronbach's alphas ranged from .81 to .94, which was well above the acceptable alpha of .70 (Nunnally, 1978). The intercorrelations between factors of the STARS are presented in Table 3.3.

Table 3.2

Internal Consistencies (Cronbach's alpha), Means, and Standard Deviations of the STARS

STARS Factors	Cronbach's alpha	*M*	*SD*	No. of Items
Interpretation Anxiety	.91	31.08	8.94	11
Test and Class Anxiety	.89	28.71	6.51	8
Fear of Asking for Help	.88	9.93	4.07	4
Worth of Statistics	.94	39.09	13.49	16
Computation Self-Concept	.90	18.77	7.06	7
Fear of Statistics Teachers	.81	11.41	4.20	5

Table 3.3

Intercorrelations between Factors of the STARS

	1	2	3	4	5	6
1. Interpretation Anxiety	-					
2. Test and Class Anxiety	.62*	-				
3. Fear of Asking for Help	.69*	.48*	-			
4. Worth of Statistics	.44*	.35*	.43*	-		
5. Computation Self-Concept	.51*	.59*	.48*	.74*	-	
6. Fear of Statistics Teachers	.40*	.29*	.42*	.68*	.61*	-

* $p < .01$

To evaluate the structure of the STARS (Cruise et al., 1985), the following models were specified and evaluated: a correlated six first-order factor model (Model 1), a six-factor model with one superordinate factor (i.e., statistics anxiety only) (Model 2), and a six-factor model with two correlated superordinate factors (i.e., statistics anxiety and negative attitudes toward statistics) (Model 3)[5]. Bootstrapping was used with 1000 bootstrap samples and the results are presented in Table 3.4. Model 1 had the lowest mean discrepancy and fit indices values, followed closely by Model 3 and lastly, Model 2. Hence, the fit indices suggest Model 1 to be the best fit to the data of the three models tested (see Figure 3.1, 3.2, and 3.3 for the standardized estimates of all three models, respectively). The nested χ^2 difference test was conducted to compare the remaining models. Model 3 ($\chi^2_{(1217)} = 2760.41$) was a better fit to the data than Model 2 ($\chi^2_{(1218)} = 2824.85$), $\Delta \chi^2_{(1)} = 64.44$, $p < .001$.

[5] One examiner suggested that Fear of Statistics Teachers appears to be assessing anxiety instead of attitudes. Hence, an additional model was specified and evaluated. This model is similar to Model 3. However, Fear of Statistics Teachers was specified to load on the statistics anxiety superordinate factor instead of the negative attitudes toward statistics superordinate factor. According to the average mean discrepancies and the fit indices (Mean Discrepancy = 3000.79, BCC = 3103.69, CAIC = 3497.21, and ECVI = 15.06), the model had a poorer fit than Model 3. These results suggested that Fear of Statistics Teachers assesses attitudes instead of anxiety.

Table 3.4

Average Mean Discrepancies and Fit Indices for Three Competing Models of the STARS

Model	Failures	Mean Discrepancy	BCC	CAIC	ECVI
1	0	2907.93	3023.56	3445.96	14.64
2	0	3012.55	3116.23	3506.14	15.13
3	0	2951.16	3054.49	3448.01	14.82

Note. Model 1 = correlated six first-order model; Model 2 = six-factor model with one superordinate factor; Model 3 = six-factor model with two correlated superordinate factors; BCC = Browne-Cudeck Criterion; CAIC = Consistent Akaike's Information Criterion; ECVI = Expected Cross-Validation Index.

3.2.1 Convergent and Divergent Validity

The theoretical appropriateness of the models was evaluated by examining convergent and divergent validity of the factors. The hypothesized superordinate factors of the STARS were derived by summing scores on the respective factors: (a) STARS-Anxiety (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help factors), (b) STARS-Negative Attitudes (Worth of Statistics, Computation Self-Concept, and Fear of Statistics Teachers factors), and (c) STARS-Total Scale (all six factors). SAS-Anxiety was derived by summing scores from the three factors of the Statistical Anxiety Scale (Vigil-Colet et al., 2008) and ATS-Positive attitudes was derived by summing scores from the two factors of the Attitudes toward Statistics scale (Wise, 1985). Table 3.5 presents the correlations between these variables.

At least one factor in each model was highly correlated with ATS-Positive Attitudes. Model 3 was the only model to discriminate between anxiety and attitudes: STARS-Anxiety had a larger correlation with SAS-Anxiety than ATS-Positive Attitudes whereas STARS-Negative Attitudes had a larger correlation with ATS-Positive Attitudes than SAS-Anxiety. Therefore, theoretical considerations suggest Model 3 best describe the data compared to competing models.

3.3 Discussion

The purpose of the current study was to examine the internal consistency and structure of the English version of the STARS (Cruise et al., 1985). Consistent with previous studies (Hanna et al., 2008; Papousek et al., 2012), acceptable internal consistency reliabilities were found in the current study. For example, Papousek et al. (2012) reported internal consistency which ranged from .80 to .96 whereas the current study reported internal consistency which ranged from .81 to .94. With regards to the structure of the STARS, it was hypothesized that Model 3 would best represent the data from the current sample. The results provided partial support for the hypothesis. Although the fit indices suggested that Model 1 provided the best fit to the data, theoretical considerations suggested that Model 3 best describe the data.

The results were consistent with previous studies that indicate that the STARS assesses a construct broader than statistics anxiety (Hanna et al., 2008; Papousek et al., 2012). The fit indices showed that Model 2 represented a poor fit to the data compared to Model 1 and Model 3. More importantly, the use of only one superordinate factor (i.e., statistics anxiety) did not discriminate between anxiety and attitudes. The total scale of the STARS had large correlations with statistics anxiety and attitudes toward statistics. This would result in multicollinearity in studies where both variables are examined concurrently (e.g., Nasser, 2004). Thus, researchers should not use the STARS solely as a measure of statistics anxiety.

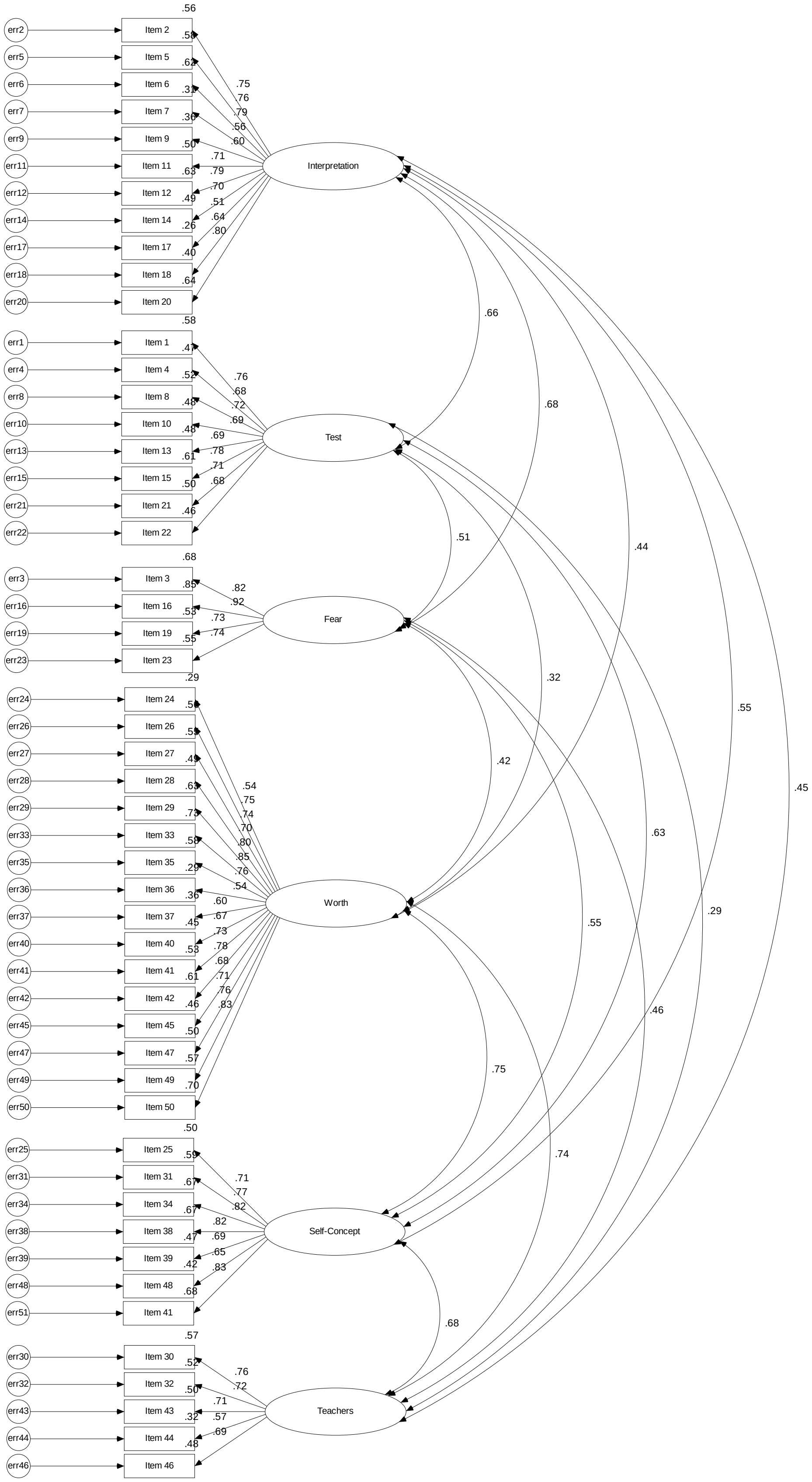


Figure 3.1. Standardized estimates for Model 1.

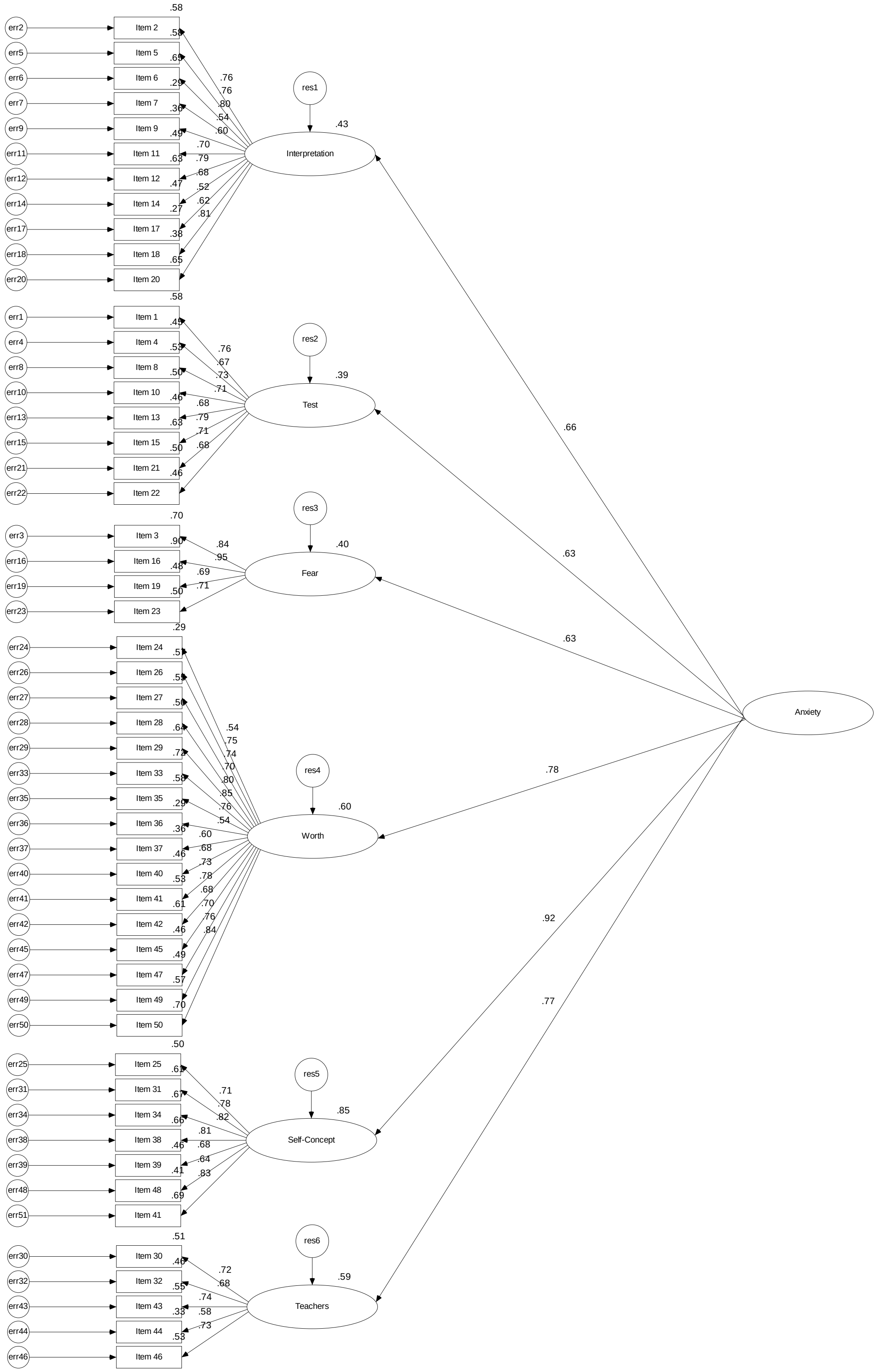


Figure 3.2. Standardized estimates for Model 2.

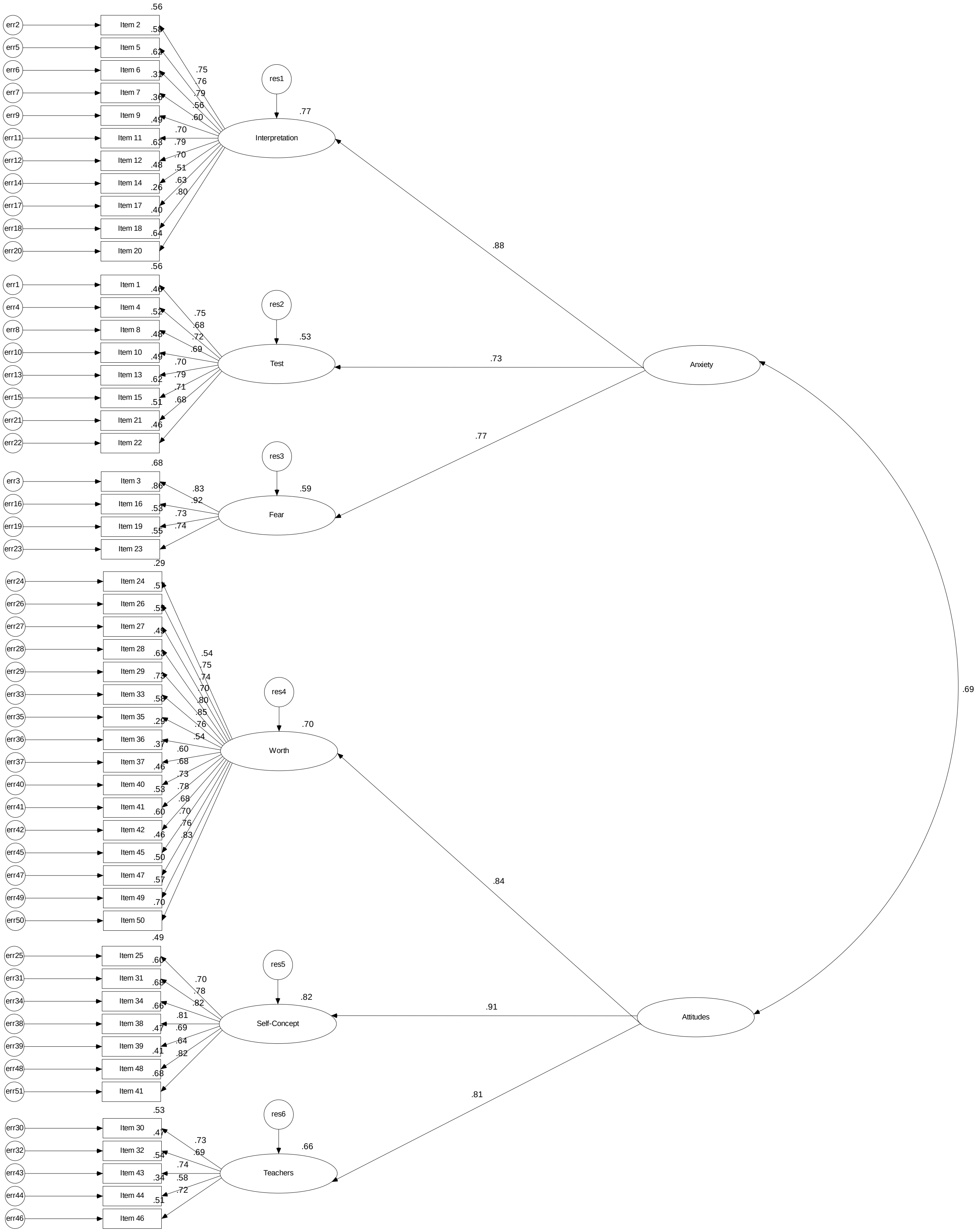


Figure 3.3. Standardized estimates for Model 3.

Table 3.5

Correlations Between the Six Factors of the STARS, STARS-Anxiety, STARS-Negative Attitudes, STARS-Total Scale, SAS-Anxiety, and ATS-Positive attitudes

STARS	SAS-Anxiety[a]	ATS-Positive Attitudes[b]
Model 1		
Part one		
Interpretation Anxiety	.78*	-.37*
Test and Class Anxiety	.73*	-.36*
Fear of Asking for Help	.79*	-.37*
Part two		
Worth of Statistics	.48*	-.79*
Computation Self-Concept	.63*	-.69*
Fear of Statistics Teachers	.46*	-.53*
Model 2		
STARS-Total Scale	.80*	-.72*
Model 3		
STARS-Anxiety	.89*	-.42*
STARS-Negative Attitudes	.57*	-.79*

[a]SAS-Anxiety assessed using the Statistical Anxiety Scale (SAS) (Vigil-Colet et al., 2008).
[b]ATS-Positive attitudes assessed using the Attitudes toward Statistics scale (ATS) (Wise, 1985).
* $p < .01$

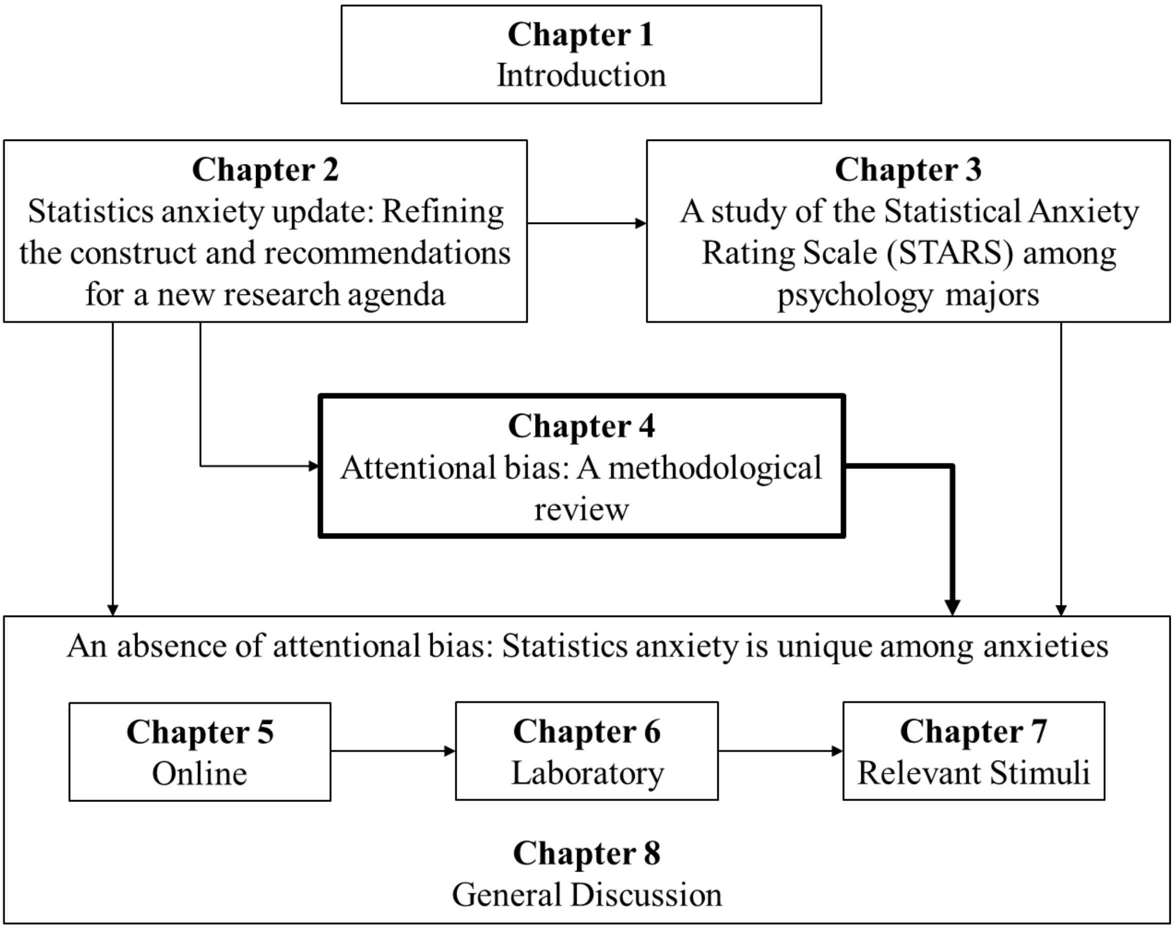
The results were also similar to a previous study that found both the correlated six first-order factor model and the six-factor model with two correlated superordinate factors to be acceptable models for the STARS (Papousek et al., 2012). The fit indices indicated Model 1 to be the best fit of the data compared to competing models. Nevertheless, the theoretical appropriateness of Model 1 is in question. Although Model 1 is useful in confirmatory factor analytic studies of the STARS (e.g., Hanna et al., 2008), it does not make substantiative sense to have six correlated factors in research. For instance, the six factors of the STARS are often used with the explicit assumption that the factors are indicators of a higher level construct (i.e., statistics anxiety) (e.g., Bell, 2003; Nasser, 2004). Additionally, while part one discriminated between anxiety and attitudes, the Computation Self-Concept factor and the Fear of Statistics Teachers factor of part two had similar correlations with both anxiety and attitudes. Hence, we recommend researchers use Model 3 in their studies.

Model 3 appears to be a promising model. In terms of fit indices, Model 3 was a better model than Model 2 because it had lower mean discrepancy and fit indices values, and had similar values on the CAIC and the ECVI with Model 1. With regards to theoretical appropriateness, Model 3 distinguished between anxiety and attitudes. This allows both variables to be studied concurrently and may provide researchers with clearer insights into their data. Therefore, we recommend researchers use part one of the STARS to assess statistics anxiety and part two to assess attitudes toward statistics.

Limitations of the study should be noted. First, the sample was drawn predominantly from psychology undergraduates in Singapore/Australia and the results might not generalize to graduate students or undergraduates in other disciplines (e.g., Information Technology). Second, the sample size did not permit separate investigations across demographic variables such as gender and campus/country (Singapore vs. Australia). In particular, since preliminary analysis found some differences in statistics anxiety for these variables, future research should examine the structure invariance of Model 3 across these variables. Lastly, given the number of items of the STARS and the complexity of the models, future research should seek to replicate the results with a larger sample size.

The use of Model 3 provides several future research directions. Currently, the general consensus has been that negative attitudes toward statistics result in statistics anxiety (e.g., Chiesi & Primi, 2010). Future research could administer both parts of the STARS at the start and end of the semester to test this notion empirically. Future research could also examine the relative importance of these two superordinate factors in predicting statistics achievement. Armed with such information, interventions could be designed to target the appropriate construct, either by reducing statistics anxiety or by reducing negative attitudes toward statistics, with the final goal of promoting statistical literacy among citizens of a democracy.

Chapter 4: Attentional bias: A methodological review



This chapter reviews the attentional bias literature and provides a methodological guide to Chapters 5, 6, and 7. An earlier version of this chapter is currently under review in a journal:

Chew, P. K. H., & Dillon, D. B. (Under Review). Attentional Bias: A Methodological Review. *Education Sciences and Psychology*

Chapter 4: Attentional Bias: A Methodological Review

Anxiety disorders are among the most common types of psychological disorder. Across the spectrum of anxiety disorders, results pooled from 46 studies published between 1980 and 2004 suggest one-year and lifetime prevalence rates of 10.6% and 16.6%, respectively (Somers, Goldner, Waraich, & Hsu, 2006). Anxiety disorders are associated with significant societal and financial costs. For example, anxiety disorders are related to lower educational attainment and marital instability (Lépine, 2002). Furthermore, costs of anxiety disorders in the USA were estimated to be USD 46.6 billion in 1990 (DuPont et al., 1996). A review of studies in Europe showed that the overall direct (e.g., healthcare) and indirect (e.g., absence from work) cost per patient diagnosed with anxiety disorders ranged from € 546 to € 1628 (Andlin-Sobocki & Wittchen, 2005). Given these costs, studies have been conducted to identify the mechanisms of anxiety disorders and develop interventions for them.

Since 1990, a large number of studies have examined the role of cognitive biases in anxiety. Cognitive bias refers to the "systematic selectivity in information processing that operates to favor one type of information over another" (MacLeod & Mathews, 2012, p. 191). There are three types of cognitive bias: attentional bias, interpretation bias, and memory bias (see Beard, 2011; Hertel & Mathews, 2011; MacLeod & Mathews, 2012 for reviews). Among these biases, attentional bias has received the most research attention. Indeed, at least eight literature reviews including two meta-analyses have been devoted to the topic (see Table 4.1). To minimize overlaps in content, the purpose of this chapter is to provide a methodological review of the attentional bias literature with the goal of providing a user guide for researchers. This chapter has two sections. The first section provides an overview of relevant cognitive theories and a description of RT tasks employed in studies of attentional bias, and reviews the evidence for attentional bias among clinical and non-clinical populations. The second section evaluates the methods of studying and analysing attentional bias by addressing several methodological limitations.

Table 4.1

Literature Reviews and Meta-Analyses on Attentional Bias

Studies	Description
J. M. Williams, Mathews, & MacLeod (1996)	The use of the emotional Stroop task to investigate attentional bias in psychopathology.
Puliafico & Kendall (2006)	Attentional bias among children and adolescents.
Bar-Haim et al. (2007)	A meta-analysis of 172 studies on attentional bias.
Cisler, Bacon, and Williams (2007)	An evaluation of the four assessment tasks commonly used in attentional bias research.
Cisler and Koster (2010)	Mechanisms of attentional bias and a description of proposed theoretical models.
Mobini and Grant (2007)	Clinical implications of attentional bias in anxiety disorders.
Phaf and Kan (2007)	A meta-analysis of 70 studies that used the emotional Stroop task.
Van Bockstaele et al. (2014)	A review of the causal evidence of attentional bias on anxiety

4.1 Attentional Bias

Attentional bias toward threat is defined as the "differential attentional allocation towards threatening stimuli relative to neutral stimuli" (Cisler & Koster, 2010, p. 203). Studies of attentional bias have primarily been motivated by Beck's schema theory (Beck & Clark, 1988, 1997; Beck, 1976) and Bower's network theory (1981, 1987). According to Beck and Clark (1988), "schemas are functional structures of relatively enduring representations of prior knowledge and experience" (p. 24). These cognitive structures guide information processing; individuals tend to elaborate or ignore stimuli that are consistent or inconsistent with existing schemas, respectively. Schema theory suggests that individuals with trait anxiety have an "anxious" schema. This schema guides the attention of these individuals to process anxiety-related stimuli in the environment (i.e., an attentional bias).

Bower (1981, 1987) makes a similar prediction, albeit for individuals with state anxiety. Bower hypothesizes that emotions are stored as nodes in a network and they are connected to other nodes containing emotionally-congruent information. Individuals experiencing an emotional state will activate the relevant emotion nodes. In turn, the emotion nodes will prime the associated nodes for subsequent processing. In other words, emotions "will enhance the salience of mood-congruent material for selective attention and learning" (Bower, 1981, p. 142). Hence, anxious individuals will show an attentional bias for anxiety-related stimuli in their environment.

Many models have been proposed to explain the cognitive mechanisms underlying attentional bias (e.g., Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Wells & Matthews, 1994; Willams, Watts, MacLeod, & Mathews, 1988). However, taken separately these models do not explain the range of findings obtained from a meta-analysis of 172 studies (Bar-Haim et al., 2007). Based on the results of the meta-analysis, Bar-Haim et al. (2007) proposed a four-stage theoretical model that integrates the key aspects of the previous models, which is presented in Figure 4.1.

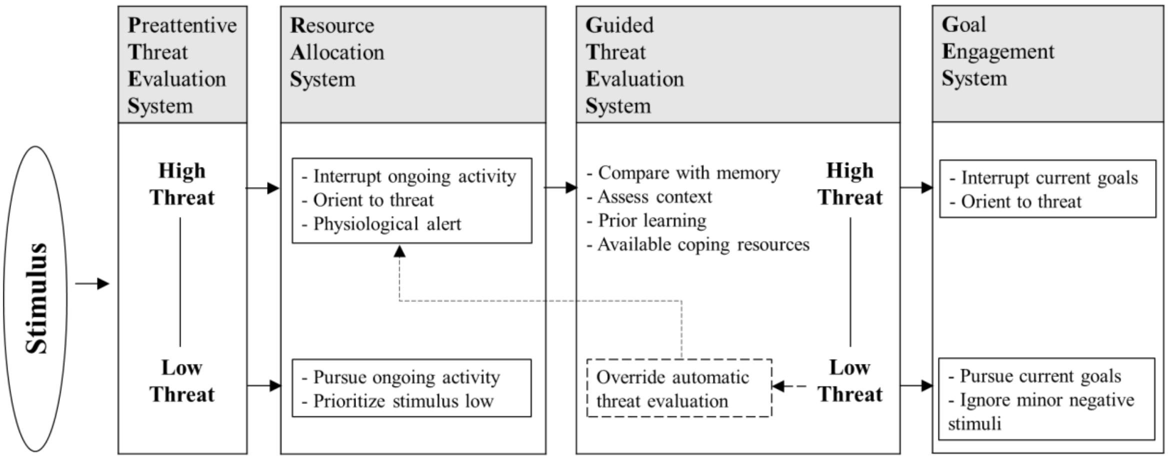


Figure 4.1. The four-stage theoretical model from Bar-Haim et al. (2007).

Bar-Haim et al. (2007) assert in their model that attentional bias is due to a malfunction in cognitive processing within each of the four stages. Each of these malfunctions results in mildly threatening stimuli being elevated to the status of highly threatening stimuli. For example, the Preattentive Threat Evaluation System (PTES) of anxious individuals might automatically evaluate mildly threatening stimuli as highly threatening whereas the Resource Allocation System (RAS) might allocate resources even to mildly threatening stimuli. The Guided Threat Evaluation System (GTES) of anxious individuals might malfunction on two levels. First, mildly threatening stimuli might be evaluated as highly threatening despite contrary evidence from context or from prior learning. Second, even if the stimuli were evaluated as mildly threatening based on existing evidence, deficiencies in the overriding mechanism might prevent the GTES from overriding the anxious state of the PTES and the RAS. These malfunctions eventually result in anxious individuals exhibiting an attentional bias toward threatening stimuli.

4.1.1 RT Tasks

Researchers have used a number of RT tasks to study attentional bias. These tasks include the spatial cueing task (e.g., Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002), the visual search task (e.g., Dandeneau, Baldwin, Baccus, Sakellaropoulo, & Pruessner, 2007), the emotional Stroop task (J. M. Williams et al., 1996), and the dot probe task (MacLeod et al., 1986). Among these tasks, the emotional Stroop task and the dot probe task are the most popular and are the focus of this review.

4.1.1.1 The emotional Stroop task. The emotional Stroop task is an adaptation of a classic paradigm first introduced by Stroop (1935). In the Stroop task, participants name the colour of the words (e.g., black) while disregarding the content of the words (e.g., red). The emotional Stroop task varies in that the content of the words represents threat (e.g., suffer) rather than colour. Earlier studies used cards with words printed on them. For instance, Mathews and MacLeod (1985) used four cards, with each card containing 96 words representing different forms of threat (e.g., ‘disease’ – physical threat, ‘failure’ – social threat, etc.). Subsequently, with increasing access to technology, researchers used computers to administer the emotional Stroop task. In a typical single trial, participants see a fixation point (+) in the centre of the screen for 500ms followed by a word that remains on the screen until a response is made. Participants respond by either speaking the colour of the word into a microphone (e.g., Constans, McCloskey, Vasterling, Brailey, & Mathews, 2004) or by pressing a key that corresponds to the colour of the word (e.g., Egloff & Hock, 2003).

Anxious individuals showed an attentional bias on the emotional Stroop task in a variety of studies (see J. M. Williams et al., 1996 for a review). These individuals were slower to name the colour of threatening words than neutral words (i.e., an interference effect) and this was explained as being because their attention was captured by the threatening words. Nevertheless, this interpretation has been disputed. Among 32 emotional Stroop task studies, the threatening words used were found to be significantly longer in length, lower in the frequency of use, and have smaller orthographic neighbourhood size than neutral words. These lexical features all lead to slower word recognition and therefore might explain the interference effect (Larsen, Mercer, & Balota, 2006). Furthermore, an attentional bias interpretation does not explain why repressors (individuals high in social desirability but low in anxiety) showed a greater interference effect than individuals high in trait anxiety. Because repressors tend to avoid threatening stimuli, the interference effect might be explained by both attentional bias and cognitive avoidance (De Ruiter & Brosschot, 1994).

4.1.1.2 The dot probe task. The dot probe task (MacLeod et al., 1986) can only be administered using a computer. In a single trial, participants see a fixation point (+) in the centre of the screen for 500ms followed by a pair of threatening and neutral stimuli randomly presented one above the other for 500ms. This is followed by a probe stimulus randomly presented in either the top or bottom location. The probe stimulus remains on the screen until a response is made (see Figure 4.2). The probe stimulus replaces the threatening stimuli in *congruent* trials and the neutral stimuli in *incongruent* trials (see Figure 4.3).

The type of probe stimulus depends on which of two versions of the dot probe task is used. The detection version requires participants to respond to a dot (.) as a probe stimulus (e.g., Koster, Crombez, Verschuere, & De Houwer, 2004) whereas the differentiation version requires participants to discriminate between two related probe stimuli (e.g., ‘<’ vs. ‘>’) (e.g., MacLeod et al., 2007). Although the detection version produces a larger attentional bias effect than the differentiation version (Salemink, van den Hout, & Kindt, 2007), both versions of the task are used currently.

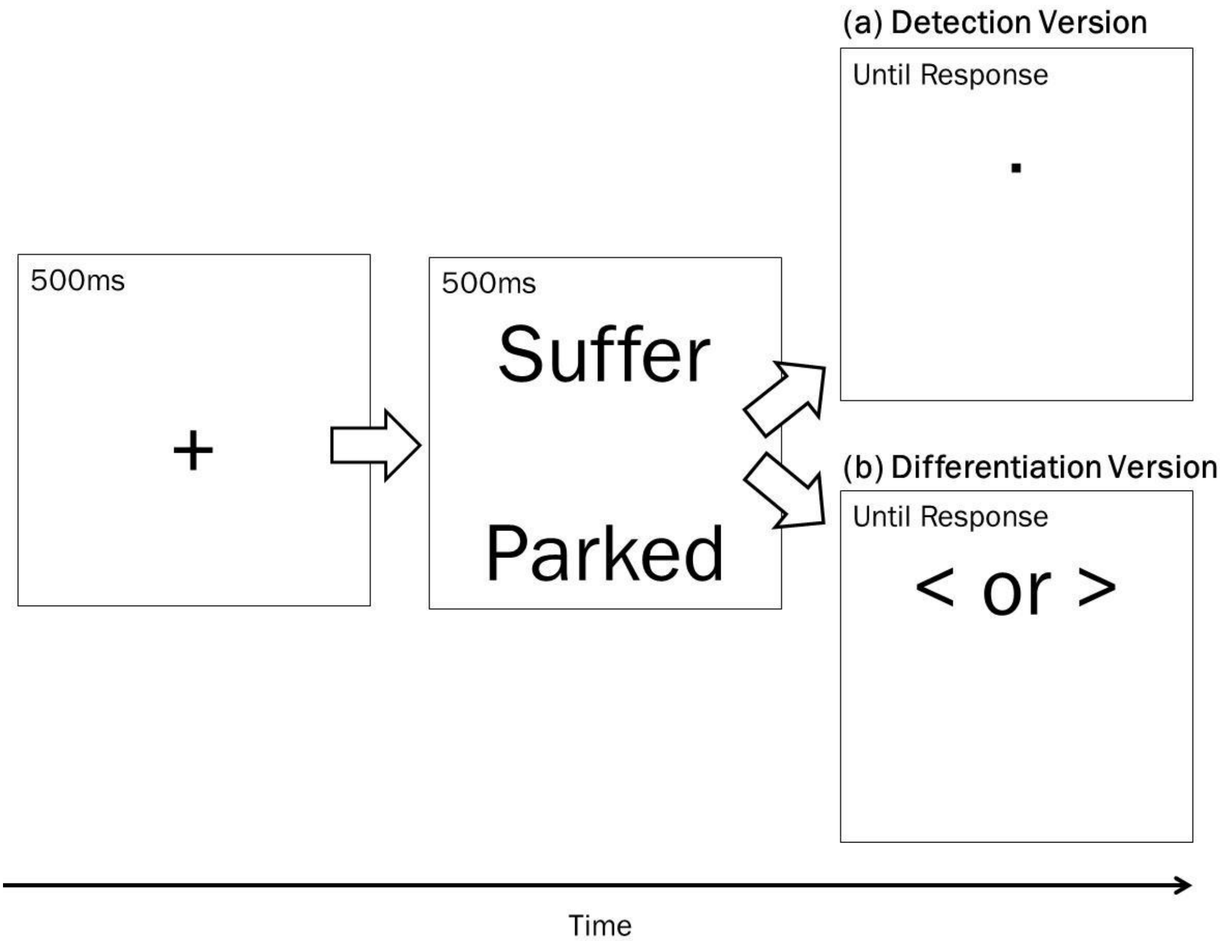


Figure 4.2. Two versions of the dot probe task. Stimuli adapted from MacLeod, Rutherford, Campbell, Ebsworthy, and Holker (2002).

Anxious individuals showed an attentional bias on the dot probe task in a variety of studies (see Bar-Haim et al., 2007 for a review). Because attention was directed to the threatening stimuli, these individuals responded faster on *congruent* trials than on *incongruent* trials. This effect is often interpreted as both vigilance for threat and a difficulty to disengage from threat (Koster et al., 2004; Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006).

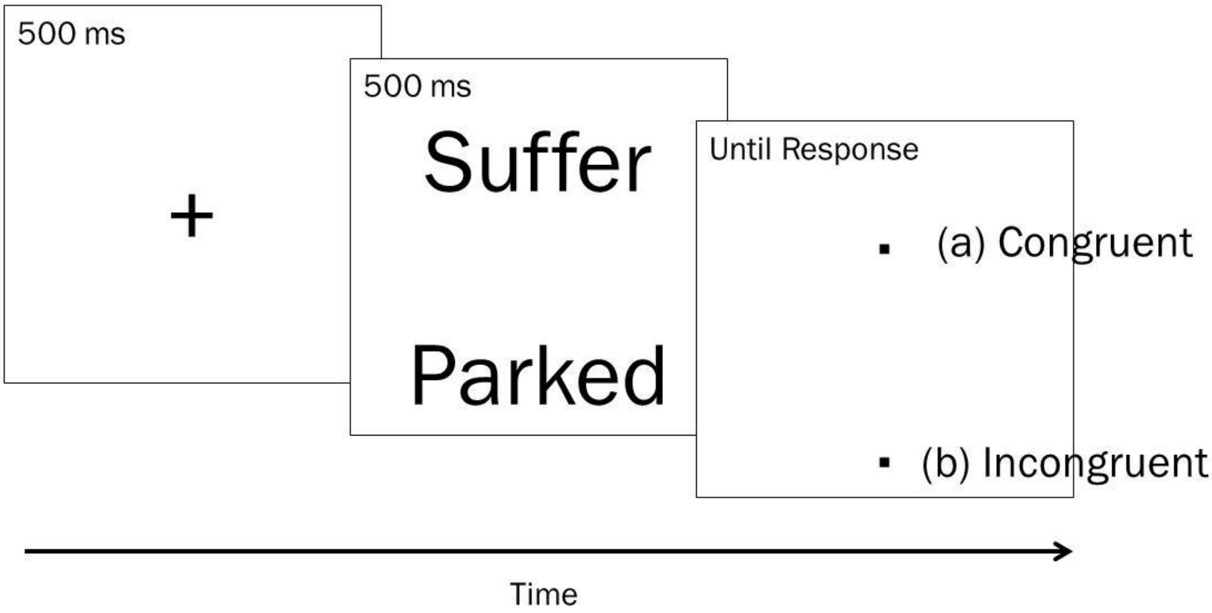


Figure 4.3. A single trial of the dot probe task. The probe stimulus replaces (a) the threatening stimuli (i.e., suffer) in congruent trials and (b) the neutral stimuli (i.e., parked) in incongruent trials. Stimuli adapted from MacLeod et al. (2002).

The dot probe task has one major advantage over the emotional Stroop task. Due to the use of colour-naming as a response, only words can be used as stimuli in the emotional Stroop task (however, see Strauss, Allen, Jorgensen, & Cramer, 2005 for a picture-word Stroop task). This is a limitation because single words might not fully represent the range of anxiety-provoking stimuli for anxious individuals (B. P. Bradley, Mogg, & Millar, 2000). Although words remain the prevailing stimuli, some studies have used faces (e.g., sad, angry, and happy faces) (e.g., Cooper & Langton, 2006; Gotlib, Krasnoperova, Yue, & Joormann, 2004) or pictures (e.g., photographs of corpses, weapons, etc.) (e.g., Elsesser, Sartory, & Tackenberg, 2004; Yiend & Mathews, 2001) as stimuli for the dot probe task.

4.1.1.3 Variants. There are two variants to the tasks. The first variant uses the backward masking procedure (e.g., replacing the stimuli after 50ms with 'XXXXX' for 450ms) to examine automatic versus strategic information processing. In general, attentional bias effects are found at both levels of information processing (Egloff & Hock, 2003; MacLeod & Rutherford, 1992; Mogg, Bradley, & Williams, 1995; Mogg, Bradley, Williams, & Mathews, 1993; Mogg & Bradley, 1999). The second variant includes various stimuli presentation times to explore early versus later stages of information processing (Cooper & Langton, 2006; Koster et al., 2006; Mogg, Bradley, Miles, & Dixon, 2004). For instance, although all participants showed an attentional bias at 100ms, only anxious participants showed an attentional bias at 500ms (Koster, Verschuere, Crombez, & Van Damme, 2005).

4.1.2 Evidence for Attentional Bias

Bar-Haim et al. (2007) included 172 published attentional bias studies (N = 2263 anxious, N = 1768 nonanxious) conducted between 1986 and 2005 in a meta-analysis. The results revealed that attentional bias had a low-to-medium effect size (d = .45); the bias was consistently found across tasks and anxious populations (e.g., clinical and nonclinical), but not in nonanxious individuals.

The examination of attentional bias in clinical populations often takes the form of a comparison in levels of attentional bias between a clinical group and a matched control group. For instance, MacLeod et al. (2007) assigned participants who met the DSM IV criteria for generalized anxiety disorder to a clinical group (n = 24), and participants with no anxiety to the control group (n = 35). Participants completed the dot probe task online. Results showed that the clinical group was faster in responding to a probe stimulus which replaced a threatening word (e.g., suffer) than a neutral word (e.g., parked). The evidence for attentional bias has been documented among many types of anxiety disorders such as generalized anxiety disorder (e.g., Dalgleish et al., 2003), panic disorder (e.g., Buckley, Blanchard, & Hickling, 2002), and post-traumatic stress disorder (e.g., Constans et al., 2004). Attentional bias has also been found for specific phobias such as spider phobia (Olatunji, Sawchuk, Lee, Lohr, & Tolin, 2008) and social phobia (Mogg, Philippot, & Bradley, 2004), but less consistently for obsessive-compulsive disorder (Amir, Najmi, & Morrison, 2009; Harkness, Harris, Jones, & Vaccaro, 2009).

Attentional bias has also been examined in non-clinical populations. Such studies often allocate participants to one of two groups based on their anxiety scores and then compare the levels of attentional bias. For instance, Egloff and Hock (2003) used a median split to divide 53 participants into low (n = 26) and high anxiety (n = 27) groups based on their scores on the trait scale of the State Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970). Participants completed the emotional Stroop task and the dot probe task. Participants with high anxiety were faster in responding to a probe stimulus that replaced a threatening word on the dot probe task, and slower in naming the colour of a threatening word on the emotional Stroop task. The evidence for attentional bias has also been documented in individuals with social anxiety (Carrigan, Drobes, & Randall, 2004), physical anxiety sensitivity, (Keogh, Dillon, Georgiou, & Hunt, 2001), dental anxiety (Johnsen et al., 2003; Jones, Stacey, & Martin, 2002), and fear of pain (Keogh, Ellery, Hunt, & Hannent, 2001) or fear of animals (Lipp & Derakshan, 2005). Although attentional bias has been consistently demonstrated in a large number of studies, certain methodological limitations should be considered.

4.2 Methodological Limitations

Several methodological limitations have not been fully considered by attentional bias researchers. These limitations include the (a) seemingly poor psychometric properties of RT tasks, (b) inappropriate practice of dichotomizing continuous variables, (c) improper handling of RT distributions, and (d) use of the mean as a summary statistic. A slight digression into the methods of scoring RT tasks is necessary for a discussion of these limitations.

4.2.1 Methods of Scoring RT Tasks

There are two methods to score and analyse the data from the tasks. The RT scoring method uses RT as a within-subjects independent variable. In this instance, RT is averaged for each stimulus type (e.g., threatening vs. neutral). For example, a 4 (Stimulus type: OCD threat, panic threat, normal threat, neutral) x 2 (Group: panic disorder patients, control) x 2 (Condition: subliminal, supraliminal) MANOVA was used to examine attentional bias for disorder-specific information on the emotional Stroop task (Kampman, Keijsers, Verbraak, Näring, & Hoogduin, 2002).

The threat bias index (TBI) scoring method uses TBI scores as the dependent variable. TBI scores are calculated differently for the emotional Stroop and dot probe tasks. In the emotional Stroop task, TBI = mean RT for threatening stimuli minus mean RT for neutral stimuli. A positive TBI indicates interference in colour naming of threatening stimuli compared to neutral stimuli (Mogg et al., 2000). In the dot probe task, TBI = mean RT for *incongruent* trials minus mean RT for *congruent* trials. A positive TBI indicates vigilance for threat whereas a negative TBI indicates avoidance of threat (MacLeod et al., 2007). Using this method, the same study mentioned earlier could analyse their data using a 2 (Group: panic disorder patients, control) x 2 (Condition: subliminal, supraliminal) MANOVA on the TBI scores (Kampman et al., 2002). Although both methods produce the same results, the TBI scoring method aids interpretation due to the reduction of one independent variable. Nevertheless, it appears that the RT scoring method produces better psychometric properties for the tasks.

4.2.2 Psychometric Properties of RT Tasks

The psychometric properties of RT tasks are assumed to be poor but this is considered unimportant in the literature. Because attentional bias has been consistently demonstrated among clinical and non-clinical populations (Bar-Haim et al., 2007; J. M. Williams et al., 1996), most studies have ignored the need for tasks to meet basic standards of reliability and validity. For example, Cisler et al. (2007) argued in a literature review that “results across the different tasks converge along a number of different lines that allow for conclusions to be drawn despite the questionable psychometric properties” (p. 226). However, given that the field of psychology has always placed a high emphasis on the psychometric properties of instruments and tasks, future research attention should be directed to this area. This review suggests two surprising possibilities: (a) the tasks might be reliable if the RT scoring method was used and (b) the tasks might be assessing two different constructs instead of different underlying processes of the same construct (i.e., attentional bias).

4.2.2.1 Reliability. The reliability assessment of the emotional Stroop task is influenced greatly by the scoring method used. In general, reported test-retest reliabilities for the RT scoring method are acceptable and they range from .73 to .94 (Eide, Kemp, Silberstein, Nathan, & Stough, 2002; Kindt, Bierman, & Brosschot, 1996; Siegrist, 1997; Strauss et al., 2005). Test-retest reliabilities reported for the TBI scoring method are unacceptable (Eide et al., 2002; Kindt et al., 1996; Siegrist, 1997; Strauss et al., 2005). Nonsignificant correlations were reported after a short interval in the same testing session (Siegrist, 1997) and after one week (Eide et al., 2002; Strauss et al., 2005), while a significant but small correlation (r = .25) was found after three months (Kindt et al., 1996). No other forms of reliabilities have been examined for the emotional Stroop task.

The dot probe task is unreliable using the TBI scoring method (Schmukle, 2005; Staugaard, 2009). The detection version of the task has reported split-half reliabilities that range from -.16 to .19, Cronbach’s alphas that range from .00 to .28, and one-week test-retest reliabilities that range from -.22 to .32 for both words and pictures (Schmukle, 2005). Similar results were reported for the differentiation version of the task using faces as stimuli

(Staugaard, 2009). The current review did not locate any published research that has investigated reliability of the dot probe task using the RT scoring method.

Several failed attempts have been made to increase the reliability of the tasks. Loss of concentration has been cited as a reason for low reliability (Kindt et al., 1996). Since anxious individuals might be resistant to such loss because the stimuli are emotionally relevant to them, reliabilities have been calculated separately for these individuals (Kindt et al., 1996; Schmukle, 2005). Nevertheless, no significant improvement in reliability was found for anxious individuals in the emotional Stroop task (Kindt et al., 1996) or the dot probe task (Schmukle, 2005). Modifications have also been made to the dot probe task to increase its reliability. For instance, the task has been modified to present word pairs for only 100ms instead of 500ms (Schmukle, 2005) or to retain the pairs of faces even after presentation of the probe stimulus (Staugaard, 2009). Neither modification yielded acceptable levels of reliability.

The TBI scoring method is problematic for two reasons. First, the use of change scores that are derived from two highly correlated conditions (i.e., mean RT for threatening and neutral stimuli, respectively) may result in low test-retest correlations (Eide et al., 2002). Second, change scores combine measurement error from both conditions. This compounding of errors may result in lower correlation coefficients (Strauss et al., 2005). As mentioned, results from the emotional Stroop task showed acceptable levels of test-retest reliability for the RT scoring method, but not for the TBI scoring method. It seems likely that the dot probe task might share the same pattern of results as the emotional Stroop task. Therefore, future research should use the RT scoring method to examine the psychometric properties of the dot probe task.

4.2.2.2 Validity. Convergent validity is assessed by examining the correlation between two measures that assess a similar construct. In this instance, the emotional Stroop task and the dot probe task should be highly correlated because they are both measures of attentional bias. However, extant research suggests otherwise. Although some studies reported significant moderate correlations that ranged from .28 to .42 (Brosschot, de Ruiter, & Kindt, 1999; Egloff & Hock, 2003), others found nonsignificant correlations that ranged from .00 to .13 between the tasks (Dalgleish et al., 2003; Mogg et al., 2000). The absence of significant large correlations suggests a lack of convergent validity.

The lack of convergent validity raises an important question. Specifically: Are the tasks assessing different underlying processes of the same construct (i.e., attentional bias) or are they assessing different constructs? Most researchers favour the first position. For example, authors of studies that found nonsignificant correlations argued that the tasks share different underlying processes (Mogg et al., 2000), the suggestion being that the emotional Stroop task assesses response inhibition whereas the dot probe task assesses attentional allocation (Cisler et al., 2007). Conversely, the authors of studies reporting significant correlations argued that the tasks share some common underlying processes (Egloff & Hock, 2003), although it is unclear what these common processes are. Despite the favouring of the first position, the second position seems equally plausible given the nonsignificant, zero correlations between the tasks (e.g., Dalgleish et al., 2003). For instance, the emotional Stroop task might be a measure of cognitive avoidance whereas the dot probe task might be a measure of attentional bias (De Ruiter & Brosschot, 1994). Future research should attempt to identify both the common and unique processes underlying both tasks.

4.2.3 Dichotomization of Continuous Variables

The practice of dichotomizing continuous variables into categorical ones is not recommended (Altman, 2006; Austin & Brunner, 2004; MacCallum, Zhang, Preacher, & Rucker, 2002; Naggara et al., 2011; Royston, Altman, & Sauerbrei, 2006). Attentional bias research among nonclinical populations tends to dichotomize the anxiety variable by either using the median split (e.g., Egloff & Hock, 2003) or using extreme scorers from a large sample (e.g., Keogh, Dillon, et al., 2001). Both methods result in a loss of information and power (MacCallum et al., 2002; Naggara et al., 2011), and inflates the Type I error rate (Austin & Brunner, 2004). Dichotomization also results in different cut-off values for different studies, making comparisons at least challenging if not impossible (Altman, 2006). For example, participants have been classified as 'High Anxiety' when they scored more than 44 (Mogg et al., 2000), 45 (Fox, 2002), or 46 (Fox, 1993) on the State-Trait Anxiety Inventory (Spielberger et al., 1970). Participants have also been classified as 'High Anxiety' and 'Low Anxiety' when they scored in the upper and lower 10% (Koster et al., 2006) or 25% (Koster et al., 2005) on the State-Trait Anxiety Inventory. A more serious limitation occurs when researchers use 'optimal' cut-off values (Royston et al., 2006). Given the well documented phenomenon of publication bias (Ferguson & Heene, 2012), researchers might be tempted to try more than one cut-off value and choose the value that would produce significant results (Royston et al., 2006). It is noteworthy that no attentional bias studies to date have used 'optimal' cut-off values.

We make three recommendations for researchers who insist on dichotomizing continuous variables. First, to pursue a confirmatory research agenda in psychology (Wagenmakers, Wetzels, Borsboom, Maas, & Kievit, 2012), we recommend researchers determine and document the cut-off value before data analysis. For instance, the cut-off value could be based on previous research and documented in the ethics approval form. Subsequently, the form should be submitted together with the paper to journals and any deviations from the initial cut-off value should be justified. Second, if a large sample size is available, the continuous variable should be dichotomized using extreme scorers instead of the median split (Naggara et al., 2011). A study on working memory span tasks reported that using extreme scorers (e.g., the top and bottom 25% of the distribution as 'high' and 'low', respectively) resulted in a misclassification of 8% of the participants whereas the median split resulted in a misclassification of 25% of the participants (Conway et al., 2005). Lastly, normative means should be used if available. For example, 40 is the normative mean for high trait anxiety on the State-Trait Anxiety Inventory (Spielberger et al., 1970). Using 40 as a cut-off value is conceptually meaningful and permits comparisons across studies.

4.2.4 Handling RT Distributions

RT data are not normally distributed. The RT distribution tends to be positively skewed; the distribution rises sharply from the left and declines to a long tail on the right (see Figure 4.4). Furthermore, RT data tend to contain outliers. Outliers occur when participants anticipate the stimuli or are distracted from the task, resulting in extremely fast or slow RTs, respectively. Using ANOVA on mean RT without dealing with skewness or outliers reduces the power to detect real differences between conditions (Wilcox, 1998). Thus, these issues have to be dealt with before data analysis.

Many statistics textbooks recommend the use of non-parametric tests when assumptions of parametric tests are violated. For instance, the Spearman's rho can be used as a non-parametric equivalent of the Pearson product-moment correlation coefficient (Siegel & Castellan, 1988). However, such recommendations are not without limitations. From a statistical perspective, it has been demonstrated that the robustness of non-parametric tests are as limited as parametric tests when outliers are present (Zimmerman, 1995) or when assumptions of normality are violated (Zimmerman, 1998). From a practical perspective, parametric tests are well known and easily interpreted by most readers. Indeed, most if not all attentional bias studies used parametric tests (e.g., Egloff & Hock, 2003; MacLeod et al., 2007). Given these limitations, other methods should be used to handle RT distributions.

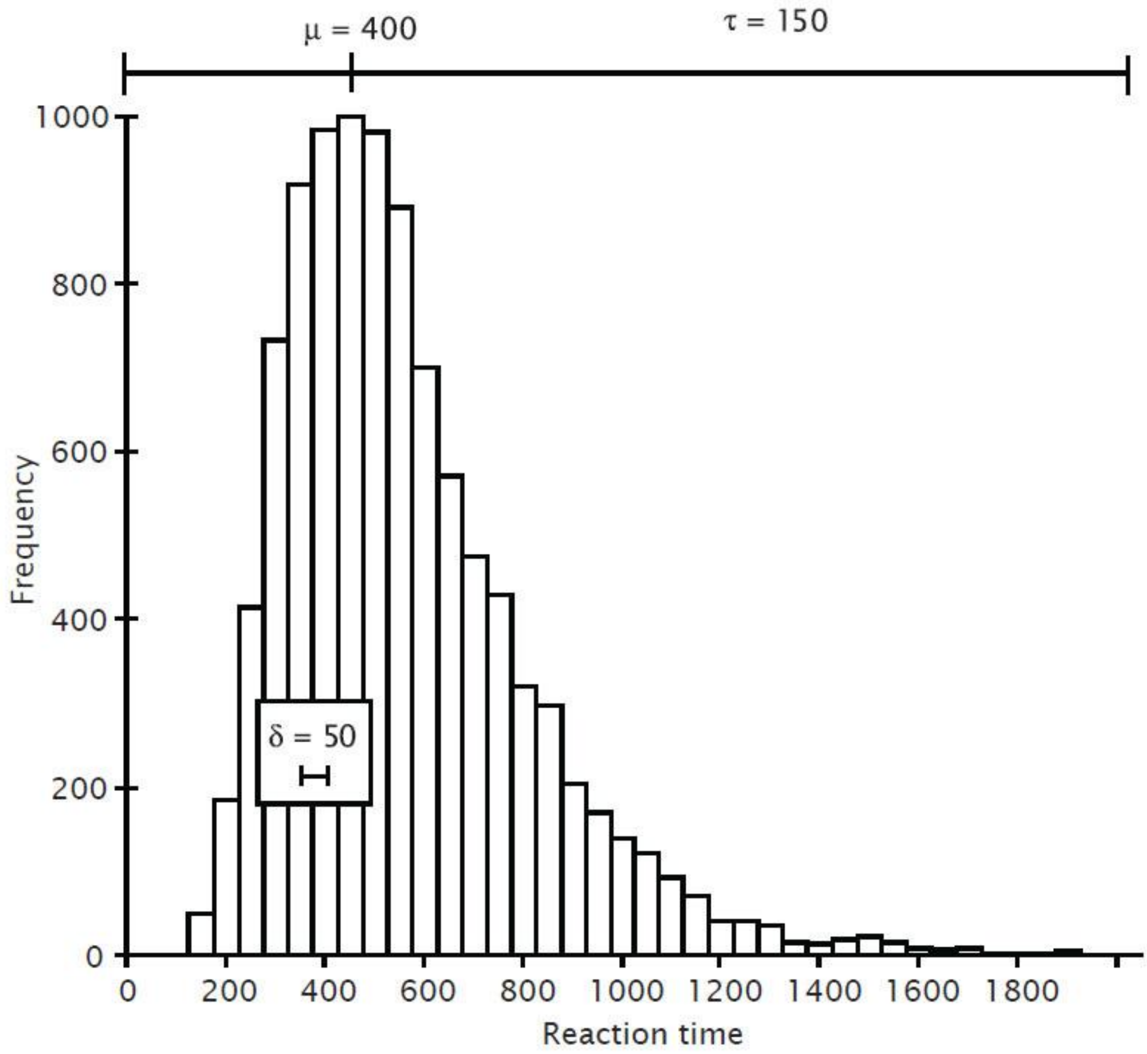


Figure 4.4. A simulated positively skewed distribution. This figure illustrates the characteristic shape of RT distributions, including the parameters mu (μ), sigma (δ), and tau (τ). Figure adapted from Whelan (2010) with permission from *The Psychological Record*.

Listed in the order of increasing power, there are four strategies to handle skewness or outliers: (a) accommodation, (b) outlier elimination (Beckman & Cook, 1983), (c) transformation (Ratcliff, 1993), and (d) whole distribution analysis (Balota & Yap, 2011). Accommodation uses median instead of the mean as a summary measure because the median is relatively uninfluenced by outliers (Ulrich & Miller, 1994). Outlier elimination uses cutoffs to remove outliers. Cutoffs are either based on an absolute value (e.g., RT more than 2000ms) or on the standard deviation (e.g., RT greater than two standard deviations above the mean). Transformation normalizes the distribution and reduces the impact of outliers. Two of the most popular methods involve applying logarithm to RT (i.e., ln RT) or transforming RT to speed (i.e., 1 / RT). Although the first method results in a more normal distribution, the second method maintains higher power. Lastly, whole distribution analysis takes into account skewness and analyses mu (μ), sigma (δ), and tau (τ) of the distribution (see Figure 4.4). Nevertheless, whole distribution analysis is seldom used due to the requirement for many data points (i.e., RT trials) and the need for programming language to use distribution fitting software (Whelan, 2010).

Few empirical studies have been conducted to compare the effects of using different strategies on attentional bias RT data. Schmukle (2005) used three strategies [no changes to RT data, outlier elimination strategy, and transformation strategy (1 / RT)] to handle RT data in his investigation on the reliability of the dot probe task. The results were similar across all three strategies, suggesting that there were no benefits to using any of the strategies over the others. However, not all strategies were used and only the dot probe task was considered. Future research should consider more strategies, use both RT tasks, and use latency operating characteristic functions to evaluate the effectiveness of each strategy (e.g., see Greenwald, Nosek, & Banaji, 2003). Due to this lack of empirical evidence, the remaining review in this section is restricted to practical and theoretical considerations.

Currently, although some studies used the accommodation strategy (e.g., MacLeod & Rutherford, 1992) or the transformation strategy (e.g., Kampman et al., 2002), most studies used the outlier elimination strategy. This strategy has two limitations. First, the selection of absolute values and standard deviation appears to be arbitrary, and varies considerably despite the use of the same RT task. For instance, one study classified RTs less than 160ms and more than 480ms on the dot probe task as outliers (B. P. Bradley et al., 2000) whereas another classified RTs less than 100ms and more than 3000ms as outliers (Dalgleish, Moradi, Taghavi, Neshat-Doost, & Yule, 2001). Studies have also excluded RTs more than two

(Mogg, Philippot, et al., 2004), two and a half (Fox et al., 2002), and three (Koster et al., 2005) standard deviations above the mean as outliers. Second, the strategy may reduce power (Whelan, 2010) and introduce biases into the sample mean and standard deviation (Ulrich & Miller, 1994). Hence, the outlier elimination strategy should not be used.

Given the limitations of alternative strategies, the transformation strategy should be used for research. Admittedly, transformed data are often difficult to interpret (Osborne, 2002). For example, transforming RT to speed reverses the typical interpretation, with higher scores indicative of faster response times instead of slower response times. Therefore, to maintain ease of interpretation, we recommend transforming the RT data using a logarithmic transformation to normalize the distribution and reduce the impact of outliers.

4.2.5 Using the Mean as Summary Statistic

Attentional bias might not be present in all anxious individuals (Bar-Haim, 2010). Some attentional bias studies reported large standard deviations using the TBI scoring method. For instance, participants with generalized anxiety disorder showed a significantly greater attentional bias (M = 23.77, SD = 39.45) than nonanxious control participants (M = -6.14, SD = 30.65) on the dot probe task (MacLeod et al., 2007). The large standard deviations suggested that bias was not exhibited by some anxious participants. This was supported by a recent literature review. On average, although anxious individuals had higher TBI scores than nonanxious individuals, an inspection of individual scores indicated that not all anxious individuals exhibited the bias (Bar-Haim, 2010). The finding was preliminary in nature and no statistics were published. However, results from another phenomenon in cognitive psychology might prove illuminating.

The word superiority effect demonstrates that individuals are more accurate in identifying a letter when it is embedded in a real word than when it is presented in isolation (Cattell, 1886; Reicher, 1969). The word superiority effect is a well-documented phenomenon (perhaps better documented than attentional bias) and is a staple topic in most cognitive psychology textbooks (e.g., Parkin, 2006). Nevertheless, despite finding evidence of the word superiority effect when the mean was used, close to 50% of the participants in a recent study (n > 500) did not show the effect when individual scores were inspected (Speelman & McGann, 2013).

These results have implications for anxiety interventions. Because attentional bias causes an emotional vulnerability to anxiety (MacLeod et al., 2002), a successful modification of the bias reduces anxiety. This intervention, commonly known as Attentional Bias Modification, is effective in reducing trait anxiety and a wide variety of anxiety disorders (see Browning et al., 2010; Hakamata et al., 2010 for reviews). However, it is currently unclear if the intervention should be used for anxious individuals without attentional bias (Bar-Haim, 2010). Furthermore, the effectiveness of the intervention was evaluated using the mean (e.g., Amir, Beard, Burns, & Bomyea, 2009; Hazen, Vasey, & Schmidt, 2009) and a similar problem exists. When individual scores are considered, the interventions might only be effective for anxious individuals with attentional bias. Given these implications, additional analysis should be conducted to clarify the results.

Inspired by the quadrant used to illustrate Type I and II errors, a similar quadrant could be used to classify participants (see Table 4.2). The TBI scoring method can be used to determine if attentional bias is exhibited by a participant. For example, TBI scores can be recoded, with positive and negative scores being indicative of a presence and absence of attentional bias on the dot probe task, respectively. The quadrant clarifies results by identifying the percentage of anxious individuals with or without attentional bias. Subsequently, this could be a new independent variable that could inform intervention research. Nevertheless, this suggestion is only applicable for studies involving clinical participants, where levels of attentional bias are compared between a clinical group and a matched nonanxious control group. However, published studies involving non-clinical populations, where participants were already dichotomized based on their anxiety scores, could use the same quadrant to clarify results.

Table 4.2

Number of Participants (Percentages) in Each Attentional Bias Category

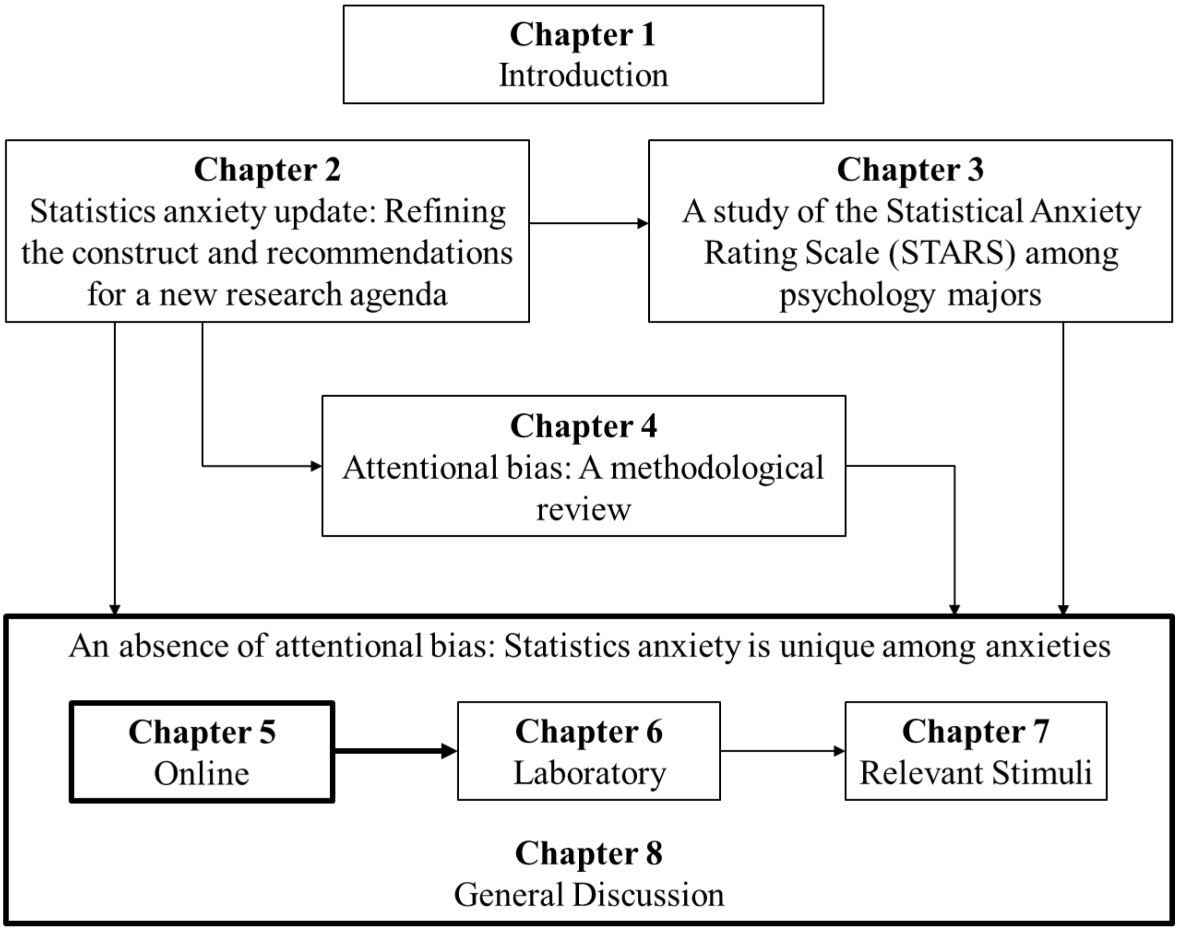
Attentional Bias	Group	
	Clinically Anxious	Nonanxious Control
Present	Count (%)[a]	Count (%)[b]
Absent	Count (%)[b]	Count (%)[a]

Note. TBI scores are used to determine the presence or absence of attentional bias.
[a]Correct classification
[b]Incorrect classification

4.3 Summary

The purpose of this chapter is to provide a methodological review of the attentional bias literature with the goal of providing a user guide for researchers. Despite the evidence for attentional bias among anxious individuals in a wide variety of studies, certain methodological limitations should be considered. These limitations include the (a) seemingly poor psychometric properties of RT tasks, (b) inappropriate practice of dichotomizing continuous variables, (c) improper handling of RT distributions, and (d) use of the mean as a summary statistic. To address these limitations, we recommend researchers (a) use the RT scoring method to examine psychometric properties of the RT task and identify the common underlying processes of both RT tasks, (b) avoid dichotomizing continuous variables, (c) applying logarithm to RT (i.e., ln RT), and (d) conduct additional analysis to clarify results, respectively. Given the costs associated with anxiety disorders (Andlin-Sobocki & Wittchen, 2005) and the causal role of attentional bias in anxiety, there is a pressing need to improve the quality of attentional bias research. In turn, intervention studies could be built upon a stronger foundation of research to deal with the high prevalence rate of anxiety disorders (Somers et al., 2006).

Chapter 5: An absence of attentional bias: Experiment 1 (Online)



This chapter examines the role of attentional bias in statistics anxiety in an online experiment. An earlier version of this chapter has been published in a journal:

Chew, P. K. H., Swinbourne, A., & Dillon, D. B. (2014). No evidence of attentional bias in statistics anxiety. *The European Journal of Social & Behavioural Sciences*, *10*(3), 1451–1465. doi:10.15405/ejsbs.131

Chapter 5: An absence of attentional bias: Experiment 1 (Online)

The purpose of Experiments 1, 2, and 3 was to examine the role of attentional bias in statistics anxiety. These experiments are documented in the current chapter, Chapter 6, and Chapter 7, respectively. As recommended by De Ruiter and Brosschot (1994), all experiments employed both the emotional Stroop task and the dot probe task. Furthermore, a measure of social desirability was included because participants who are repressors (high in social desirability, low in anxiety) have been found to exhibit a different pattern of attentional bias than participants who are truly low anxious (low in social desirability, low in anxiety) (Derakshan, Eysenck, & Myers, 2007; Ioannou, Mogg, & Bradley, 2004).

Two hypotheses were specified for the three experiments. Firstly, it is hypothesized that participants with higher statistics anxiety will be slower to name the colour of threatening stimuli on the emotional Stroop task than their low-anxious counterparts (interference hypothesis). Secondly, it is hypothesized that participants with higher statistics anxiety will be faster in responding to a probe stimulus that replaces a threatening stimulus on the dot probe task than their low-anxious counterparts (facilitation hypothesis).

5.1 Method

5.1.1 Participants

Participants were a convenience sample of 136 psychology undergraduates at James Cook University. Data from 42 participants (31%) were removed due to missing data on either the tasks or the instruments. The final sample consisted of 94 participants (73% females) from the James Cook University's Singapore (56%) and Australia (44%) campuses. Their ages ranged from 18 to 50 years (*M* = 23.88, *SD* = 7.45). The predominantly female sample was consistent with the gender distribution of the psychology undergraduate population in Singapore and Australia. Participants were either currently enrolled in a statistics course (84%) or had successfully completed at least one statistics course but were not currently enrolled in a statistics course (16%). All participants had normal or corrected-to-normal eyesight and were not colour blind. The exclusion criteria were included in the recruitment poster and on the Sona Systems (a research participation management system). Participants were either granted extra course credit or were given a movie voucher for their participation in the experiment. A sample size of 94 exceeds the recommended sample size for multiple regression (i.e., $N >= 50 + 8(3 \text{ predictors}) = 74$). Post hoc power analysis revealed an obtained power of .88 (alpha = .05) and .71 (alpha = .01) (Faul, Erdfelder, Buchner, & Lang, 2009).

5.1.2 Stimuli Generation and Evaluation

A total of 65 pairs of words and 30 pairs of symbols were generated by the author. Potentially threatening words and symbols related to statistics were adopted from an introductory statistics textbook (Gravetter & Wallnau, 2007). Thirty-one threatening words were matched with neutral words for letter length and frequency of usage according to a frequency dictionary (Davies & Gardner, 2010). Threatening words not found in the frequency dictionary (e.g., factorial) were paired and matched for letter length with neutral words (e.g., decanting) adopted from MacLeod et al. (2002). Threatening symbols (e.g., $\bar{y}$) were matched with neutral symbols (e.g., %) found on a standard QWERTY keyboard.

Eight final-year psychology students completed the Background Information Form (described in Chapter 3) and rated a total of 130 words and 60 symbols, presented in random order, on a 9-point scale that ranged from 1 = *Very Negative* to 5 = *Neutral* to 9 = *Very Positive* (MacLeod et al., 2002) on SurveyGizmo (2015), an online survey software. To have a sufficient number of stimuli (cf. attentional bias literature), the 36 most negative words and the 12 most negative symbols, and their corresponding neutral stimuli were retained. This resulted in a total of 72 words and 24 symbols that were used in Experiments 1 and 2 (see Appendix 5.1). Threatening stimuli had a mean rating of less than 4.63 whereas neutral stimuli had a mean rating between 5.00 and 6.63. Threatening words (M = 4.13, SD = .37) were rated more negatively than neutral words [M = 5.87, SD = .40, t (70) = -19.09, p < .001] and threatening symbols (M = 4.16, SD = .34) were rated more negatively than neutral symbols [M = 5.84, SD = .28, t (22) = -13.15, p < .001]. This procedure of stimuli generation and evaluation is consistent with many attentional bias studies (e.g., MacLeod et al., 2002).

5.1.3 Tasks

Both the emotional Stroop task and the dot probe task (MacLeod et al., 1986) were administered online using INQUISIT 4.0 (2015), which measures RT with millisecond accuracy (De Clercq, Crombez, Buysse, & Roeyers, 2003).

5.1.3.1 The emotional Stroop task. Participants saw a fixation point (+) in the centre of the screen for 500 milliseconds followed by a stimulus (word or symbol) that remained on the screen until a response was made. There was a 500 millisecond interval between each trial. Each stimulus was randomly presented in one of four colours and participants responded using response keys which corresponded to the colour of the stimulus. A reminder was present at the bottom of the screen for each trial (i.e., ‘D’ = red, ‘F’ = green, ‘J’ = blue, and ‘K’ = yellow). The keyboard response was used instead of a vocal response to increase similarity in response modes between the emotional Stroop task and the dot probe task (Egloff & Hock, 2003). Participants completed 20 practice trials to familiarize themselves with the task before completing 96 experimental trials (72 words and 24 symbols). An error message (a red ‘X’) was provided in practice trials but not in experimental trials.

5.1.3.2 The dot probe task. Participants saw a fixation point (+) in the centre of the screen for 500 milliseconds followed by a pair of stimuli randomly presented one above the other for 500 milliseconds which were then followed by a probe stimulus (either ‘F’ or ‘J’) randomly presented in either the top or bottom location. The probe stimulus remained on the screen until a response was made. There was a 500 millisecond interval between each trial.

Participants responded using response keys which corresponded to the type of probe stimulus (either 'F' or 'J'). The probe stimulus replaced the threatening stimuli in *congruent* trials and the neutral stimuli in *incongruent* trials. Participants completed 10 practice trials to familiarize themselves with the task before completing 96 experimental trials (36 pairs of words and 12 pairs of symbols). An error message (a red 'X') was provided in practice trials but not in experimental trials.

5.1.4 Instruments

5.1.4.1 The Background Information Form and the STARS. The Background Information Form and the STARS have been described in in detail in Chapter 3. The Background Information Form was designed to assess basic demographic information such as age, gender, and statistics course enrolled. The STARS was designed to assess statistics anxiety (Cruise et al., 1985). The STARS had internal consistencies that ranged from .86 to .90 in the current experiment.

5.1.4.2 The Marlowe-Crowne Social Desirability Scale. The Marlowe-Crowne Social Desirability Scale is a unidimensional, 33-item instrument designed to assess social desirability or defensiveness (e.g., I am always courteous, even to people who are disagreeable) (Crowne & Marlowe, 1960). Responses are made on a True/False scale. Negative items are reverse scored and the items are summed to produce a single score, with higher scores indicating higher levels of socially desirable responding. Scores on the instrument can range from 0 to 33. The scale was administered as a "Personal Reaction Inventory" to mask the true purpose of the instrument. Crowne and Marlowe (1960) reported an internal consistency of .88 (n = 39) and a four-week test-retest reliability of .89 (n = 31) for the scale. More recently, Loo and Loewen (2004) reported an internal consistency of .75 (n = 663) for the scale. The scale has been used to discriminate repressors from participants who are truly low anxious (Ioannou et al., 2004; Mogg et al., 2000; Newman & McKinney, 2002). The instrument had an internal consistency of .72 in the current experiment. The instrument is presented in Appendix 5.2.

5.1.5 Procedure

Participants completed the emotional Stroop task and the dot probe task (MacLeod et al., 1986) online in the participants' own environment using INQUISIT 4.0 (2015). Both tasks took about 30 minutes to complete. Subsequently, participants completed the Background Information Form, the STARS (Cruise et al., 1985), and the Marlowe-Crowne Social Desirability Scale (Crowne & Marlowe, 1960) on SurveyGizmo (2015). Each instrument took about 10 minutes to complete. Except for the Background Information Form, all instruments and tasks were counterbalanced to control for order effects. Informed consent was implied when participants clicked on the 'Next' button to proceed with the tasks. This procedure was approved by the James Cook University Human Research Ethics Committee (see Appendix 5.3).

5.2 Results

All results were analysed using SPSS version 21. Alpha was set at .01 to reduce the chance of Type 1 errors due to multiple comparisons. Incorrect responses were removed from the RT data. The number of incorrect responses ranged from 0 to 21 (Median = 3.00, M = 3.99, SD = 3.81) for words and ranged from 0 to 19 (Median = 1.00, M = 1.79, SD = 2.44) for symbols on the emotional Stroop task. The number of incorrect responses ranged from 0 to 19 (Median = 4.00, M = 5.10, SD = 4.42) for words and ranged from 0 to 12 (Median = 1.00, M =1.82, SD = 2.12) for symbols on the dot probe task. Incorrect responses accounted for 6.6% of the data.

The visual inspection of the histograms suggests that the RT data were positively skewed. Hence, RT data were transformed by applying a logarithmic transformation to normalize the distribution and reduce the impact of outliers (Ratcliff, 1993). Subsequently, Threat Bias Indices (TBI) were calculated. In the emotional Stroop task, TBI = mean RT for threatening stimuli minus mean RT for neutral stimuli. In the dot probe task, TBI = mean RT for *incongruent* trials minus mean RT for *congruent* trials. In both tasks, a positive TBI indicates an attentional bias towards threat.

Preliminary analysis suggested that participants with missing data on either the tasks or the instruments did not differ significantly on demographic variables (e.g., age and gender), RT on the tasks, and statistics anxiety scores to participants with no missing data. Preliminary analysis also indicated that scores on the social desirability scale was not significantly correlated with the TBI. Hence, social desirability was not included in further analyses.

The means and standard deviations of the STARS (Cruise et al., 1985) and the TBI are presented in Table 5.1. The median percentile rank equivalent scores (MPRES) for the STARS are also presented. The MPRES were calculated by comparing median anxiety scores of the current sample to the percentile rank norms for undergraduate students in the USA reported by the author of the STARS (i.e. Cruise et al., 1985). A MPRES of 80 for Interpretation Anxiety indicates that at least 50% of the current sample scored higher than 80% of the norm group on this factor. The MPRES ranges from 76 to 80, suggesting that the current sample is a group high on statistics anxiety. A series of four multiple regressions was used to examine the ability of the three factors of statistics anxiety (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help) to predict each of the four TBI. Assumption tests were conducted to ensure no violation of multicollinearity, normality, linearity, homoscedasticity, and independence of residuals (see Appendix 5.4). The three factors of statistics anxiety did not significantly predict each of the four TBI. The results are presented in Table 5.2.

Table 5.1

Means and Standard Deviations of the STARS and the TBI

RT Tasks	*M*	*SD*		
Emotional Stroop task				
TBI for words	19.9	91.0		
TBI for symbols	-29.9	231.0		
Dot probe task				
TBI for words	-10.3	37.2		
TBI for symbols	-2.4	82.9		
Statistics Anxiety	*M*	*SD*	Median	MPRES
Interpretation Anxiety	30.3	8.1	31	80
Test and Class Anxiety	28.0	6.1	29	76
Fear of Asking for Help	10.0	3.8	10	77

Note. Untransformed data (i.e., mean RT in millisecond) are reported in this table for the TBI. Multiple regression analyses were conducted on transformed data (i.e., ln RT). MPRES = median percentile rank equivalent scores. The MPRES were obtained by comparing median anxiety scores to the percentile rank norms pertaining to undergraduate students reported by Cruise et al. (1985).

Table 5.2

Four Standard Multiple Regressions Predicting Each of the Four TBI

	Emotional Stroop task		Dot probe task	
	TBI Words	TBI Symbols	TBI Words	TBI Symbols
Variables	β	β	β	β
Interpretation Anxiety	-.04	-.17	-.19	.01
Test and Class Anxiety	.12	.28	.35	.15
Fear of Asking for Help	-.16	.09	-.19	-.16
R^2	.02	.07	.07	.02
F (3, 93)	.60	2.17	2.16	.67

Note. No statistically significant results were found.

5.3 Discussion

The results provided no support for either the interference hypothesis or the facilitation hypothesis. No evidence of attentional bias in statistics anxiety was found for either the emotional Stroop task or the dot probe task. These results are inconsistent with the attentional bias literature (Bar-Haim et al., 2007).

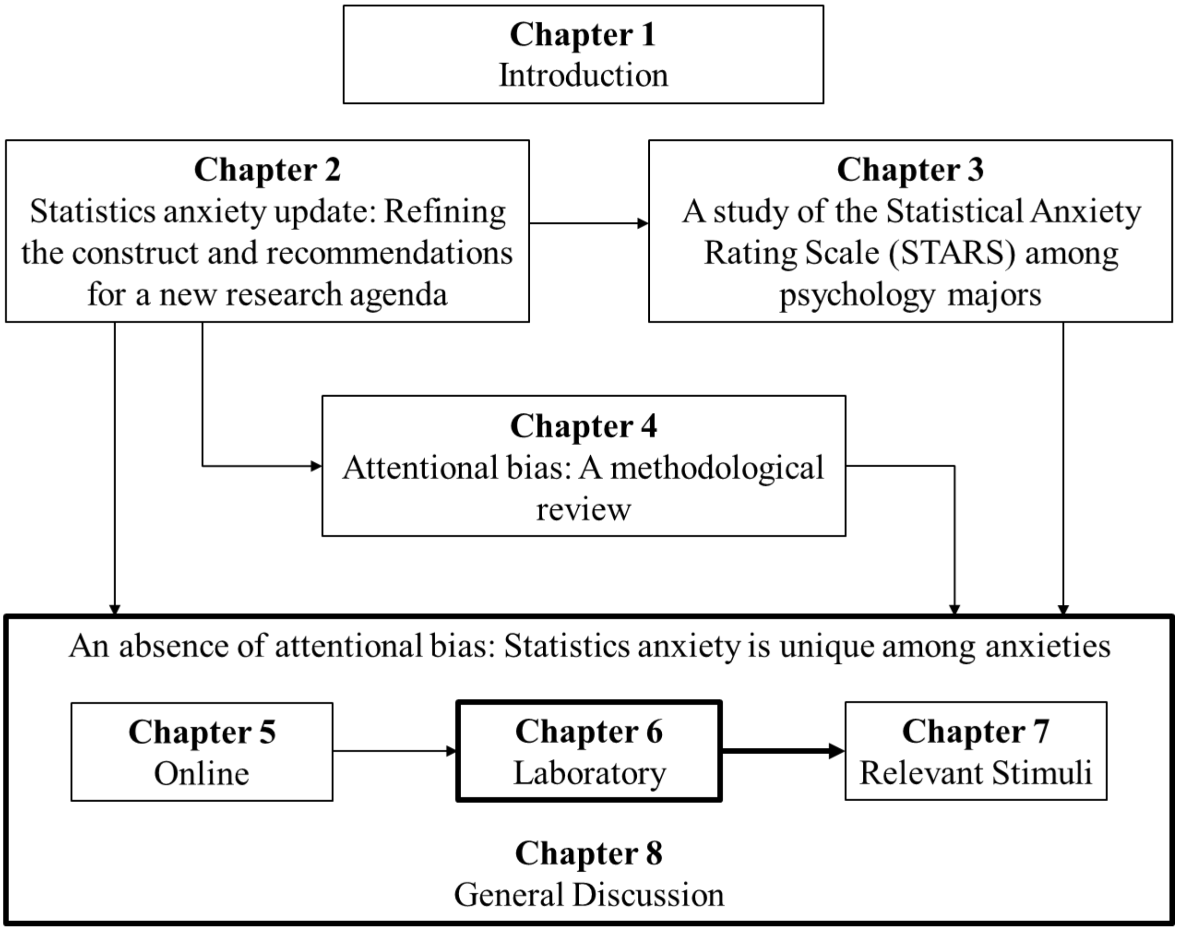
The nonsignificant results might be explained by the construct in question. This study appears to be the first investigation of attentional bias in statistics anxiety. The cognitive processes that underlie statistics anxiety might be different from that of other anxieties.

Specifically, individuals high in statistics anxiety did not exhibit an attentional bias toward threat in the current experiment. However, this speculation is unlikely given the similarities between statistics anxiety and other types of anxieties. For example, statistics anxiety is similar to specific phobias because the symptoms only emerge when students are learning or applying statistics (Onwuegbuzie, 1999). Yet, attentional bias has been found among specific phobias such as spider phobia (Olatunji et al., 2008) and social phobia (Mogg, Philippot, et al., 2004). Hence, it seems likely that the nonsignificant results are due to methodological limitations.

Firstly, conducting the experiment online might have affected the results. Currently, most studies on attentional bias are conducted in a laboratory (which lacks ecological validity), with only a handful of studies conducted online (e.g., MacLeod et al., 2007). Anecdotal evidence suggests that participants are less motivated and focused in online studies. Indeed, the current experiment had large standard deviations (up to 220.96 milliseconds) compared to other studies (e.g., up to 110 milliseconds in Egloff & Hock, 2003). The current experiment also had a higher percentage of incorrect responses compared to other studies. Because the impact of outliers was reduced by transforming the data (Ratcliff, 1993), only incorrect responses were excluded from the analysis and they accounted for 6.6% of the data. In contrast, Egloff and Hock (2003) excluded both outliers and incorrect responses and they accounted for only 3% of the data. Lastly, almost a third (30.88%) of the participants did not complete the experiment and had missing data on either the tasks or the instruments.

Second, the current experiment did not account for the suppression effect. Research has shown that attentional bias is suppressed when anxious participants expect a threatening event (Amir et al., 1996; Helfinstein, White, Bar-Haim, & Fox, 2008). For example, attentional bias was suppressed among participants with PTSD when they expected to watch a videotape about combat in Vietnam after completing the emotional Stroop task. In contrast, participants with PTSD who were randomly assigned to the control condition showed the typical attentional bias effect (Constans et al., 2004). The suppression effect presents a conundrum for future research. According to the definition, statistics anxiety only occurs when students take a statistics course or when they do statistical analyses (Cruise et al., 1985). Hence, the current experiment recruited students who were currently enrolled in a statistics course (84.0%). However, enrolment in a statistics course might result in these students expecting an encounter with statistics-related threatening events (e.g., lectures, assignments, etc.) after the experiment. In turn, this expectation might suppress their attentional bias for threatening stimuli. These limitations are addressed in Experiment 2.

Chapter 6: An absence of attentional bias: Experiment 2 (Laboratory)



This chapter examines the role of attentional bias in statistics anxiety in a laboratory experiment. An earlier version of this chapter is currently under review in a journal:

Chew, P. K. H., Swinbourne, A., & Dillon, D. B. (Under Review). An absence of attentional bias: Statistics anxiety is unique among anxieties. *SAGE Open*

Chapter 6: An absence of attentional bias: Experiment 2 (Laboratory)

This experiment addresses the limitations of Experiment 1 by replicating the experiment in a laboratory and by considering the suppression effect. Anecdotal evidence suggests that students experience statistics anxiety before enrolling in a statistics course. Often, these students receive information about the anxiety involved in statistics courses from their seniors. Alternatively, students might associate statistics with mathematics and develop anxiety based on prior negative experience with mathematics. Indeed, some of these students delay enrolling in statistics courses until the last semester of their program (Roberts & Bilderback, 1980). Hence, the recruitment criteria were expanded to include this group of students. Since these students were not currently enrolled in a statistics course, recruiting them circumvents the suppression effect because they would not expect any statistics-related threatening events (e.g., lectures, assignments, etc.) after the experiment. If the suppression effect was responsible for the nonsignificant results in Experiment 1, attentional bias should be present among this group of students but absent among students currently enrolled in a statistics course.

6.1 Method

6.1.1 Participants

Participants were a convenience sample of 105 undergraduates at James Cook University. Data from six participants (6%) were removed due to errors in task completion, missing data, or being colour blind. The final sample consisted of 99 participants (68% females) enrolled in the psychology (97%) or business (3%) degree program from the James Cook University's Singapore (79%) and Australia (21%) campuses. Their ages ranged from 16 to 49 years (M = 22.16, SD = 5.03). The predominantly female sample was consistent with the gender distribution of the psychology undergraduate population in Singapore and Australia. Participants were divided into three groups based on their experience with statistics courses: 38 participants had never taken a statistics course before but expected to enrol in one in the future (NeverTakenStats), 31 participants were currently enrolled in a statistics course (TakingStats), and 30 participants had successfully completed at least one statistics course but were not currently enrolled in a statistics course (TakenStats). All participants had normal or corrected-to-normal eyesight and were not colour blind. The exclusion criteria were included in the recruitment poster and on the Sona Systems (a research participation management system). Participants were either granted extra course credit or were given a movie voucher for their participation in the experiment. A sample size of 99 exceeds the recommended sample size for multiple regression (i.e., N >= 50 + 8(3 predictors) = 74). Post hoc power analysis revealed an obtained power of .90 (alpha = .05) and .74 (alpha = .01) (Faul et al., 2009).

6.1.2 Procedure

Participants completed the emotional Stroop task and the dot probe task (MacLeod et al., 1986) on a computer in a laboratory using INQUISIT 4.0 (2015). Participants completed the experiment in silence with at least one empty seat between each participant. Both tasks took about 30 minutes to complete. Subsequently, participants completed the Background Information Form, the STARS (Cruise et al., 1985), and the Marlowe-Crowne Social Desirability Scale (Crowne & Marlowe, 1960) on SurveyGizmo (2015). The STARS had internal consistencies that ranged from .84 to .89 whereas the Marlowe-Crowne Social Desirability Scale had an internal consistency of .74 in the current experiment. Each instrument took about 10 minutes to complete. Except for the Background Information Form, all instruments and tasks were counterbalanced to control for order effects. Informed consent was implied when participants clicked on the ‘Next’ button to proceed with the tasks. This procedure was approved by the James Cook University Human Research Ethics Committee (see Appendix 5.3).

6.2 Results

All results were analysed using SPSS version 21. Alpha was set at .01 to reduce the chance of Type 1 errors due to multiple comparisons. Incorrect responses were removed from the RT data. The number of incorrect responses ranged from 0 to 12 (Median = 3.00, M = 3.73, SD = 2.95) for words and ranged from 0 to 17 (Median = 1.00, M = 1.66, SD = 2.48) for symbols on the emotional Stroop task. The number of incorrect responses ranged from 0 to 16 (Median = 4.00, M = 4.63, SD = 3.78) for words and ranged from 0 to 8 (Median = 1.00, M =1.55, SD = 1.64) for symbols on the dot probe task. Incorrect responses accounted for 6.0% of the data. Similar to Chapter 5, the data were prepared by applying a logarithmic transformation to normalize the distribution (Ratcliff, 1993) and calculating TBI for each stimuli type (i.e., words and symbols).

Preliminary analysis indicated that scores on the social desirability scale was not significantly correlated with the TBI. Hence, social desirability was not included in further analyses. The means and standard deviations of the STARS (Cruise et al., 1985) and the TBI for each group are presented in Table 6.1. A one-way between-subjects MANOVA was conducted with group as the independent variable (NeverTakenStats vs. TakingStats, vs. TakenStats), and the first three factors of the STARS and the four TBI as dependent variables to examine differences between groups. No statistically significant differences were found, F (12, 182) = 1.59, p = .97; Wilks' Lambda =.82. Hence, results were collapsed across groups. The descriptive statistics are presented in Table 6.2. The median percentile rank equivalent scores (MPRES) for the STARS ranges from 68 to 83, suggesting that the current sample is a group high on statistics anxiety.

Table 6.1

Means (Standard Deviations) of the STARS and the TBI for each Group

	NeverTakenStats		TakingStats		TakenStats	
Statistics Anxiety						
Interpretation Anxiety	30.8	(7.2)	28.1	(8.3)	28.4	(9.2)
Test and Class Anxiety	26.9	(6.0)	25.1	(6.5)	27.3	(5.7)
Fear of Asking for Help	11.0	(3.5)	9.4	(3.1)	10.2	(4.1)
Emotional Stroop task						
TBI for words	17.4	(60.1)	30.6	(71.8)	.1	(66.2)
TBI for symbols	-17.0	(207.8)	53.1	(162.6)	-15.7	(196.0)
Dot probe task						
TBI for words	9.0	(26.6)	3.8	(21.6)	-2.2	(26.9)
TBI for symbols	-25.6	(66.6)	-4.0	(53.5)	4.6	(43.0)

Note. Untransformed data (i.e., mean RT in millisecond) are reported in this table for the TBI. Multiple regression analyses were conducted on transformed data (i.e., ln RT).

Table 6.2

Means and Standard Deviations of the STARS and the TBI (Collapsed Across Groups)

RT Tasks	*M*	*SD*		
Emotional Stroop task				
TBI for words	16.3	66.2		
TBI for symbols	5.3	191.9		
Dot probe task				
TBI for words	4.0	25.4		
TBI for symbols	-9.7	57.2		
Statistics Anxiety	*M*	*SD*	Median	MPRES
Interpretation Anxiety	29.2	8.2	30	77
Test and Class Anxiety	26.5	6.1	27	68
Fear of Asking for Help	10.2	3.6	11	83

Note. Untransformed data (i.e., mean RT in millisecond) are reported in this table for the TBI. Multiple regression analyses were conducted on transformed data (i.e., ln RT). MPRES = median percentile rank equivalent scores. The MPRES were obtained by comparing median anxiety scores to the percentile rank norms pertaining to undergraduate students reported by Cruise et al. (1985).

A series of four multiple regressions was used to examine the ability of the three factors of statistics anxiety (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help) to predict each of the four TBI. Assumption tests were conducted to ensure no violation of multicollinearity, normality, linearity, homoscedasticity, and independence of residuals (see Appendix 6.1). The three factors of statistics anxiety did not significantly predict each of the four TBI. The results are presented in Table 6.3.

Table 6.3

Four Standard Multiple Regressions Predicting Each of the Four TBI

	Emotional Stroop task		Dot probe task	
	TBI Words	TBI Symbols	TBI Words	TBI Symbols
Variables	β	β	β	β
Interpretation Anxiety	.03	.09	.08	.05
Test and Class Anxiety	-.13	-.20	-.07	.05
Fear of Asking for Help	.21	.18	.03	-.08
R^2	.04	.04	.01	.01
F (3, 98)	1.30	1.28	.15	.19

Note. No statistically significant results were found.

6.3 Discussion

The results provided no support for either the interference hypothesis or the facilitation hypothesis. No evidence of attentional bias in statistics anxiety was found for either the emotional Stroop task or the dot probe task. These results are consistent with those from Experiment 1 but inconsistent with the attentional bias literature (Bar-Haim et al., 2007).

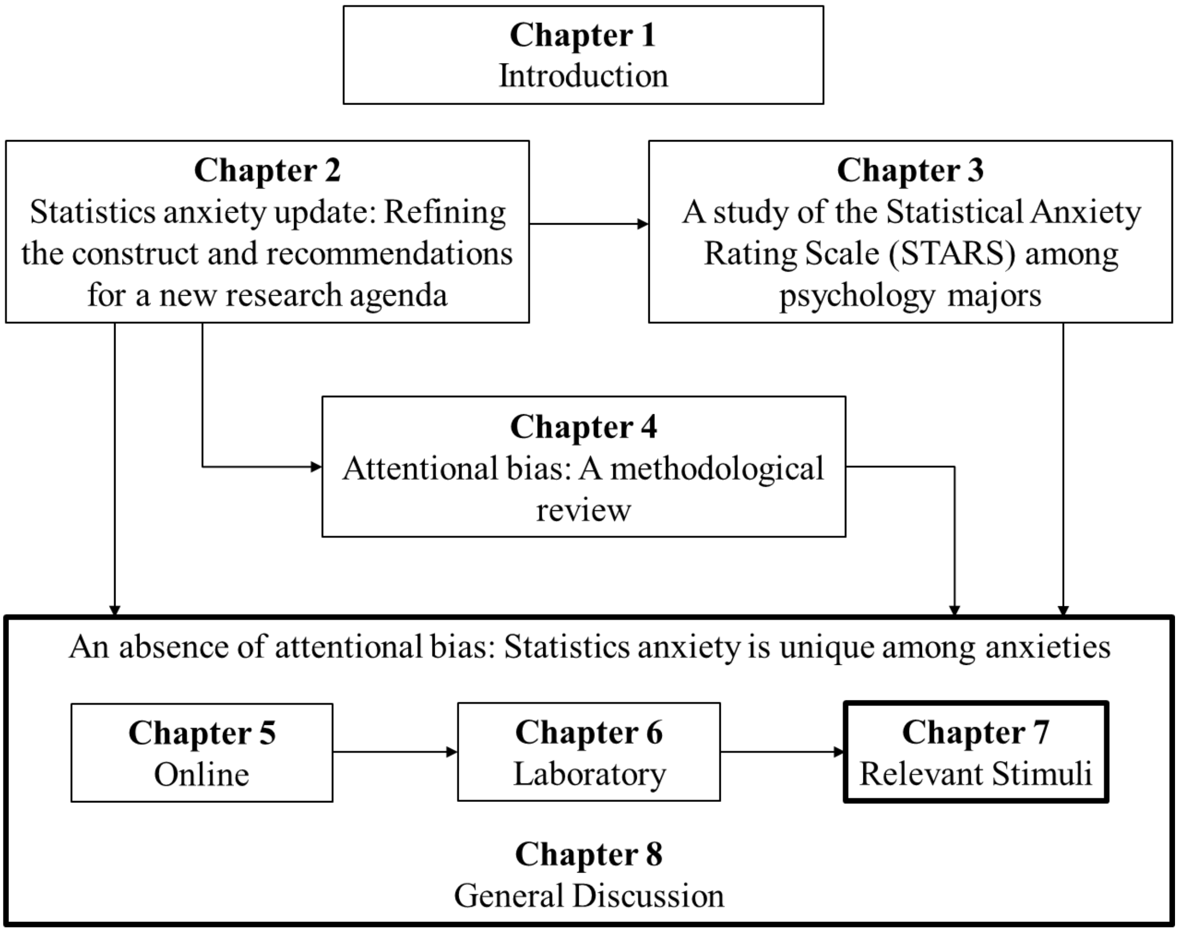
Conducting the experiment in a laboratory yielded marginal benefits compared to Experiment 1. Although there was a lower percentage of missing data and smaller standard deviations on both tasks, the means of the three factors of the STARS (Cruise et al., 1985) and the percentage of incorrect responses remained similar. Furthermore, both experiments found the same statistically nonsignificant results. These results suggest that there was no difference to participants in terms of attentional bias in completing the experiment online or in a laboratory. Currently, only a handful of attention bias studies are conducted online (e.g., MacLeod et al., 2007), with most studies conducted in a laboratory. Our results suggest that future research could be conducted online to improve ecological validity and ease of administration.

Participants from all three groups (NeverTakenStats vs. TakingStats, vs. TakenStats) had similar levels of statistics anxiety and TBI. This result supports our observation that students experience statistics anxiety before enrolling in a statistics course. An in-depth discussion of the implications is beyond the scope of the current research agenda. However, future research could examine the causes of this form of anticipatory anxiety and implement interventions to reduce it. Finally, the absence of attentional bias among participants who had never taken a statistics course before suggests that the suppression effect was not responsible for the nonsignificant results in Chapter 5.

Studies that investigated attentional bias in OCD might explain the nonsignificant results in statistics anxiety. OCD is partially unique as a heterogeneous disorder; attentional bias was consistently demonstrated only among participants with contamination concerns (Summerfeldt & Endler, 1998) and not those with checking concerns (Harkness et al., 2009; Moritz & von Mühlenen, 2008). Similarly, the nonsignificant results obtained so far could be due to the incorrect conceptualization of statistics anxiety as a homogeneous construct. This conceptualization led to the selection of statistics-related words (e.g., skewness) and symbols (e.g., *df*) as stimuli for the tasks. Although these stimuli were rated more negatively than their neutral counterparts in Experiment 1, the nonsignificant results indicate that these stimuli might not be relevant to the concerns of students high in statistics anxiety.

The three factors of statistics anxiety are often taken as indicators of a global homogeneous construct (i.e., statistics anxiety). However, each of those factors assesses anxiety in different situations and are associated with different student concerns. Hence, more relevant stimuli could be used by considering each factor individually. For example, students high in Fear of Asking for Help might share similar concerns with individuals high in social anxiety. These students should exhibit attentional bias toward words associated with social anxiety (Mathews, Mogg, May, & Eysenck, 1989). This hypothesis is examined in Experiment 3.

Chapter 7: An absence of attentional bias: Experiment 3 (Relevant Stimuli)



This chapter examines the role of attentional bias in statistics anxiety using stimuli relevant to each factor of the STARS. An earlier version of this chapter is currently under review in a journal:

Chew, P. K. H., Swinbourne, A., & Dillon, D. B. (Under Review). An absence of attentional bias: Statistics anxiety is unique among anxieties. *SAGE Open*

Chapter 7: An absence of attentional bias: Experiment 3 (Relevant Stimuli)

This experiment addresses the limitations of Experiments 1 and 2. Those experiments used the three factors of statistics anxiety as indicators of a global homogeneous construct (i.e., statistics anxiety), resulting in the use of statistics-related words (e.g., skewness) and symbols (e.g., *df*) as stimuli for the tasks. However, the nonsignificant results obtained so far suggest that the conceptualization might be incorrect. Accordingly, in this experiment, statistics anxiety is conceptualized as a multidimensional construct consisting of three factors: (a) Interpretation Anxiety, (b) Test and Class Anxiety, and (c) Fear of Asking for Help (Papousek et al., 2012). Interpretation Anxiety refers to the feelings of anxiety encountered when interpreting statistical data. Test and Class Anxiety concerns the anxiety involved in attending a statistics class or when taking a statistics test. Lastly, Fear of Asking for Help relates to the anxiety experienced when seeking help.

In contrast to Experiments 1 and 2, the three factors of statistics anxiety were considered individually and stimuli relevant to each factor were adopted from other studies. Specifically, ego-threat words (e.g., inferior) were used for Interpretation Anxiety (MacLeod et al., 2002), examination-related threat words (e.g., stupidity) for Test and Class Anxiety (MacLeod & Rutherford, 1992), and social anxiety threat words (e.g., ridicule) for Fear of Asking for Help (Mathews et al., 1989). In each of these studies, participants with high scores on the trait scale of the State-Trait Anxiety Inventory (STAI) showed an attentional bias toward the threat words. Hence, the STAI was administered to control for the effects of general anxiety.

7.1 Method

7.1.1 Participants

Participants were a convenience sample of 110 psychology undergraduates at James Cook University. Data from six participants (5%) were removed due to missing data. The final sample consisted of 104 participants (67% females) from the James Cook University's Singapore campus. Their ages ranged from 17 to 44 years (M = 22.13, SD = 3.42). The predominantly female sample was consistent with the gender distribution of the psychology undergraduate population in Singapore. Participants were divided into three groups based on their experience with statistics courses: 37 participants had never taken a statistics course before but expected to enrol in one in the future (NeverTakenStats), 30 participants were currently enrolled in a statistics course (TakingStats), and 37 participants had successfully completed at least one statistics course but were not currently enrolled in a statistics course (TakenStats). All participants had normal or corrected-to-normal eyesight and were not colour blind. The exclusion criteria were included in the recruitment poster and on the Sona Systems (a research participation management system). Participants were either granted extra course credit or were given a movie voucher for their participation in the experiment. Post hoc power analysis revealed an obtained power of .97 (alpha = .05) and .90 (alpha = .01) (Faul et al., 2009).

7.1.2 Stimuli

The stimuli are presented in Appendix 7.1. A total of 50 pairs of words was used: 14 pairs of words were used for Interpretation Anxiety (MacLeod et al., 2002), 12 pairs of words for Test and Class Anxiety (MacLeod & Rutherford, 1992), and 24 pairs of words for Fear of Asking for Help (Mathews et al., 1989). The threat words were matched on average length and frequency with the neutral words. Some words were repeated because they are relevant to more than one factor of statistics anxiety. For example, the word 'inadequate' is relevant to both Interpretation Anxiety and Test and Class Anxiety.

7.1.3 Tasks

The tasks were similar to those for Chapters 5 and 6. Participants completed a different number of trials due to a different set of stimuli. For the emotional Stroop task, participants completed 20 practice trials to familiarize with the task before completing 100 experimental trials (50 threat words and 50 neutral words). For the dot probe task, participants completed 10 practice trials to familiarize with the task before completing 100 experimental trials (50 pairs of words).

7.1.4 Instruments

7.1.4.1 The STAI[6]. Form Y of the STAI is a two-part, 40-item instrument designed to assess the two factors of general anxiety (Spielberger et al., 1970). Part 1 consists of 20 items which assess state anxiety (STAI-S; e.g., I am tense). Participants respond on a 4-point Likert scale that ranges from 1 = *Not at All* to 4 = *Very Much So*. Appropriate item scores are summed, with higher scores indicating higher levels of state anxiety. Part 2 consists of 20 items which assess trait anxiety (STAI-T; e.g., I am content). Participants respond on a four-point Likert scale that ranges from 1 = *Almost Never* to 4 = *Almost Always*. Appropriate item scores are summed, with higher scores indicating higher levels of trait anxiety. Scores on each factor can range from 20 to 80. Spielberger et al. (1970) reported internal consistencies that ranged from .86 to .95 and two-month test-retest reliabilities that ranged from .65 to .75 for the two factors. The current experiment found an internal consistency of .93 for each of the two factors.

7.1.5 Procedure

Participants completed the emotional Stroop task and the dot probe task (MacLeod et al., 1986) on a computer in a laboratory using INQUISIT 4.0 (2015). Participants completed the experiment in silence with at least one empty seat between each participant. Both tasks took about 30 minutes to complete. Subsequently, participants completed the Background Information Form, the STARS (Cruise et al., 1985), the Marlowe-Crowne Social Desirability Scale (Crowne & Marlowe, 1960), and the STAI (Spielberger et al., 1970) on SurveyGizmo

[6] This instrument was not presented in the Appendix because it is copyrighted by Mind Garden, Inc.

(2015). The STARS had internal consistencies that ranged from .88 to .91 whereas the Marlowe-Crowne Social Desirability Scale had an internal consistency of .71 in the current experiment. Each instrument took about 10 minutes to complete. Except for the Background Information Form, all instruments and tasks were counterbalanced to control for order effects. Informed consent was implied when participants clicked on the 'Next' button to proceed with the tasks. This procedure was approved by the James Cook University Human Research Ethics Committee (see Appendix 5.3).

7.2 Results

All results were analysed using SPSS version 21. Alpha was set at .01 to reduce the chance of Type 1 errors due to multiple comparisons. Incorrect responses were removed from the RT data. The descriptive statistics of incorrect responses for each stimulus type are presented in Table 7.1. Incorrect responses accounted for 5.9% of the data. Similar to Chapters 5 and 6, the data were prepared by applying a logarithmic transformation to normalize the distribution (Ratcliff, 1993) and calculating TBI for each stimulus type.

Table 7.1

Descriptive Statistics of Incorrect Responses for each Stimulus Type

				Range	
Stimuli	Median	*M*	*SD*	Minimum	Maximum
Emotional Stroop task					
Ego-threat words	1.00	1.49	1.71	0	8
Examination-related words	1.00	1.35	1.40	0	5
Social Anxiety words	2.00	2.50	2.23	0	12
Dot probe task					
Ego-threat words	1.50	1.80	1.57	0	6
Examination-related words	1.00	1.48	2.02	0	17
Social Anxiety words	2.00	3.19	3.05	0	13

Preliminary analysis indicated that scores on the social desirability, trait anxiety, and state anxiety scales were not significantly correlated with the TBI. Hence, these variables were not included in further analyses. The means and standard deviations of the STARS

(Cruise et al., 1985) and the TBI for each group are presented in Table 7.2. A one-way between-subjects MANOVA was conducted with groups as the independent variable (NeverTakenStats vs. TakingStats, vs. TakenStats), and the first three factors of the STARS and the six TBI as dependent variables to examine differences between groups. No statistically significant difference was found, F (18, 186) = 0.66, p = .85; Wilks' Lambda =.88. Hence, results were collapsed across groups. The descriptive statistics are presented in Table 7.3. The median percentile rank equivalent scores (MPRES) for the STARS ranges from 68 to 83, suggesting that the current sample is a group high on statistics anxiety.

Table 7.2

Means (Standard Deviations) of the STARS and the TBI for each Group

	NeverTakenStats		TakingStats		TakenStats	
Statistics Anxiety						
Interpretation Anxiety	31.4	(8.8)	29.9	(10.6)	32.5	(8.3)
Test and Class Anxiety	26.1	(7.9)	26.1	(8.5)	27.6	(6.4)
Fear of Asking for Help	10.1	(4.0)	9.9	(4.8)	11.1	(4.0)
Emotional Stroop task						
TBI for Ego-threat words	-3.2	(119.9)	16.0	(130.3)	-10.1	(194.8)
TBI for Examination-related words	26.1	(405.8)	-16.8	(15.0)	-.1	(131.7)
TBI for Social Anxiety words	-7.2	(103.2)	-.9	(85.8)	5.9	(118.0)
Dot probe task						
TBI for Ego-threat words	.6	(39.4)	-19.9	(85.9)	.6	(47.6)
TBI for Examination-related words	-3.5	(37.3)	-2.2	(41.6)	16.5	(113.6)
TBI for Social Anxiety words	63.4	(282.6)	3.41	(38.8)	-3.6	(28.8)

Note. Untransformed data (i.e., mean RT in millisecond) are reported in this table for the TBI. Correlations and simple regression analyses were conducted on transformed data (i.e., ln RT).

Table 7.3

Means and Standard Deviations of the STARS and the TBI (Collapsed Across Groups)

RT Tasks	*M*	*SD*		
Emotional Stroop task				
TBI for Ego-threat words	-.1	152.3		
TBI for Examination-related words	4.4	271.2		
TBI for Social Anxiety words	-.7	103.4		
Dot probe task				
TBI for Ego-threat words	-5.3	59.2		
TBI for Examination-related words	4.0	74.6		
TBI for Social Anxiety words	22.3	172.6		
Statistics Anxiety	*M*	*SD*	Median	MPRES
Interpretation Anxiety	31.4	8.8	32	83
Test and Class Anxiety	26.7	7.6	27	68
Fear of Asking for Help	10.4	4.2	10	77

Note. Untransformed data (i.e., mean RT in millisecond) are reported in this table for the TBI. Correlations and simple regression analyses were conducted on transformed data (i.e., ln RT). MPRES = median percentile rank equivalent scores. The MPRES were obtained by comparing median anxiety scores to the percentile rank norms pertaining to undergraduate students reported by Cruise et al. (1985).

A series of six simple linear regressions was used to examine the ability of the three factors of statistics anxiety (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help) to predict the TBI of their relevant stimuli. Assumption tests were conducted to ensure no violation of linearity, homoscedasticity, and independence of residuals (see Appendix 7.2). The results are presented in Table 7.4. The three factors of statistics anxiety did not significantly predict the TBI.

Table 7.4

Six Simple Regression Outcomes with the Three Factors of Statistics Anxiety as Predictors and the Six TBI as Criteria

Predictors	Criteria	β	R^2	F (1, 103)
	Emotional Stroop task			
Interpretation Anxiety	TBI for Ego-threat words	.21	.05	4.89
Test and Class Anxiety	TBI for Examination-related words	-.11	.01	1.23
Fear of Asking for Help	TBI for Social Anxiety words	-.02	.00	.06
	Dot probe task			
Interpretation Anxiety	TBI for Ego-threat words	.11	.01	1.26
Test and Class Anxiety	TBI for Examination-related words	.01	.00	.00
Fear of Asking for Help	TBI for Social Anxiety words	-.02	.00	.04

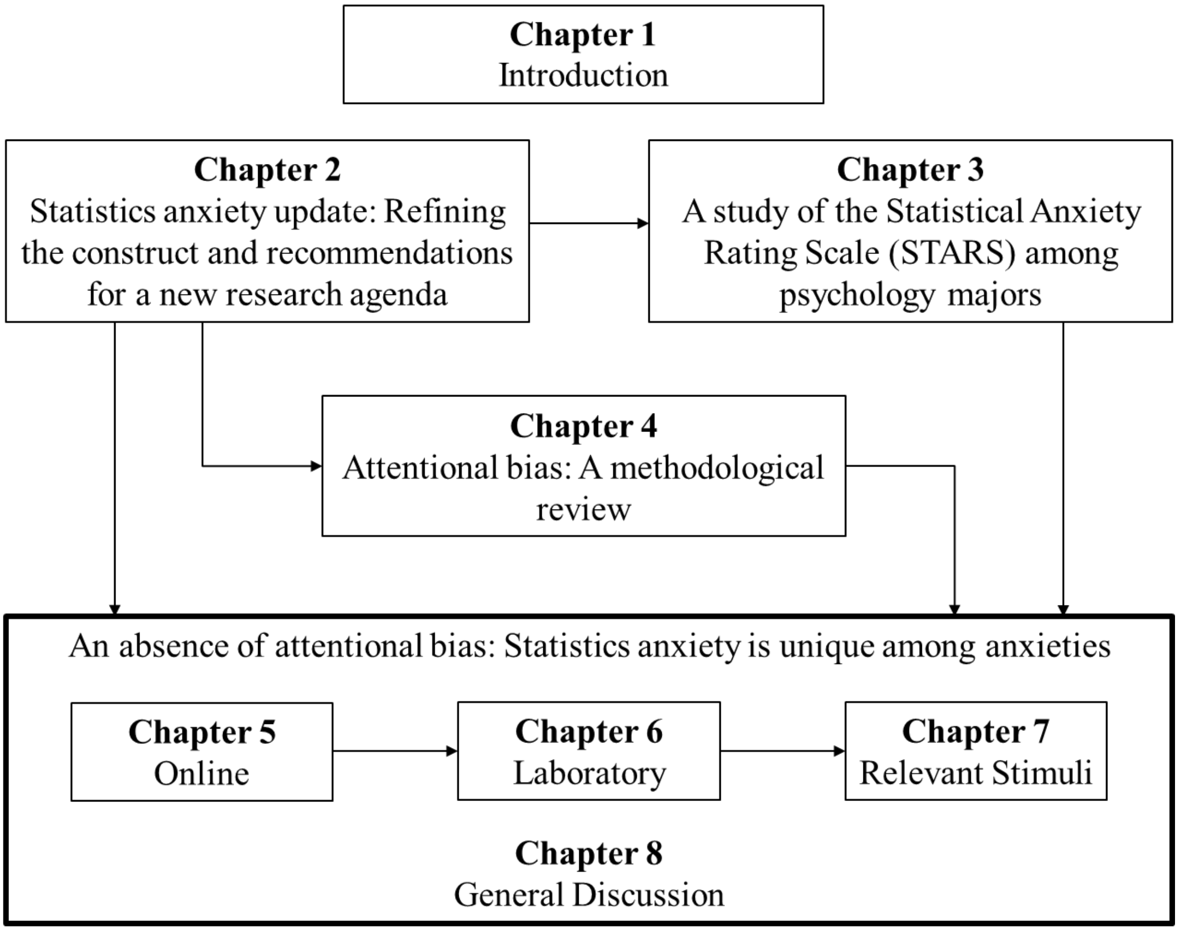
Note. No statistically significant results were found.

7.3 Discussion

The results provide no support for either the interference hypothesis or the facilitation hypothesis. No evidence of attentional bias in statistics anxiety was found for the emotional Stroop task and the dot probe task. These results are consistent with those of Experiments 1 and 2, but inconsistent with the attentional bias literature (Bar-Haim et al., 2007).

Individuals high in each factor of statistics anxiety did not exhibit attentional bias toward threatening stimuli relevant to their concerns. These results suggest no differences in conceptualizing statistics anxiety as a homogeneous construct (Experiments 1 and 2) or as a multidimensional construct consisting of three factors (the current experiment) since attentional bias was absent in both conceptualizations. This finding differentiates statistics anxiety from OCD. OCD is partially unique because attentional bias was found only among participants with contamination concerns (Summerfeldt & Endler, 1998) and not with checking concerns (Harkness et al., 2009; Moritz & von Mühlenen, 2008). In contrast, statistics anxiety is unique due to the complete absence of attentional bias on both a global level and on the individual factors level.

Chapter 8: General Discussion



This chapter summarizes the main findings from Chapters 5, 6, and 7, and discusses their implications for future research. An earlier version of this chapter is currently under review in a journal:

Chew, P. K. H., Swinbourne, A., & Dillon, D. B. (Under Review). An absence of attentional bias: Statistics anxiety is unique among anxieties. *SAGE Open*

Chapter 8: General Discussion

The purpose of the current study was to examine the role of attentional bias in statistics anxiety. The results of the three experiments provide no support for either the interference hypothesis or the facilitation hypothesis. The findings of Experiments 2 and 3 eliminate alternative explanations for the nonsignificant results: (a) conducting the study online, (b) suppression of attentional bias, and (c) conceptualizing statistics anxiety as a global, homogeneous construct. These eliminations support the initial explanation for the results from Experiment 1: the cognitive processes that underlie statistics anxiety might be different from that of other anxieties.

Attentional bias is a central feature of anxieties (Bar-Haim et al., 2007). Yet, no evidence of attentional bias was found in statistics anxiety, suggesting that this form of anxiety is unique among anxieties. The model proposed by Bar-Haim et al. (2007) does not explain the results of the current study. For example, the absence of attentional bias could be due to the Guided Threat Evaluation System (GTES) overriding the anxious state of the Resource Allocation System (RAS). However, this explanation is unlikely for two reasons. First, it is unclear why the GTES would malfunction for other anxieties but not for statistics anxiety. Second, an override is only possible with contrary evidence from context, memory, or from prior learning. Experiments 2 and 3 showed that students report high levels of statistics anxiety regardless of their experience with statistics courses. These results suggest that the context (for students who were currently enrolled in a statistics course), memory and prior learning (for students who have successfully completed at least one statistics course) of these individuals would provide supporting, instead of contrary, evidence for the anxious state of the RAS. The lack of an override would eventually facilitate the development of an attentional bias.

The four-stage theoretical model (Bar-Haim et al., 2007) was modified by adding an Exception to accommodate the results of the current study (see Figure 8.1). Since statistics-related stimuli used in Experiments 1 and 2 were rated more negatively than neutral stimuli, the Preattentive Threat Evaluation System (PTES) should consider the stimuli as high threat. However, instead of proceeding directly to the RAS, an Exception occurs where individuals with statistics anxiety allocate a low priority to the highly threatening stimuli in the RAS. This process eventually results in an absence of attentional bias.

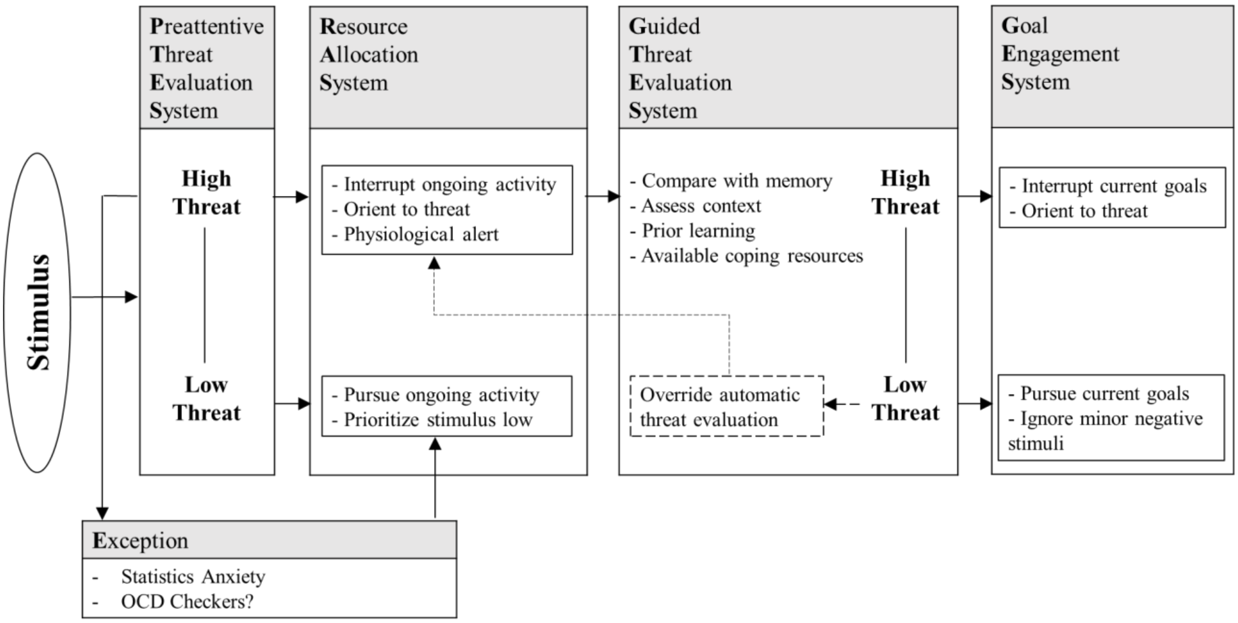


Figure 8.1. An Exception in the model. This figure illustrates the addition of an Exception as a modification to the four-stage theoretical model (Bar-Haim et al., 2007).

Given that attentional bias was not found among OCD checkers (Harkness et al., 2009; Moritz & von Mühlenen, 2008), future research should investigate if this form of anxiety could be classified with statistics anxiety because it might explain why the Exception occurs. Harkness et al. (2009) postulated that the absence of attentional bias among OCD checkers could be due to these individuals interpreting danger "based on the *absence* of disconfirming evidence rather than the *presence* of danger signals, that is, OCD checkers may preferentially seek indicators of safety [instead of being] vigilant for indicators of danger." (p. 441). Hence, an Exception occurs because these individuals are not vigilant for threatening stimuli in the environment. Accordingly, when confronted with such stimuli, these individuals will assign a low priority to the stimuli and continue to pursue ongoing activity.

Statistics anxiety might operate in a similar manner. For example, students with Fear of Asking for Help would be vigilant for indicators of safety, such as the presence of a friendly instructor, in a statistics course. In the *absence* of such indicators, the high anxiety levels of these students will probably be maintained. Conversely, in the *presence* of such indicators, the anxiety levels of these students might possibly be reduced. While speculative, this account offers an explanation for the effectiveness of some interventions for statistics anxiety. Research has shown that instructors can reduce students' levels of statistics anxiety by using humour in class (V. A. Wilson, 1999) or increasing their use of immediacy behaviours (A. S. Williams, 2010). However, these interventions do not modify the threat. Instead, by using these interventions, the instructor will be perceived as approachable and friendly by students. Consequently, the instructor serves as an indicator of safety, resulting in a reduction in students' levels of anxiety.

Alternatively, the absence of attentional bias could be due to the nature of statistics anxiety. Given that statistics anxiety is only experienced when learning or using statistics (i.e., a situation-specific anxiety; Cruise et al., 1985; Onwuegbuzie et al., 1997; Zeidner, 1991), the inclusion of context might be necessary to elicit a cognitive bias. In other words, statistics-related words and symbols (Experiments 1 and 2), and general words (Experiment 3) might be insufficient to elicit a cognitive bias when presented alone to the participants. Accordingly, future research should investigate the role of interpretation bias in statistics anxiety. Individuals high in statistics anxiety might interpret ambiguous events in a threatening manner, effectively reinforcing their anxiety. This form of bias is often examined through the use of incomplete sentences which provides a context to the situation (Beard, 2011; Hertel & Mathews, 2011; MacLeod & Mathews, 2012). For example, in response to an ambiguous incomplete sentence: ‘the lecturer is … confident that I will do well in the statistics examination,’ anxious individuals might be faster in responding to the word ‘not’ (resolving the ambiguity negatively) than the word ‘very’ (resolving the ambiguity positively). Future research should investigate which of the two cognitive mechanisms (i.e., vigilant for safety indicators vs. interpretation bias) underlie statistics anxiety. Subsequently, relevant interventions can be developed (i.e., inclusion of safety indicators in classrooms vs. interpretation training) to reduce statistics anxiety.

Theoretical implications aside, the absence of attentional bias suggests that attentional bias modification, a program which can be completed online by students (MacLeod et al., 2007), would not be effective as an intervention for statistics anxiety. Given that most interventions for statistics anxiety are instructor-centred (e.g., Pan & Tang, 2004; A. S. Williams, 2010; V. A. Wilson, 1999), a shift in research focus is needed. Specifically, instead of conducting research typical of statistics anxiety (i.e., research on the antecedents of, effects of, and interventions for statistics anxiety), we need to examine if a gap exists between research and practice. For example, are instructors aware that they could exhibit immediacy behaviours to reduce statistics anxiety (A. S. Williams, 2010)? If a gap exists, research should be directed at finding ways of informing, facilitating, and empowering instructors to use these interventions.

Limitations of the study should be noted. First, the stimuli used in Experiment 3 were not rated by participants for negativity (cf. Experiment 1 and 2). However, once attentional bias has been found using a set of stimuli, it is common for subsequent studies to adopt the stimuli without re-evaluating them for negativity. For example, the same set of stimuli from a previous study (MacLeod et al., 2002) was used in subsequent studies (Amir, Beard, et al., 2009; MacLeod et al., 2007). Second, images were not used as stimuli (e.g., angry faces as stimuli for individuals with high scores on the Fear of Asking for Help factor). This is a limitation because single words might not fully represent the range of anxiety-provoking stimuli for anxious individuals (B. P. Bradley et al., 2000). However, no evidence to date has provided support for a form of anxiety where attentional bias was found only with images but not with words. Hence, although these limitations could be controlled for in future research by (a) having participants rate the stimuli in a pilot study and (b) using images as stimuli, respectively, it is unlikely that these procedures would have an effect on the results.

Limitations notwithstanding, the current study provides first evidence for a form of anxiety without attentional bias. In summary, a series of experiments addressed perceived limitations of the methods and showed that statistics anxiety is unique among anxieties due to the complete absence of attentional bias on both a global level and on the individual factors level. The results has three implications: (a) a theoretical model of attentional bias (Bar-Haim et al., 2007) was modified to accommodate the results of the current study, (b) two cognitive mechanisms (i.e., vigilant for safety indicators vs. interpretation bias) were hypothesized to underlie statistics anxiety, and (c) a shift in research focus is needed to examine if instructors are aware of effective statistics anxiety interventions in the literature.

Future research should examine the second and third implications of the current study. Given the well-documented negative effects of statistics anxiety (e.g., Hanna & Dempster, 2009; Onwuegbuzie & Seaman, 1995), there is a pressing need to identify the cognitive mechanism underlying this form of anxiety to inform the development of effective, theory-based interventions. Subsequently, research should examine methods of bridging the gap between research and practice with regards to statistics anxiety interventions. The implementation of effective interventions for statistics anxiety allows psychology students to learn statistics with minimal anxiety, with the final goal of promoting statistical literacy among citizens of a democracy.

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Appendix 1.1: Statistics Courses in Undergraduate Psychology Programs in Singapore and Australia

A comprehensive search was conducted on the websites and course brochures of all public universities in Singapore and Australia to retrieve information about statistics courses in their undergraduate psychology programs. Key search terms included phrases like "quantitative methods", "research methods", "statistical methods", "statistics", "research design", and "data analysis". If a university offers more than one psychology program (e.g., Bachelor of Arts (Psychology) and Bachelor of Psychology), the program with the longer duration and/or with an Honours component is considered. However, not all universities publish course information on their website. For these universities, an email was sent to request for the relevant information. Two universities had not replied up to the time of thesis submission.

(a) Universities in Singapore (3 Universities)			
No.	Name of University	No. of statistics course offered	No. of mandatory statistics course
1	Nanyang Technological University	2	2
2	National University of Singapore	5	2
3	Singapore Management University	3	1

(a) Universities in Australia (39 Universities)			
No.	Name of University	No. of statistics course offered	No. of mandatory statistics course
1	Australian Catholic University	4	4
2	Australian National University	2	2
3	Bond University	4	4
4	Central Queensland University	4	4
5	Charles Darwin University	3	3
6	Charles Sturt University	2	2
7	Curtin University	3	3
8	Deakin University	2	2
9	Edith Cowan University	3	3
10	Federation University	2	2
11	Flinders University	3	3
12	Griffith University	3	3
13	James Cook University	3	3
14	La Trobe University	2	2

15	Macquarie University	4	2
16	Monash University	3	3
17	Murdoch University	3	1
18	Queensland University of Technology	4	4
19	RMIT University	No information	No information
20	Southern Cross University	3	3
21	Swinburne University of Technology	3	3
22	University of Adelaide	3	3
23	University of Canberra	2	2
24	University of Melbourne	1	1
25	University of New England	2	2
26	University of New South Wales	2	2
27	University of Newcastle	5	5
28	University of Notre Dame	5	2
29	University of Queensland	3	3
30	University of South Australia	3	3
31	University of Southern Queensland	4	4
32	University of Sydney	2	2
33	University of Tasmania	3	3
34	University of Technology Sydney	No Psych Program	No Psych Program
35	University of the Sunshine Coast	3	2
36	University of Western Australia	2	2
37	University of Western Sydney	No information	No information
38	University of Wollongong	4	4
39	Victoria University	3	3

Appendix 1.2: Statistics Courses in JCU

The description, learning outcomes, and modes of assessment of the three statistics courses in JCU are presented here.

Introductory Statistics (PY2103 - Describing and Analysing Behaviour)

Description:
The purpose of this subject is to introduce students to concepts of research methodology and design as they apply to experimental psychology research. Students will learn about the scientific method and issues such as probability, causality and sampling. They will also acquire skills in designing experimental studies by learning to formulate research hypotheses and the operationalisation of concepts into variables. Problems that can arise with research, such as threats to validity and reliability, will also be presented. In addition, students will acquire skills in inferential statistics, including hand and computer calculation of parametric and nonparametric statistical tests. A major component of the subject will be the acquisition of skills in using the statistical package SPSS, as well as presenting research findings in APA format. It is intended that by the completion of this subject students can integrate the methodological understanding and the analytical and computer skills acquired in this subject.

Learning Outcomes:

- Acquire practical experience in conducting, analysing, interpreting and presenting research;
- Acquire skills in calculating relevant inferential statistical tests by hand and using the SPSS computer package;
- Understand the scientific method and how it is applied to experimental research in psychology;
- Understand the steps to constructing an experiment and issues that can weaken the design of an experiment.

URL (Retrieved 15 April 2015):
https://secure.jcu.edu.au/app/studyfinder/?subject=py2103

Intermediate Statistics (PY2107 - Experimental Investigation and Analysis of Behaviour)

Description:
This subject introduces and examines the design and implementation of experimental research. Emphasis is on the use of the experiment as an inferential tool to test theory and build an empirical foundation for the science. As such, coverage will include detailed discussion of matters of experimental design and the practical use of statistical procedures. Beginning with the basic designs and using these as building blocks for more complex designs, all major experimental designs commonly used by psychologists will be covered. In parallel with a detailed description of major designs, a comprehensive conceptual description and practical application of appropriate statistical analysis of data collected from each of the designs will also be provided.

Learning Outcomes:

- Provide an appreciation for the richness of information available from different experimental designs;
- Provide the basic information necessary to design and to analyse experiments;
- Provide the necessary skills and understanding necessary to critically evaluate research findings and inferences drawn from experimental data;
- Provide the skills to analyse data using SPSS.

URL (Retrieved 15 April 2015):
https://secure.jcu.edu.au/app/studyfinder/?subject=PY2107

Advanced Statistics (PY3101 - Advanced Behavioural Research Design and Analysis)

Description:
This subject covers research designs that are non-experimental or quasi-experimental in nature. These include methods that are often more appropriate for research in field settings where experiments are neither practical nor sensible. The different types of validity and the benefits and limitations of weighing one type of validity against another will be considered. In addition, some of the most popular and powerful multivariate statistical techniques will also be introduced in lectures and practicals. The statistical material will cover multiple and logistic regression, factor analysis, discriminant analysis and multi-dimensional scaling analysis. The emphasis will be on the conceptual understanding and use of these techniques rather than mathematical arguments and proofs. Practicals will focus on everyday applications of the knowledge you gain from your study of research design.

Learning Outcomes:

- To view research in applied settings in a practical and logical manner;
- To apply the methods of scientific research to answer questions and solve problems in field settings;
- To recognise the strengths and limitations of these methodologies;
- To interpret and critically evaluate the results of applied research;
- To focus on the conceptual understanding of the statistical techniques presented and their application to different research settings;
- Produce a research proposal paying particular attention to the design and analysis components of the proposed study.

URL (Retrieved 15 April 2015):
https://secure.jcu.edu.au/app/studyfinder/?subject=py3101

Appendix 2.1: Overview of the Statistics Anxiety Literature (2003 to 2015)

(a) Quantitative Studies (58 studies)							
No.	Studies	*N*	(% females)	Academic Level	Field of Study	Country	Measure
1	(Baloğlu, 2002)	221	(74.0%)	-	-	USA	STARS
2	(Baloğlu, 2003)	246	(74.4%)	Undergraduates and Graduates	Majority in Social Sciences	USA	STARS
3	(Baloğlu et al., 2011)	223 237	(66.4%) (75.1%)	Undergraduates and Graduates	-	Turkey USA	STARS
4	(Bell, 2001)	99		-	-	USA	STARS
5	(Bell, 2003)	121		-	-	USA	STARS
6	(Bell, 2005)	231		-	-	USA	STARS
7	(Bell, 2008)	66		-	-	USA	STARS
8	(Beurze et al., 2013)	520	(67.0%)	Undergraduates	Medicine	Netherlands	STARS
9	(D. R. Bradley & Wygant, 1998)	42 56	(64.3%) (76.8%)	Undergraduates	Psychology	USA	Varied
10	(Bui & Alfaro, 2011)	104	(73.1%)	-	-	USA	STARS
11	(Chew & Dillon, 2012)	37	(65.0%)	Undergraduates	Psychology	Singapore	STARS
12	(Chew & Dillon, 2014a)	197	(79.2%)	Undergraduates	Psychology	Singapore	Statistical Anxiety Scale & STARS
13	(Chew & Dillon, 2014b)	83	(69.0%)	Undergraduates	Psychology	Singapore	STARS
14	(Chiesi & Primi, 2010)	487	(82.6%)	Undergraduates	Psychology	Italy	STARS
15	(Chiesi et al., 2011)	512 336	(81.0%) (81.5%)	Undergraduates	Psychology	Italy Spain	Statistical Anxiety Scale
16	(Collins & Onwuegbuzie, 2007)	92	(82.2%)	Graduates	-	USA	STARS
17	(Cruise et al., 1985)	1150		-	-	USA	STARS
18	(D'Andrea & Waters, 2002)	17	(94.1%)	Graduates	Education	USA	STARS

19	(Daley & Onwuegbuzie, 1997)	90		Graduates	Varied	USA	STARS
20	(Davis, 2003)	41	(100%)	Graduates	Social Work	USA	STARS
21	(DeVaney, 2010)	120	(80.8%)	Graduates	Varied	USA	STARS
22	(Dunn, 2013)	101	(75.0%)	Graduates	Education	USA	STARS
23	(Earp, 2007)	347 433	(59.9%) (58.7%)	Undergraduates and Graduates	-	USA	Statistics Anxiety Measure
24	(Galli et al., 2008)	442	(83.0%)	-	Psychology	Italy	STARS
25	(Hanna & Dempster, 2009)	52	(78%)	Undergraduates	Psychology	UK	STARS
26	(Hanna et al., 2008)	650	(82.0%)	Undergraduates	Psychology	UK	STARS
27	(Hsiao & Chiang, 2011)	77	(81.0%)	Graduates	Varied	Taiwan	STARS
28	(Jordan et al., 2014)	99	(75.0%)	Undergraduates	Psychology and Nursing	UK	STARS
29	(Keeley et al., 2008)	83	(73.5%)	Undergraduates	Varied	USA	STARS
30	(Kesici et al., 2011)	320	(59.1%)	Undergraduates	Varied	Turkey	STARS
31	(Koh & Zawi, 2014)	141		Graduates	Education	Malaysia	Statistics Anxiety Measure
32	(Lalonde & Gardner, 1993)	91	(79.1%)	Undergraduates	Psychology	-	Varied
33	(Liu et al., 2011)	201		Undergraduates	Education and History	China	STARS
34	(McGrath et al., 2015)	28	(82.1%)	Graduates	Psychology	Canada	STARS
35	(Mji & Onwuegbuzie, 2004)	196	(70.9%)	-	Varied	South Africa	STARS
36	(Nasser, 2004)	162	(96.0%)	-	Education	Israel	STARS
37	(Onwuegbuzie, 1995)	21	(100%)	Graduates	Varied	USA	STARS
38	(Onwuegbuzie, 1999)	225	(81.8%)	Graduates	Education	USA	STARS
39	(Onwuegbuzie, 2000)	225	(80.0%)	Graduates	Varied	USA	STARS
40	(Onwuegbuzie, 2003)	130	(96.5%)	Graduates	Education	USA	STARS
41	(Onwuegbuzie, 2004)	135	(92.6%)	Graduates	Education	USA	STARS
42	(Onwuegbuzie & Seaman, 1995)	26	(80.8%)	Graduates	Varied	USA	STARS

43	(Pan & Tang, 2004)	21 (90.5%)	Graduates	Education	USA	Statistics Anxiety Scale
44	(Papousek et al., 2012)	400 (79.3%) 66 (74.2%) 96 (80.2%)	Undergraduates	Psychology and Education	Austria	STARS
45	(Perepiczka et al., 2011)	166 (81.9%)	Graduates	Education	USA	STARS
46	(Pretorius & Norman, 1992)	337 (58.0%)	Undergraduates	Psychology	South Africa	Statistics Anxiety Scale
47	(Rodarte-Luna & Sherry, 2008)	323 (59.1%)	Undergraduates and Graduates	Psychology	USA	STARS
48	(Ruggeri et al., 2008)	196 (76.2%)	Undergraduates	Psychology	UK	STARS
49	(Schact & Stewart, 1990)	-	Undergraduates	Sociology	USA	Varied
50	(Tremblay et al., 2000)	166 (68.7%)	Undergraduates	Psychology	Canada	Varied
51	(Vigil-Colet et al., 2008)	159 (87.4%)	Undergraduates	Psychology	Spain	Statistical Anxiety Scale
52	(Watson et al., 2002)	69	Graduates	Education	USA	STARS
53	(Watson, Lang, et al., 2003)	69	Graduates	Education	USA	STARS
54	(A. S. Williams, 2010)	76 (72.4%)	Graduates	Varied	USA	STARS
55	(A. S. Williams, 2013)	97 (66.0%)	Graduates	Varied	USA	STARS
56	(A. S. Williams, 2014)	103 (58.3%)	Graduates	Varied	USA	STARS
57	(Zanakis & Valenzi, 1997)	357	Undergraduates	Business	-	Unnamed Instrument
58	(Zeidner, 1991)	431 (72.0%)	-	Social Sciences and Education	Israel	Statistics Anxiety Inventory

(b) Other Studies (7 studies)		
No.	Studies	Remarks
59	(Baloğlu, 1999)	A comparison of mathematics anxiety, statistics anxiety, and general anxiety

60	(Baloğlu, 2004)	Similarities and differences between statistics anxiety and mathematics anxiety
61	(Baloğlu & Zelhart, 2003)	Literature review on statistics anxiety
62	(Onwuegbuzie et al., 1997)	A phenomenological study of the components of statistics anxiety
63	(Onwuegbuzie & Wilson, 2003)	Literature review on statistics anxiety
64	(Schact, 1990)	An evaluation of 12 statistics textbooks
65	(Watson, Kromrey, et al., 2003)	Development of a conceptual model for statistics anxiety

Appendix 3.1: Background Information Form

For each of the following statements mark the one best response. Notice that the response scale changes on each item.

JCU Student ID:	________
JCU Email:	________
JCU Campus:	Townsville / Cairns / Singapore
Nationality:	________
Age (in years):	________
Gender:	Male / Female
Ethnicity:	Caucasian / Chinese / Malay / Indian / Others (please specify): ________
Number of math courses taken:	________

Are you currently enrolled in a statistics course?	Yes / No

If yes:

Statistics course enrolled:	FP0105 / PY2103 / PY2107 / PY3101 / BU1007 / BU2010
No. of attempt(s) on course:	1st attempt / 2nd attempt / 3rd attempt
Expected grade:	N / P / C / D / HD
Number of hours spent outside of class studying statistics per week (in hours):	________
Total number of courses enrolled this trimester:	1 / 2 / 3 / 4

If no:

Statistics course completed (circle all that apply):	FP0105 / PY2103 / PY2107 / PY3101 / BU1007 / BU2010
Total number of courses enrolled this trimester:	1 / 2 / 3 / 4

Appendix 3.2: Statistical Anxiety Rating Scale (STARS)

It should be emphasized that the STARS is not a test and that no grades will be given. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence.

Do not spend too much time with each question as the first impression is generally the best answer.

Describe your anxieties as they currently exist. You may have to project yourself into any situations that you have not encountered before.

Part 1: Please rate the following statements using this 5-point scale. Circle your responses.

1	2	3	4	5
No Anxiety				Strong Anxiety

No.	Item	Scale
1	Studying for an examination in a statistics course	1 2 3 4 5
2	Interpreting the meaning of a table in a journal article	1 2 3 4 5
3	Going to ask my statistics teacher for individual help with material I am having difficulty understanding	1 2 3 4 5
4	Doing the coursework for a statistics course	1 2 3 4 5
5	Making an objective decision based on empirical data	1 2 3 4 5
6	Reading a journal article that includes some statistical analyses	1 2 3 4 5
7	Trying to decide which analysis is appropriate for my research project	1 2 3 4 5
8	Doing an examination in a statistics course	1 2 3 4 5
9	Reading an advertisement for a car which includes figures on miles per gallon, depreciation, etc	1 2 3 4 5
10	Walking into the room to take a statistics test	1 2 3 4 5
11	Interpreting the meaning of a probability value once I have found it	1 2 3 4 5
12	Arranging to have a body of data put into the computer	1 2 3 4 5
13	Finding that another student in class got a different answer than I did to a statistical problem	1 2 3 4 5
14	Determining whether to reject or retain the null hypothesis	1 2 3 4 5
15	Waking up in the morning on the day of a statistics test	1 2 3 4 5
16	Asking one of your lecturers for help in understanding a printout	1 2 3 4 5
17	Trying to understand the odds in a lottery	1 2 3 4 5
18	Watching a student search through a load of computer printouts from his/her research	1 2 3 4 5
19	Asking someone in the computer lab for help in understanding a printout	1 2 3 4 5
20	Trying to understand the statistical analyses described in the abstract of a journal article	1 2 3 4 5
21	Enrolling in a statistics course	1 2 3 4 5
22	Going over a final examination in statistics after it has been	1 2 3 4 5

	marked	
23	Asking a fellow student for help in understanding a printout	1 2 3 4 5

Part 2: Please rate the following statements using this 5-point scale. Circle your responses.

1	2	3	4	5
Strongly Disagree				Strongly Agree

No.	Item	Scale
24	I am a subjective person, so the objectivity of statistics is inappropriate for me	1 2 3 4 5
25	I have not done maths for a long time. I know I will have problems getting through statistics	1 2 3 4 5
26	I wonder why I have to do all these things in statistics when in actual life I will never use them	1 2 3 4 5
27	Statistics is worthless to me since it is empirical and my area of specialization is abstract	1 2 3 4 5
28	Statistics takes more time than it is worth	1 2 3 4 5
29	I feel statistics is a waste	1 2 3 4 5
30	Statistics teachers are so abstract they seem inhuman	1 2 3 4 5
31	I cannot even understand secondary school maths; how can I possibly do statistics?	1 2 3 4 5
32	Most statistics teachers are not human	1 2 3 4 5
33	I lived this long without knowing statistics, why should I learn it now?	1 2 3 4 5
34	Since I have never enjoyed maths I do not see how I can enjoy statistics	1 2 3 4 5
35	I do not want to learn to like statistics	1 2 3 4 5
36	Statistics is for people who have a natural leaning toward maths	1 2 3 4 5
37	Statistics is a pain I could do without	1 2 3 4 5
38	I do not have enough brains to get through statistics	1 2 3 4 5
39	I could enjoy statistics if it were not so mathematical	1 2 3 4 5
40	I wish the statistics requirement would be removed from my academic program	1 2 3 4 5
41	I do not understand why someone in my field needs statistics	1 2 3 4 5
42	I do not see why I have to fill my head with statistics. It will have no use in my career	1 2 3 4 5
43	Statistics teachers speak a different language	1 2 3 4 5
44	Statisticians are more number oriented than they are people oriented	1 2 3 4 5
45	I cannot tell you why, but I just do not like statistics	1 2 3 4 5
46	Statistics teachers talk so fast you cannot logically follow them	1 2 3 4 5
47	Statistical figures are not fit for human consumption	1 2 3 4 5
48	Statistics is not really bad. It is just too mathematical	1 2 3 4 5
49	Affective skills are so important in my (future) profession that I do not want to clutter my thinking with something as cognitive	1 2 3 4 5

	as statistics					
50	I am never going to use statistics so why should I have to take it?	1	2	3	4	5
51	I am too slow in my thinking to get through statistics	1	2	3	4	5

Appendix 3.3: Statistical Anxiety Scale

It should be emphasized that the SAS is <u>not</u> a test and that no grades will be given. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence.

Do not spend too much time with each question as the first impression is generally the best answer.

Describe your anxieties as they currently exist. You may have to project yourself into any situations that you have not encountered before.

Please rate the following statements using this 5-point scale. Circle your responses.

1	2	3	4	5
No Anxiety				Considerable Anxiety

No.	Item	Scale				
1	Studying for an examination in a statistics course	1	2	3	4	5
2	Interpreting the meaning of a table in a journal article	1	2	3	4	5
3	Going to ask my statistics teacher for individual help with material I am having difficulty understanding	1	2	3	4	5
4	Realizing the day before an exam that I cannot do some problems that I thought were going to be easy	1	2	3	4	5
5	Asking a private teacher to explain a topic that I have not understood at all	1	2	3	4	5
6	Reading a journal article that includes some statistical analyses	1	2	3	4	5
7	Asking the teacher how to use a probability table	1	2	3	4	5
8	Trying to understand a mathematical demonstration	1	2	3	4	5
9	Doing the final examination in a statistics course	1	2	3	4	5
10	Reading an advertisement for an automobile which includes figures on gas mileage, compliance with population regulations, etc	1	2	3	4	5
11	Walking into the classroom to take a statistics test	1	2	3	4	5
12	Asking the teacher about how to do an exercise	1	2	3	4	5
13	Getting to the day before an exam without having had time to revise the syllabus	1	2	3	4	5
14	Waking up in the morning on the day of a statistics test	1	2	3	4	5
15	Realizing, just before you go into the exam, that I have not prepared a particular exercise	1	2	3	4	5
16	Copying a mathematical demonstration from the blackboard while the teacher is explaining it	1	2	3	4	5
17	Asking one of your teachers for help in understanding a printout	1	2	3	4	5
18	Trying to understand the odds in a lottery	1	2	3	4	5
19	Seeing a classmate carefully studying the results table of a problem he has solved	1	2	3	4	5

20	Going to a statistics exam without having had enough time to revise	1	2	3	4	5
21	Asking a teacher for help when trying to interpret a results table	1	2	3	4	5
22	Trying to understand the statistical analyses described in the abstract of a journal article	1	2	3	4	5
23	Going to the teacher’s office to ask questions	1	2	3	4	5
24	Asking a private teacher to tell me how to do an exercise	1	2	3	4	5

Appendix 3.4: Attitudes toward Statistics scale

For each of the following statements mark the rating category that most indicates how you currently feel about the statement. Please respond to all of the items.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

No.	Item	Scale				
1	I feel that statistics will be useful to me in my profession	1	2	3	4	5
2	The thought of being enrolled in a statistics course makes me nervous	1	2	3	4	5
3	A good researcher must have training in statistics	1	2	3	4	5
4	Statistics seems very mysterious to me	1	2	3	4	5
5	Most people would benefit from taking a statistics course	1	2	3	4	5
6	I have difficulty seeing how statistics relates to my field of study	1	2	3	4	5
7	I see being enrolled in a statistics course as a very unpleasant experience	1	2	3	4	5
8	I would like to continue my statistical training in an advanced course	1	2	3	4	5
9	Statistics will be useful to me in comparing the relative merits of different objects, methods, programs, etc.	1	2	3	4	5
10	Statistics is not really very useful because it tells us what we already know anyway	1	2	3	4	5
11	Statistical training is relevant to my performance in my field of study	1	2	3	4	5
12	I wish that I could have avoided taking my statistics course	1	2	3	4	5
13	Statistics is a worthwhile part of my professional training	1	2	3	4	5
14	Statistics is too math oriented to be of much use to me in the future	1	2	3	4	5
15	I get upset at the thought of enrolling in another statistics course	1	2	3	4	5
16	Statistical analysis is best left to the "experts" and should not be part of a lay professional's job	1	2	3	4	5
17	Statistics is an inseparable aspect of scientific research	1	2	3	4	5
18	I feel intimidated when I have to deal with mathematical formulas	1	2	3	4	5
19	I am excited at the prospect of actually using statistics in my job	1	2	3	4	5
20	Studying statistics is a waste of time	1	2	3	4	5
21	My statistical training will help me better understand the research being done in my field of study	1	2	3	4	5
22	One becomes a more effective "consumer" of research findings if one has some training in statistics	1	2	3	4	5
23	Training in statistics makes for a more well-rounded professional experience	1	2	3	4	5

24	Statistical thinking can play a useful role in everyday life	1	2	3	4	5
25	Dealing with numbers makes me uneasy	1	2	3	4	5
26	I feel that statistics should be required early in one's professional training	1	2	3	4	5
27	Statistics is too complicated for me to use effectively	1	2	3	4	5
28	Statistical training is not really useful for most professionals	1	2	3	4	5
29	Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write	1	2	3	4	5

Appendix 3.5: JCU's Human Research Ethics Committee Approval Letter

This administrative form has been removed

Appendix 5.1: Stimuli Pairs for Experiments 1 and 2

Words (36 Pairs)		**Symbols (12 Pairs)**	
Statistics-Related (Threatening)	**Neutral**	**Statistics-Related (Threatening)**	**Neutral**
Statistics	Furniture	$\bar{y}$	%
Error	Brief	σ	*
Variable	Initial	θ	)
Statistical	Preliminary	H_0	_
Factor	Beyond	H_1	‘
Estimate	Telephone	s_p^2	{
Calculation	Astronomer	$\bar{D}$	]
Analysis	Character	SS	}
Analyze	Jacket	df	\
*Parameter	Mythology	p	/
Quasi	Filed	$\hat{y}$	:
Histogram	Signature	R^2	=
Skewness	Textured		
Kurtosis	Fetching		
Median	League		
Variance	Feathers		
z-score	t-shirt		
Probability	Connections		
Alpha	Inner		
Beta	Note		
Power	Check		
t-test	e-mail		
Matched	Bridges		
Estimation	Transition		
ANOVA	AFAIK		
F-ratio	X-factor		
Posthoc	Keyhole		
Pairwise	Shearing		
Tukey	Confer		
Factorial	Decanting		
Coefficient	Centerpiece		
Regression	Everything		
Residual	Hallmark		
Chi-square	Pre-school		
SPSS	ASAP		
p-value	g-shock		

*Statistics-related words listed from here onwards are not found in the frequency dictionary (Davies & Gardner, 2010). Hence, most of the neutral words for these words are adopted from (MacLeod et al., 2002) and matched for length instead.

Appendix 5.2: Social Desirability Scale

This instrument will appear to participants as a ‘Personal Reaction Inventory’.

Listed below are a number of statements concerning personal attitudes and traits. Read each item and decide whether the statement is true or false as it pertains to you personally. It’s best to go with your first judgment and not spend too long mulling over any one question.

No.	Item	Scale
1	Before voting I thoroughly investigate the qualifications of all the candidates	True / False
2	I never hesitate to go out of my way to help someone in trouble	True / False
3	It is sometimes hard for me to go on with my work if I am not encouraged	True / False
4	I have never intensely disliked anyone.	True / False
5	On occasions I have had doubts about my ability to succeed in life	True / False
6	I sometimes feel resentful when I don’t get my way	True / False
7	I am always careful about my manner of dress	True / False
8	My table manners at home are as good as when I eat out in a restaurant	True / False
9	If I could get into a movie without paying and be sure I was not seen I would probably do it	True / False
10	On a few occasions, I have given up something because I thought too little of my ability	True / False
11	I like to gossip at times	True / False
12	There have been times when I felt like rebelling against people in authority even though I knew they were right	True / False
13	No matter who I’m talking to, I’m always a good listener	True / False
14	I can remember “playing sick” to get out of something	True / False
15	There have been occasions when I have taken advantage of someone	True / False
16	I’m always willing to admit it when I make a mistake	True / False
17	I always try to practice what I preach	True / False
18	I don’t find it particularly difficult to get along with loudmouthed, obnoxious people	True / False
19	I sometimes try to get even rather than forgive and forget	True / False
20	When I don’t know something I don’t mind at all admitting it	True / False
21	I am always courteous, even to people who are disagreeable	True / False
22	At times I have really insisted on having things my own way	True / False
23	There have been occasions when I felt like smashing things	True / False
24	I would never think of letting someone else be punished for my wrong-doings	True / False
25	I never resent being asked to return a favor	True / False
26	I have never been irked when people expressed ideas very different from my own	True / False
27	I never make a long trip without checking the safety of my car	True / False
28	There have been times when I was quite jealous of the good fortune of others	True / False
29	I have almost never felt the urge to tell someone off	True / False
30	I am sometimes irritated by people who ask favors of me	True / False

31	I have never felt that I was punished without cause	True / False
32	I sometimes think when people have a misfortune they only got what they deserved	True / False
33	I have never deliberately said something that hurt someone’s feelings	True / False

Appendix 5.3: JCU's Human Research Ethics Committee Approval Letter

This administrative form
has been removed

Appendix 5.4: Assumption Tests for Multiple Regression (Experiment 1)

A series of four multiple regressions was used to examine the ability of the three factors of statistics anxiety (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help) to predict each of the four TBI in Experiment 1. Assumption tests were conducted to ensure no violation of multicollinearity, normality, linearity, homoscedasticity, and independence of residuals. The results of these tests are presented as follows.

1) Multicollinearity

Collinearity Diagnostics and Intercorrelations between the Three Factors of Statistics Anxiety

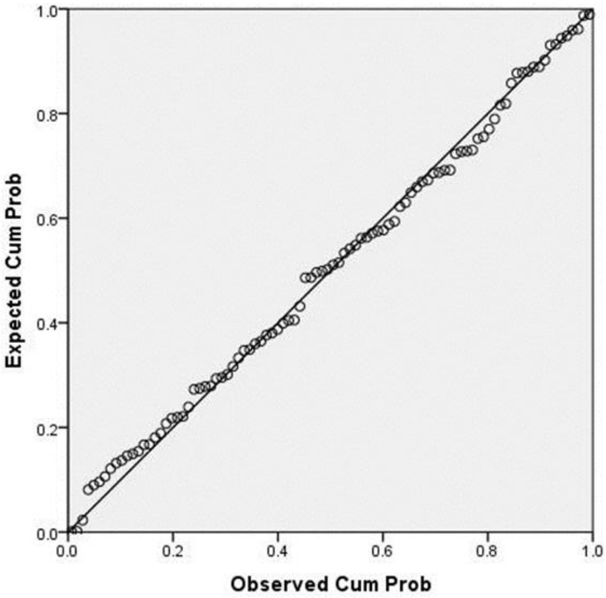
	1	2	3
1. Interpretation Anxiety	-		
2. Test and Class Anxiety	.63*	-	
3. Fear of Asking for Help	.43*	.56*	-
Tolerance	.59	.50	.68
Variance Inflation Factor	1.69	2.00	1.48

* $p < .01$

2) Outliers, normality, linearity, homoscedasticity, and independence of residuals

DV: TBI for words (Emotional Stroop task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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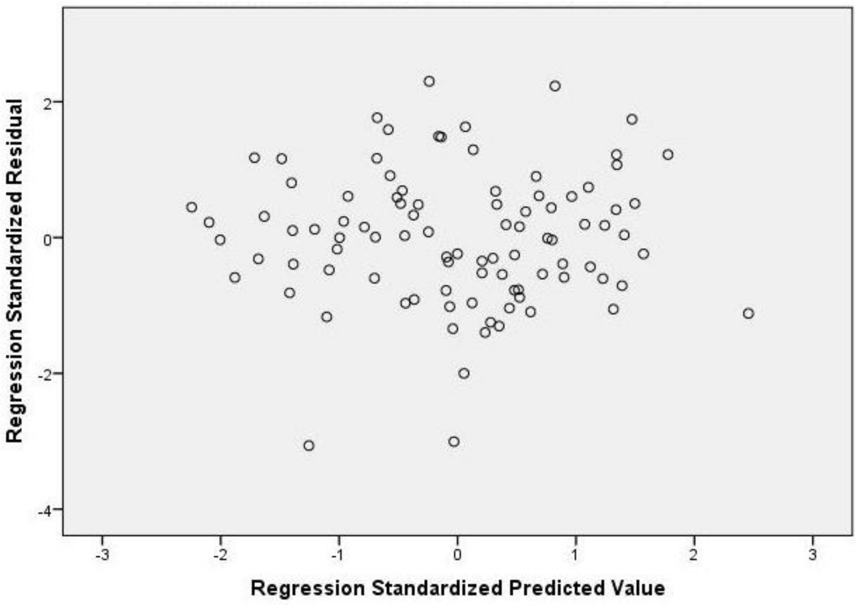
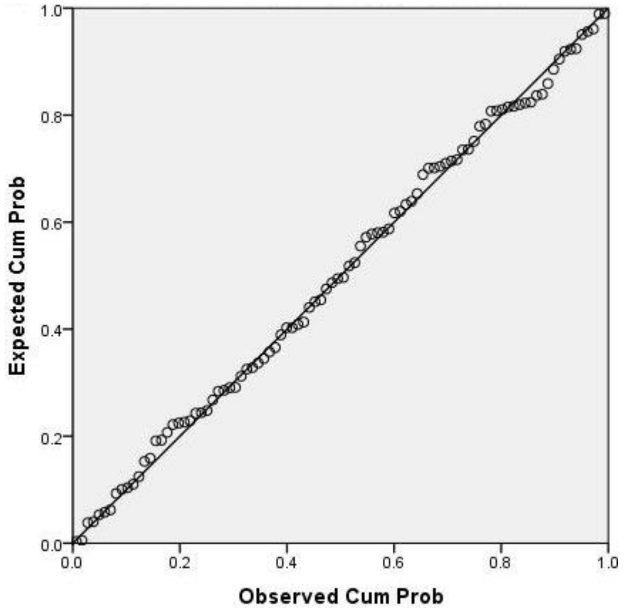


Mahalanobis Distance and Cook's Distance

	Obtained Value	Critical Value
Mahalanobis Distance	11.60	16.27 (3 Predictors)
Cook's Distance	.10	1

DV: TBI for symbols (Emotional Stroop task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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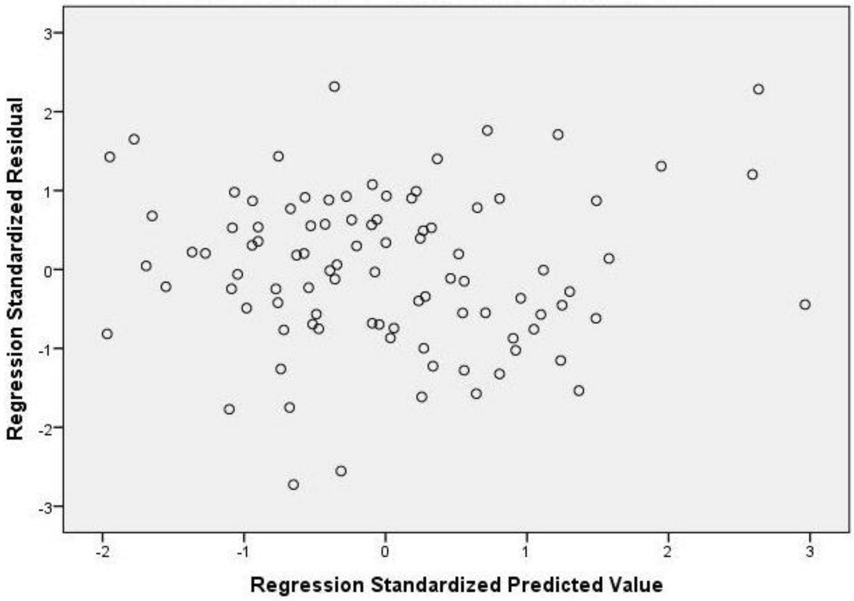
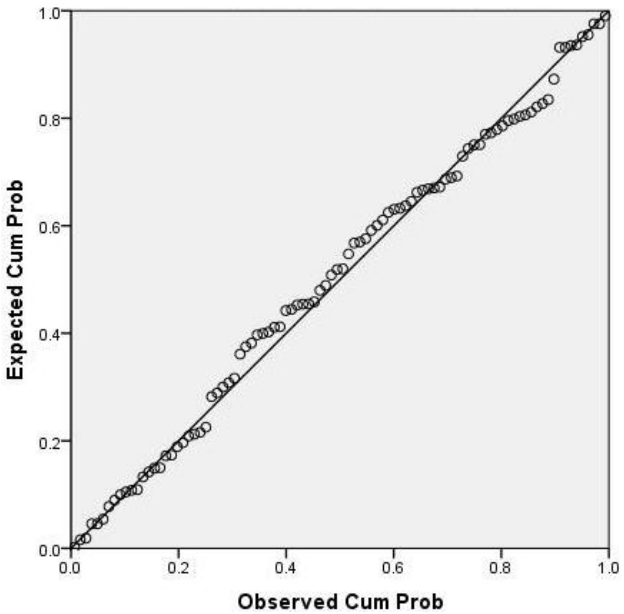


Mahalanobis Distance and Cook's Distance

	Obtained Value	Critical Value
Mahalanobis Distance	11.60	16.27 (3 Predictors)
Cook's Distance	.14	1

DV: TBI for words (Dot probe task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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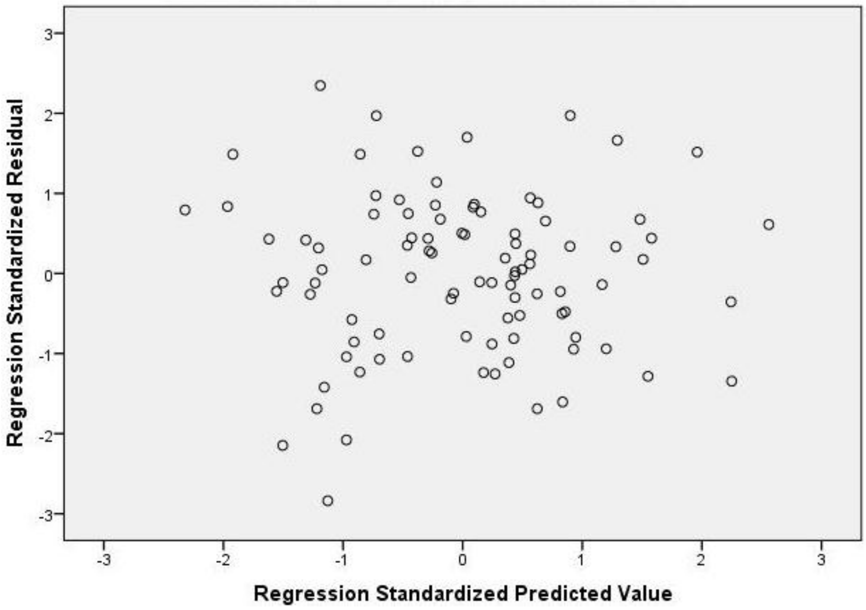
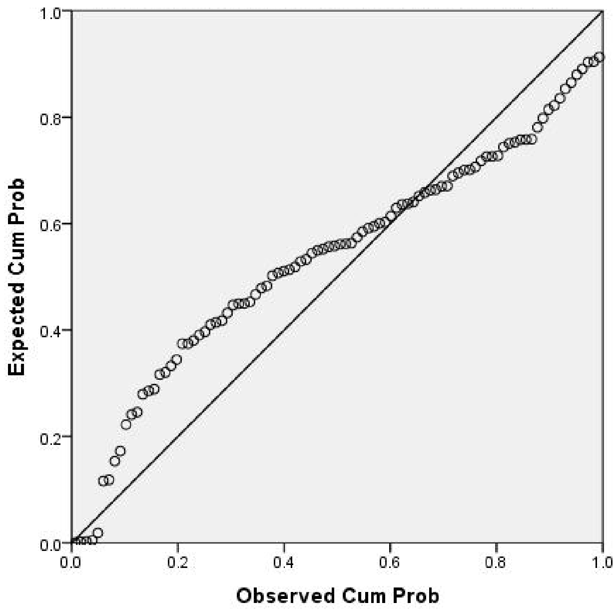


Mahalanobis Distance and Cook's Distance

	Obtained Value	Critical Value
Mahalanobis Distance	11.60	16.27 (3 Predictors)
Cook's Distance	.19	1

DV: TBI for symbols (Dot probe task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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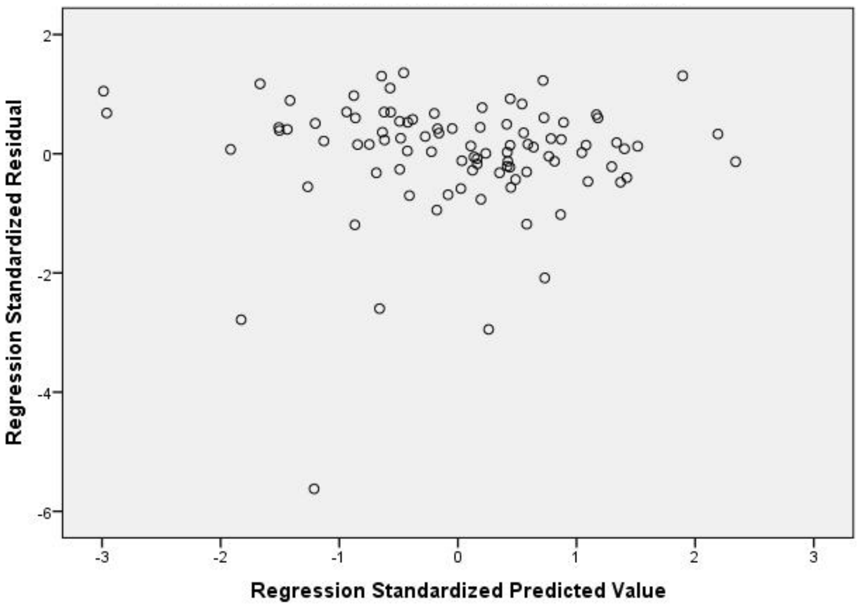


Mahalanobis Distance and Cook's Distance

	Obtained Value	Critical Value
Mahalanobis Distance	11.60	16.27 (3 Predictors)
Cook's Distance	.30	1

Appendix 6.1: Assumption Tests for Multiple Regression (Experiment 2)

A series of four multiple regressions was used to examine the ability of the three factors of statistics anxiety (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help) to predict each of the four TBI in Experiment 2. Assumption tests were conducted to ensure no violation of multicollinearity, normality, linearity, homoscedasticity, and independence of residuals. The results of these tests are presented as follows.

1) Multicollinearity

Collinearity Diagnostics and Intercorrelations between the Three Factors of Statistics Anxiety

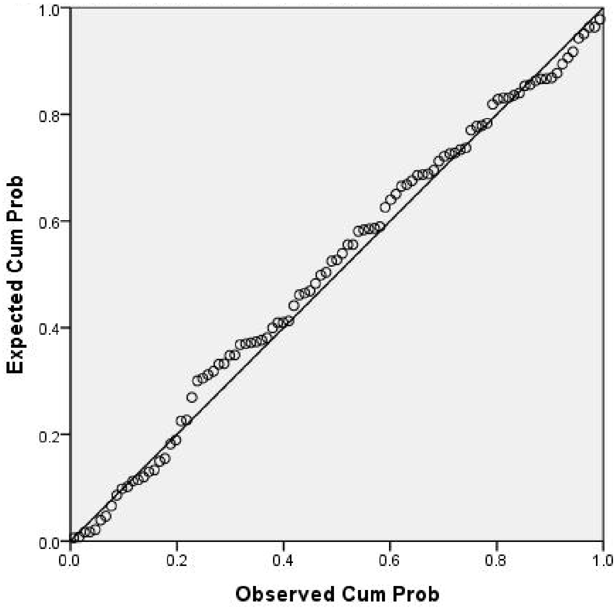
	1	2	3
1. Interpretation Anxiety	-		
2. Test and Class Anxiety	.71*	-	
3. Fear of Asking for Help	.57*	46*	-
Tolerance	.43	.50	.67
Variance Inflation Factor	2.34	2.01	1.50

* $p < .01$

2) Outliers, normality, linearity, homoscedasticity, and independence of residuals

DV: TBI for words (Emotional Stroop task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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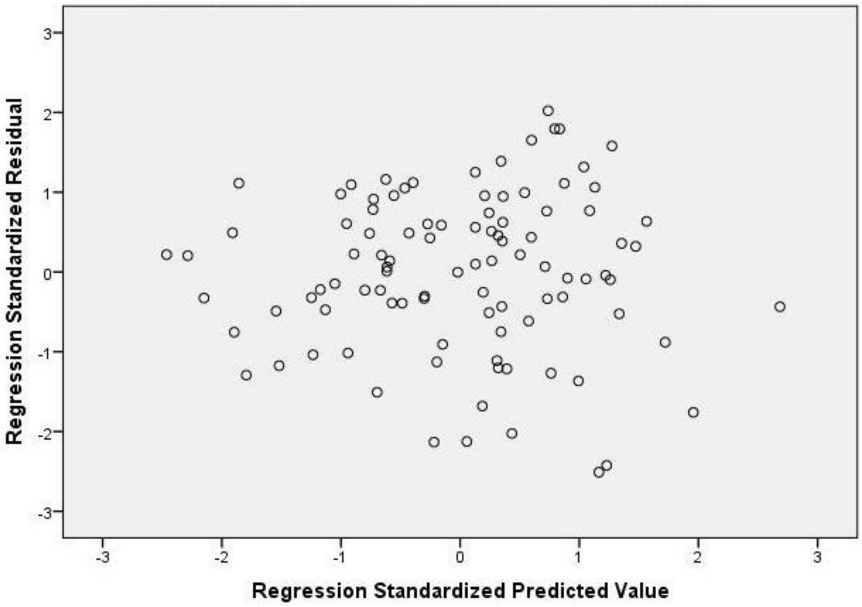
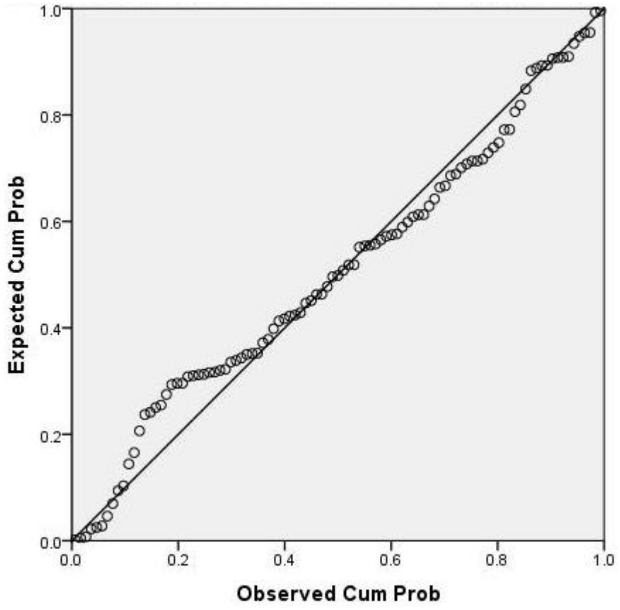


Mahalanobis Distance and Cook's Distance

	Obtained Value	Critical Value
Mahalanobis Distance	13.91	16.27 (3 Predictors)
Cook's Distance	.071	1

DV: TBI for symbols (Emotional Stroop task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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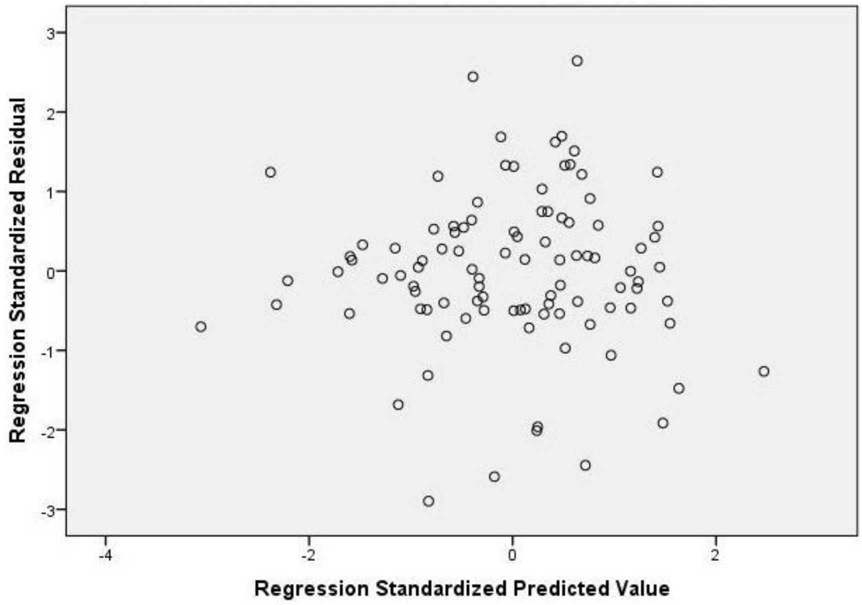
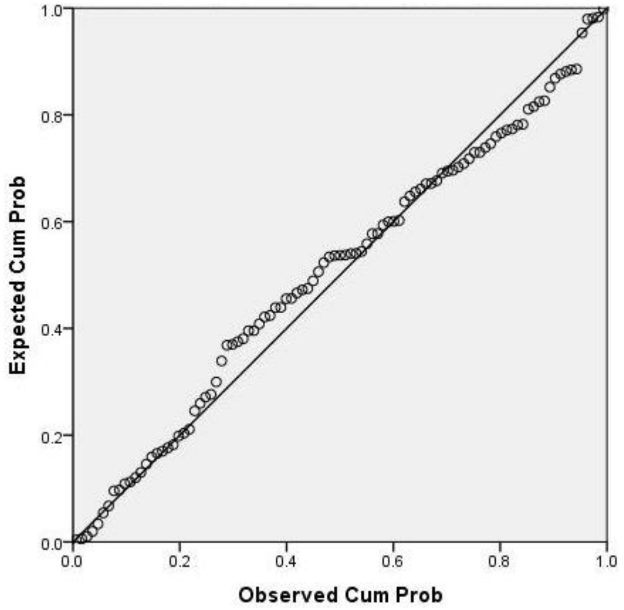


Mahalanobis Distance and Cook's Distance

	Obtained Value	Critical Value
Mahalanobis Distance	13.91	16.27 (3 Predictors)
Cook's Distance	.09	1

DV: TBI for words (Dot probe task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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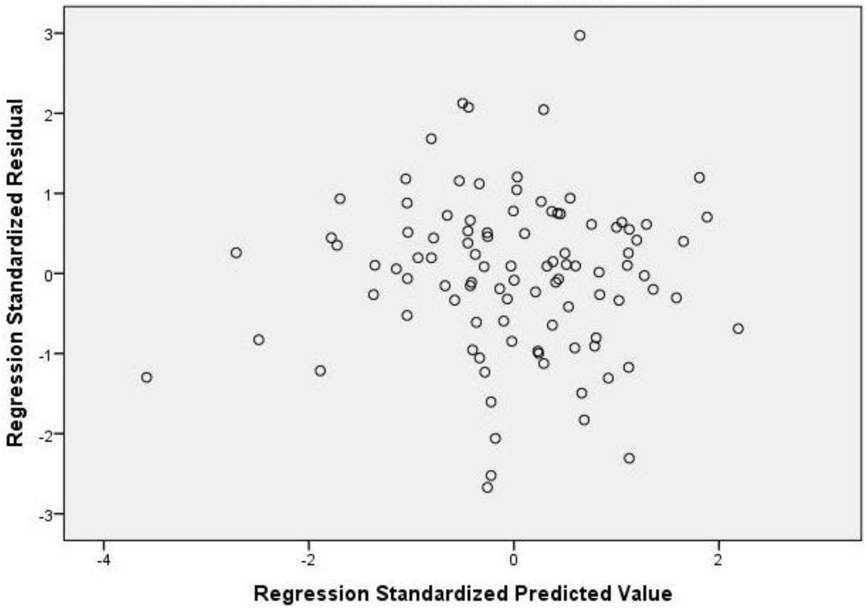
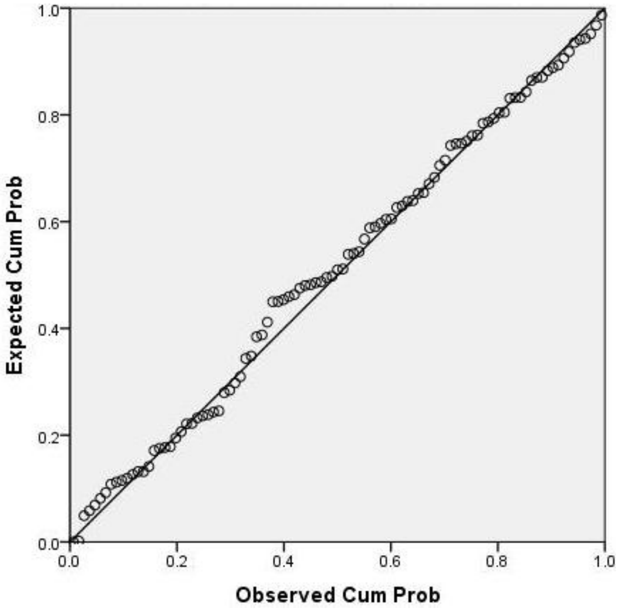


Mahalanobis Distance and Cook's Distance

	Obtained Value	Critical Value
Mahalanobis Distance	13.91	16.27 (3 Predictors)
Cook's Distance	.09	1

DV: TBI for symbols (Dot probe task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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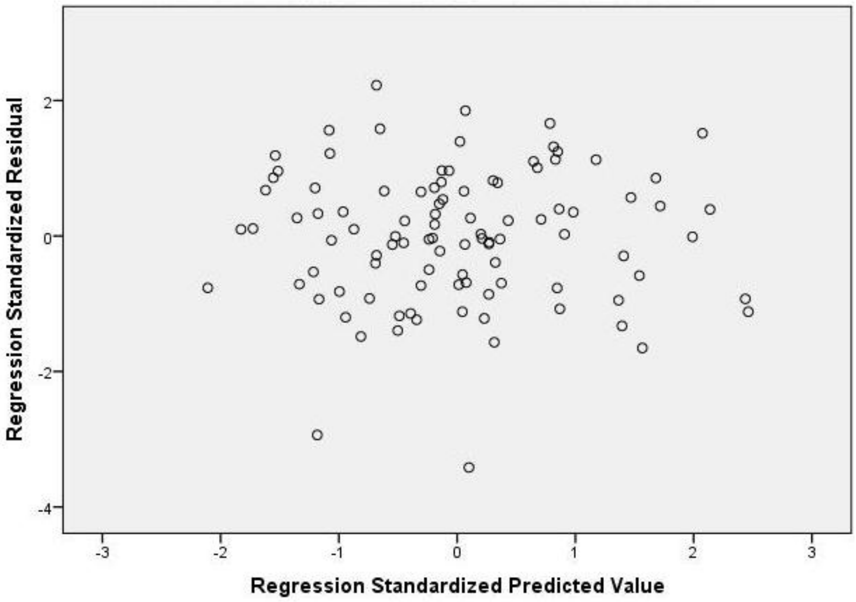


Mahalanobis Distance and Cook's Distance

	Obtained Value	Critical Value
Mahalanobis Distance	13.91	16.27 (3 Predictors)
Cook's Distance	.071	1

Appendix 7.1: Stimuli Pairs for Experiment 3

Words relevant to Interpretation Anxiety (14 Pairs)*	
Threatening	**Neutral**
Discouraged	Connection
Afraid	Detail
Worthless	Batteries
Hopeless	Feathers
Inadequate	Transition
Apprehension	Instrumental
Fear	Note
Worry	Inner
Distress	Creature
Inferior	Shearing
Worried	Context
Scared	Planet
Stress	Cities
Mistaken	Expanded

*Threat and Neutral word pairs adopted from (MacLeod et al., 2002).

Words relevant to Test and Class Anxiety (12 Pairs)*	
Threatening	**Neutral**
Stupidity	Framework
Disgraced	Optimism
Incompetent	Conversation
Failure	Careful
Inferior	Scholarly
Test	Proficient
Inept	Accomplishment
Discredited	Achievement
Inadequate	Fortunate
Careless	Prestige
Unsuccessful	Merit
Examination	Praiseworthy

*Threat and Neutral word pairs adopted from (MacLeod & Rutherford, 1992).

Words relevant to Fear of Asking for Help (24 Pairs)*	
Threatening	**Neutral**
Despised	Cruise
Fail	Emblem
Hostile	Fountain
Insult	Fringe
Lonely	Inactive
Pathetic	Leaf
Persecuted	Scarf
Unloved	Wardrobe
Immature	Carpet
Inept	Cherry
Intimidated	Gravy
Mistake	Opera
Offended	Pear
Scorn	Surplus
Stupid	Terrace
Useless	Violet
Criticism	Bath
Foolish	Emerge
Humiliated	Marble
Indecisive	Predict
Inferior	Purchase
Ridicule	Shampoo
Silly	Shower
Worthless	Threshold

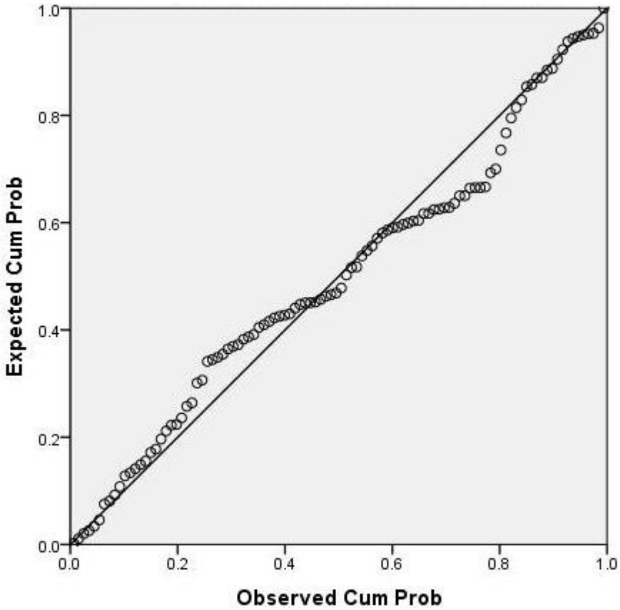
*Threat and Neutral word pairs adopted from (Mathews et al., 1989).

Appendix 7.2: Assumption Tests for Simple Linear Regression (Experiment 3)

A series of six simple linear regressions was used to examine the ability of the three factors of statistics anxiety (Interpretation Anxiety, Test and Class Anxiety, and Fear of Asking for Help) to predict the TBI of their relevant stimuli in Experiment 3. Assumption tests were conducted to ensure no violation of linearity, homoscedasticity, and independence of residuals. The results of these tests are presented as follows.

DV: TBI for Ego-threat words (Emotional Stroop task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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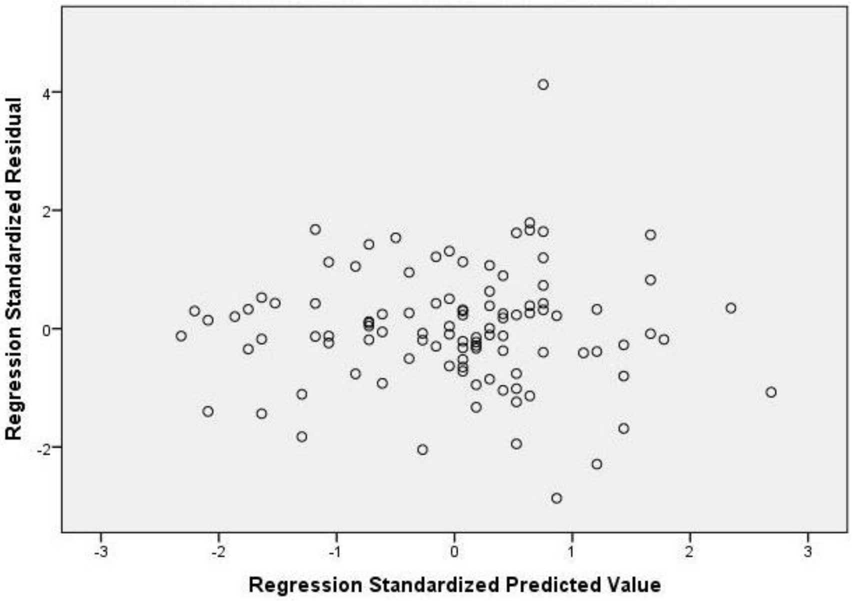
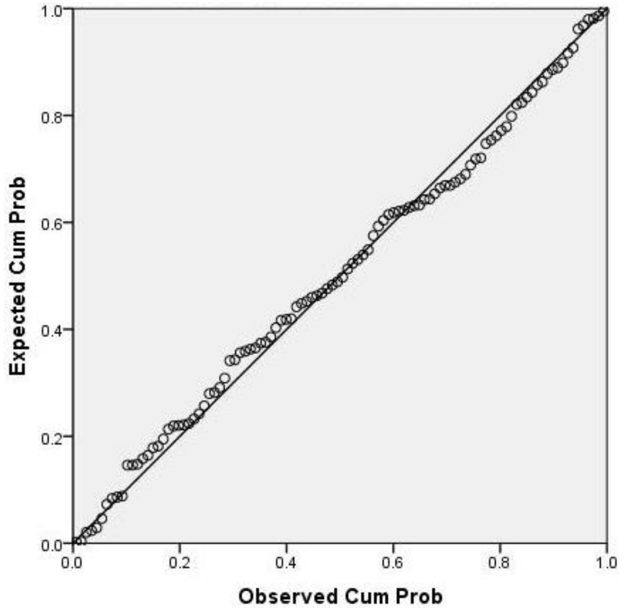


Cook's Distance

	Obtained Value	Critical Value
Cook's Distance	.13	1

DV: TBI for Examination-related words (Emotional Stroop task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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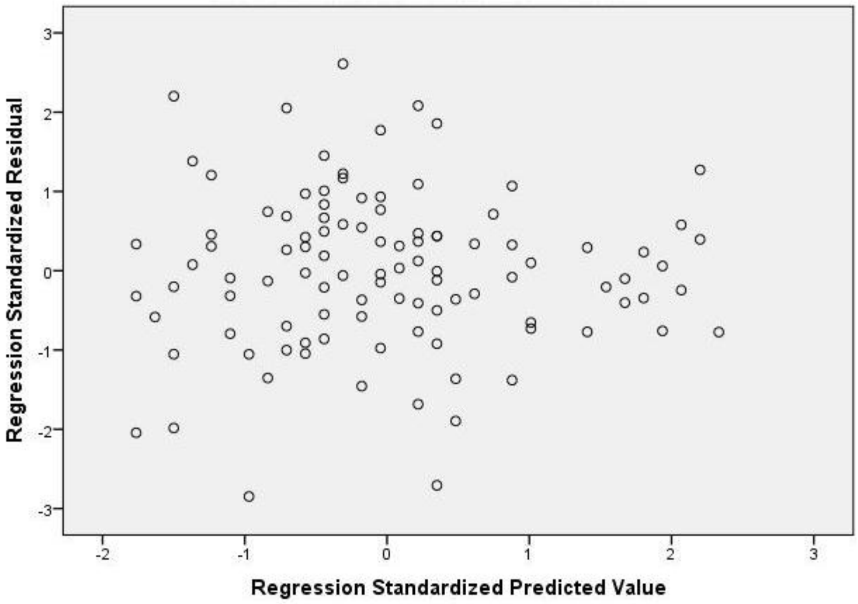
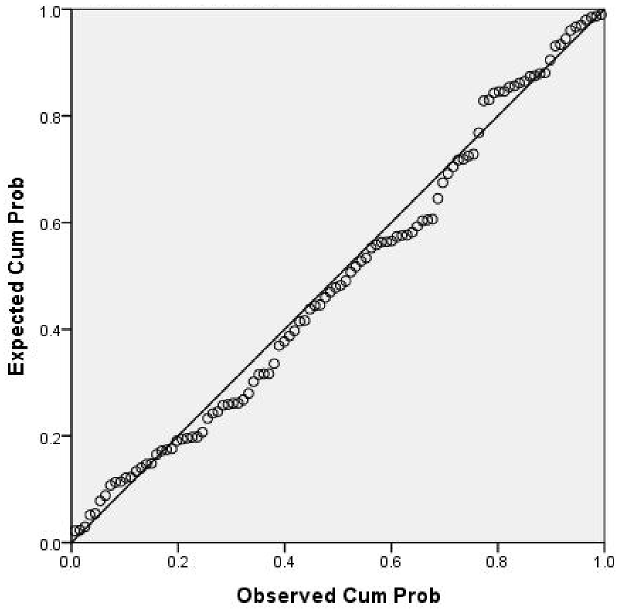


Cook's Distance

	Obtained Value	Critical Value
Cook's Distance	.09	1

DV: TBI for Social Anxiety words (Emotional Stroop task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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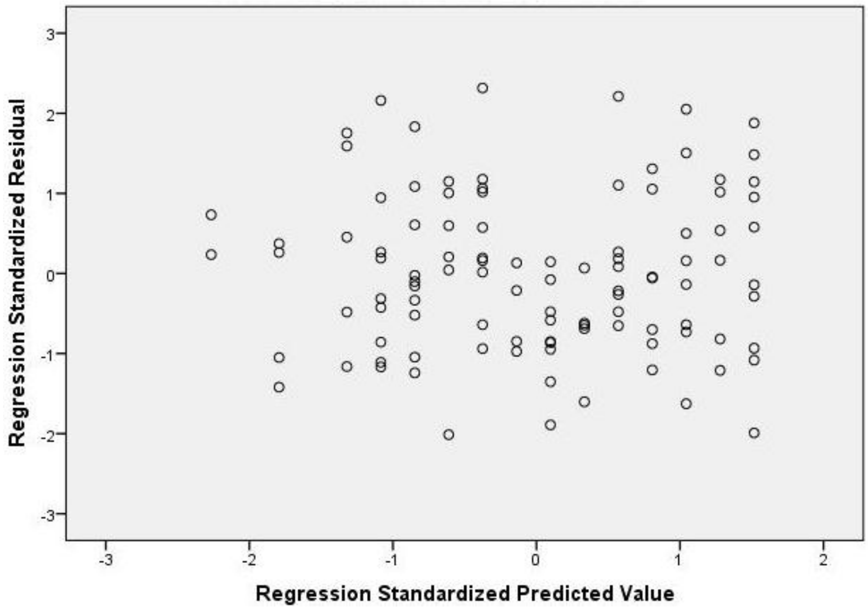
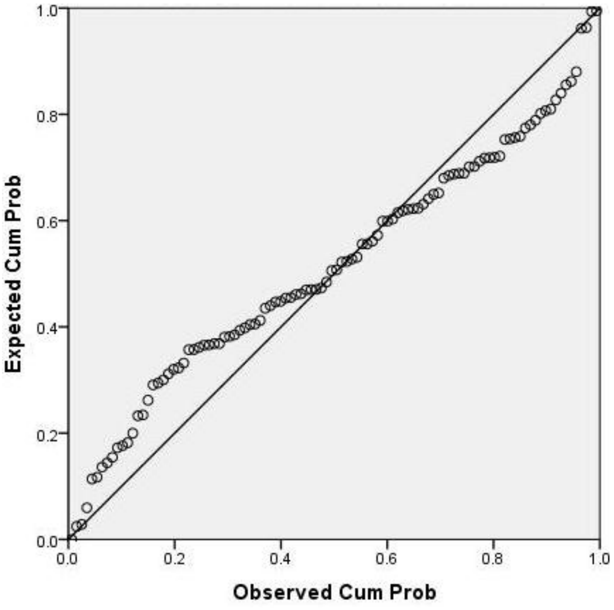


Cook's Distance

	Obtained Value	Critical Value
Cook's Distance	.07	1

DV: TBI for Ego-threat words (Dot probe task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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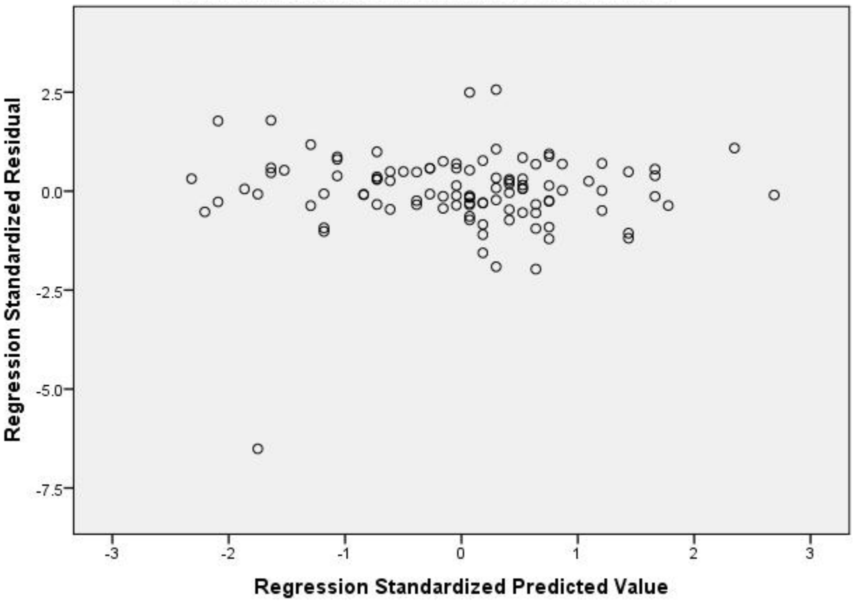
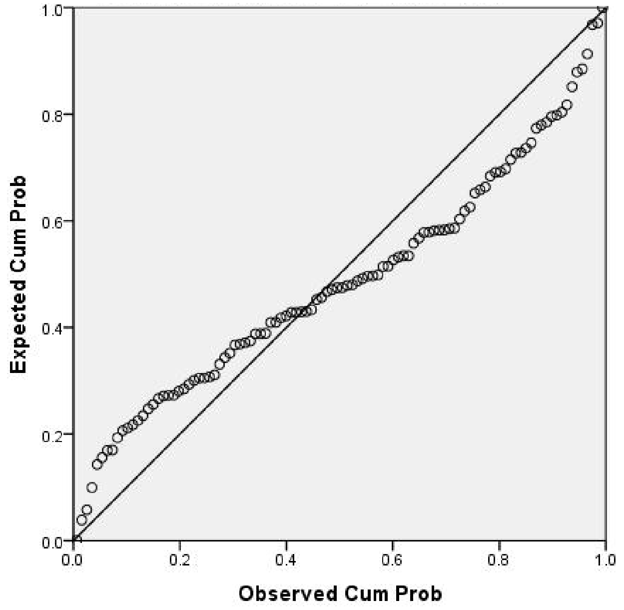


Cook's Distance

	Obtained Value	Critical Value
Cook's Distance	.90	1

DV: TBI for Examination-related words (Dot probe task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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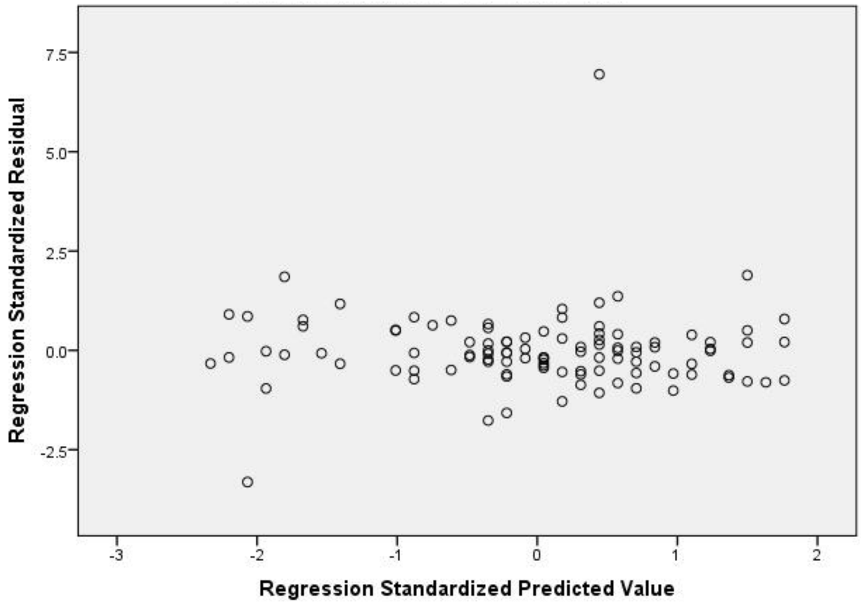
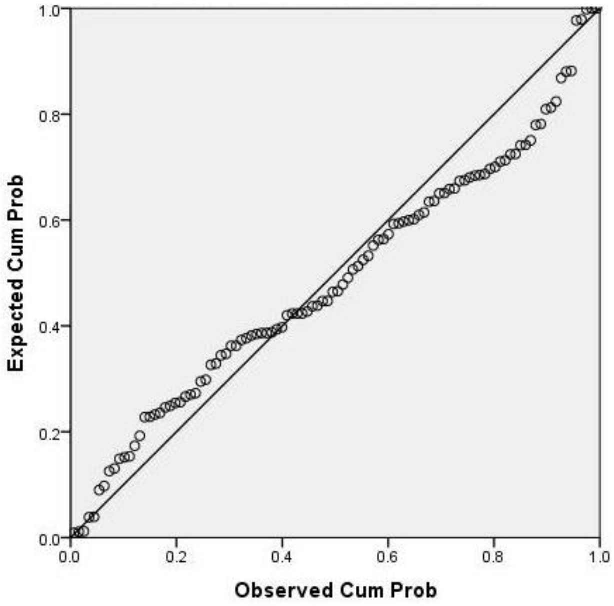


Cook's Distance

	Obtained Value	Critical Value
Cook's Distance	.31	1

DV: TBI for Social Anxiety words (Dot probe task)

Normal Probability Plot (P-P) of the Regression Standardised Residual



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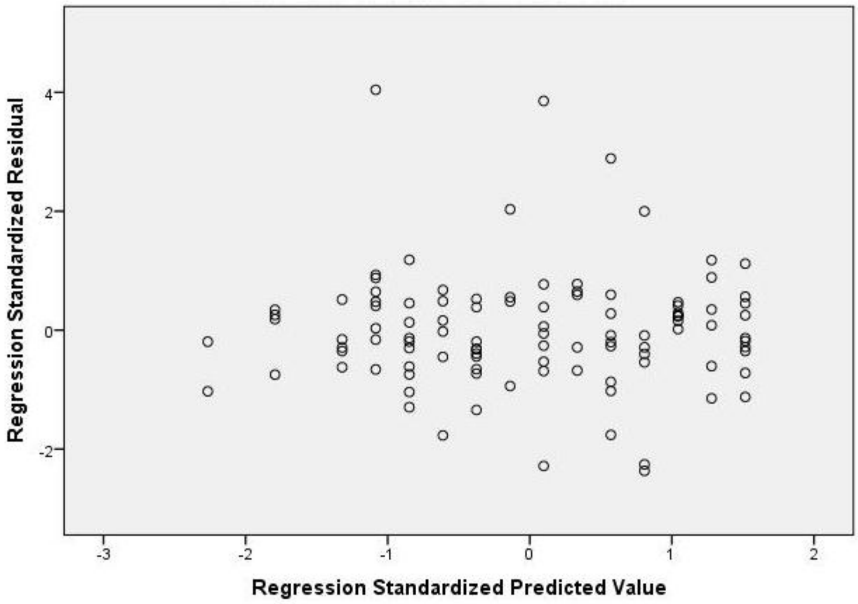

Cook's Distance

	Obtained Value	Critical Value
Cook's Distance	.18	1