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ATTENTIONAL BIAS: A METHODOLOGICAL REVIEW

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Abstract
The high prevalence rate and associated costs of anxiety disorders have resulted in increasing research attention on the role of attentional bias in anxiety. Although seven literature reviews and meta-analyses are devoted to attentional bias, none of them consider the methodological aspects of the studies. This article reviews the literature to provide a methodological user guide for researchers. First, we describe common reaction time (RT) tasks and review the evidence for attentional bias. Second, we evaluate the methods of studying attentional bias and make recommendations to address the following limitations: 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.

Keywords: attentional bias, methodological review, emotional Stroop task, dot probe task

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 USD46.6 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 EUR546 to EUR1628 (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, increasing research attention has been directed to the role of attentional biases in anxiety. Indeed, at least eight literature reviews including two meta-analyses have been devoted to the topic (see Table 1). To minimize overlaps in content, the purpose of this paper is to provide a methodological review of the attentional bias literature with the goal of providing a user guide for researchers. This paper has two sections. The first section provides an overview of relevant cognitive theories, a description of reaction time (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 analyzing attentional bias by addressing several methodological limitations.

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). Despite the existence of several cognitive theories (Eysenck, Derakshan, Santos, & Calvo, 2007; Öhman, 1993) and models (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van IJzendoorn, 2007; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Wells & Matthews, 1994; Willams, Watts, MacLeod, & Mathews, 1988) explaining attention, studies on attentional bias have been primarily motivated by Beck’s schema theory (Beck & Clark, 1988, 1997; Beck, 1976) and Bower’s network theory (1981, 1987).

Table 1

ISSN 1512-1801

Summary of Literature Reviews and Meta-Analyses on Attentional Bias

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

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.

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 (Williams, Mathews, & MacLeod, 1996), and the dot probe task (MacLeod, Mathews, & Tata, 1986). Among these tasks, the emotional Stroop task and the dot probe task are the most popular and are the focus of this review.

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 color 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 color. 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 center 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 color of the word into a microphone (e.g., Constans, McCloskey, Vasterling, Brailey, & Mathews, 2004) or by pressing a key that corresponds to the color 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

ISSN 1512-1801

interpretation has been disputed. Among 32 emotional Stroop task studies, the threatening words used were found to be significantly longer in length, lower in 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).

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 center 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 1). The probe stimulus replaces the threatening stimuli in *congruent* trials and the neutral stimuli in *incongruent* trials (see Figure 2).

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, Soong, Rutherford, & Campbell, 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.

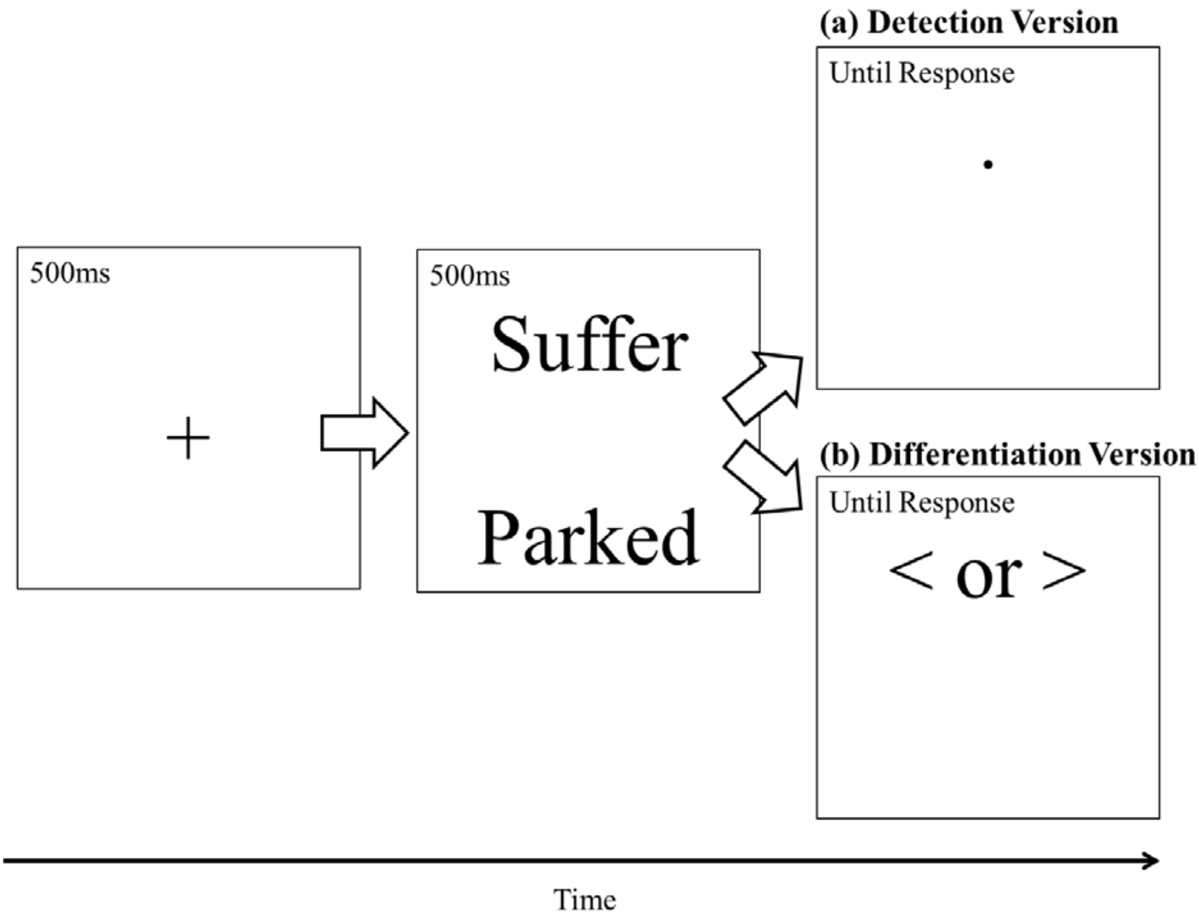

Figure 1. A single trial of the (a) detection version and the (b) differentiation version of the dot probe task on the computer. Stimuli adapted from MacLeod, Rutherford, Campbell, Ebsworthy,

ISSN 1512-1801

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).

The dot probe task has one major advantage over the emotional Stroop task. Due to the use of color-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 (Bradley, Mogg, & Millar, 2000). Although words remain the prevailing stimuli, some studies have used faces (e.g., sad, angry, and happy faces) (Cooper & Langton, 2006; Gotlib, Krasnoperova, Yue, & Joormann, 2004) or pictures (e.g., photographs of corpses, weapons, etc.) (Elsesser, Sartory, & Tackenberg, 2004; Yiend & Mathews, 2001) as stimuli for the dot probe task.

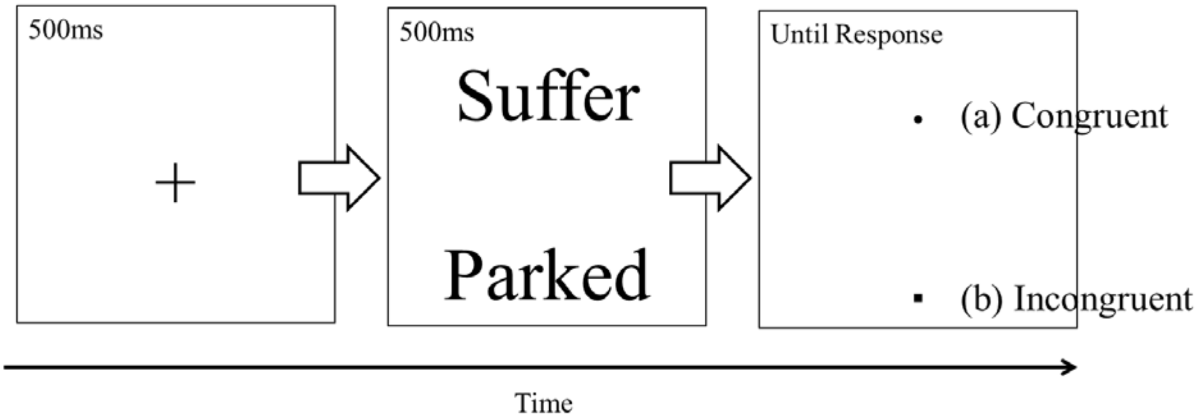

Figure 2. A single trial of the dot probe task. The probe stimulus replaces (a) the threatening stimuli (i.e., suffer) in congruent trials and (b) the neutral stimuli (i.e., parked) in incongruent trials. Stimuli adapted from MacLeod, Rutherford, Campbell, Ebsworthy, and Holker (2002).

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).

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

ISSN 1512-1801

= 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). Evidence of attentional bias has been documented among many types of anxiety disorders such as generalized anxiety disorder (Dalgleish et al., 2003), panic disorder (Buckley, Blanchard, & Hickling, 2002),and post-traumatic stress disorder (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 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. Evidence of 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.

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.

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.

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

ISSN 1512-1801

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).

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. 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. 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. 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. 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.

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.

ISSN 1512-1801

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, 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.

Dichotomization of Continuous Variables

The practice of dichotomizing continuous variables into categorical ones is not recommended. 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, Zhang, Preacher, & Rucker, 2002; Naggara et al., 2011), and inflates the Type I error rate (Austin & Brunner, 2004). Dichotomization also results in different cutoff 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’ cutoff values. Given the well documented phenomenon of publication bias (Ferguson & Heene, 2012), researchers might be tempted to try more than one cutoff value and choose the value that would produce significant results (Royston, Altman, & Sauerbrei, 2006). It is noteworthy that no attentional bias studies to date have used ‘optimal’ cutoff 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.

The best solution is to allow the anxiety variable to remain continuous. The General Linear Model (GLM) should be used to analyze the data when the RT scoring method is used. An excellent guide suggests four steps to using the GLM (see page 83; Taylor, 2011). Specifically when measuring attentional bias data, first, select ‘Analyze’, ‘General Linear Model’, followed by ‘Repeated Measures’ on SPSS. Second, enter conditions (e.g., *congruent* vs. *incongruent* trials) as a within-subject variable and anxiety as a covariate (thus, allowing the variable to remain continuous). Third, look for a significant interaction effect between conditions and anxiety. Lastly,

ISSN 1512-1801

examine the relationship between anxiety and the difference between conditions (i.e., *incongruent* minus *congruent* trials). A positive correlation provides evidence for attentional bias on the dot probe task. Specifically, higher values of anxiety are associated with higher values of *incongruent* trials relative to *congruent* trials (i.e., faster in responding to *congruent* trials). Pearson product-moment correlation coefficient should be used to analyze the data when the TBI scoring method is used (e.g., Egloff & Hock, 2001). Similarly, a positive correlation provides evidence for attentional bias on the dot probe task, with higher anxiety associated with higher TBI scores. The use of the GLM or correlation allows the anxiety variable to remain continuous and serves as a better optimized analysis to the often-used ANOVA.

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 3). 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 R 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. It is not uncommon for journal editors to request authors to report parametric tests in their manuscripts, with the non-parametric equivalent omitted or relegated to a footnote. Given these limitations, we suggest other methods of dealing with RT distributions.

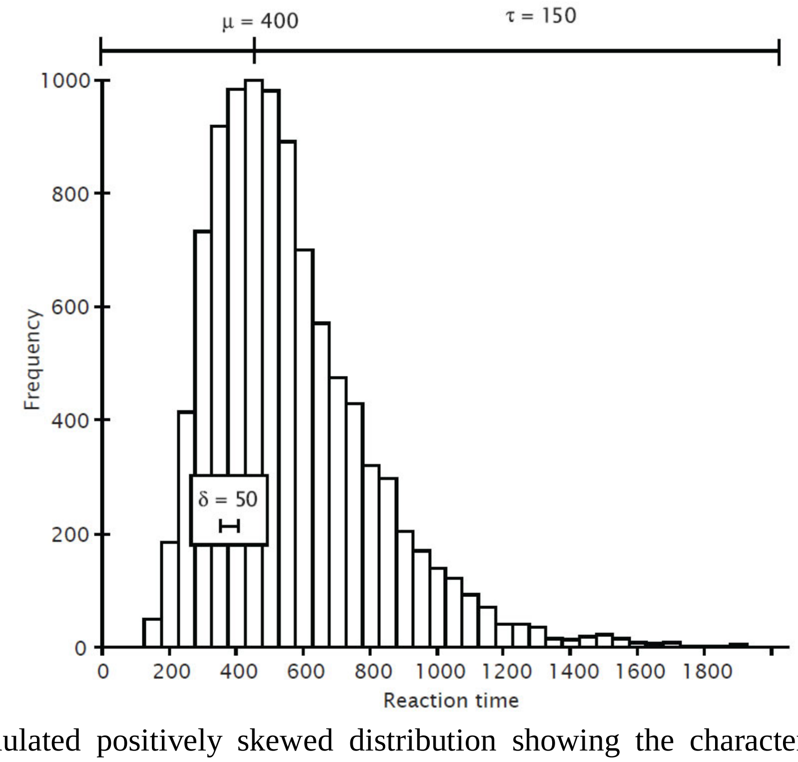

Figure 3. A simulated positively skewed distribution showing the characteristic shape of RT distributions, including the parameters mu (μ), sigma (δ), and tau (τ). Figure adopted from Whelan (2010). We gratefully acknowledge *The Psychological Record* for granting permission.

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Listed in 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 analyzes mu (μ), sigma (δ), and tau (τ) of the distribution (see Figure 3). 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 (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, we recommend the transformation strategy for research. 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.

Using the Mean as Summary Statistic

Attentional bias might not be present in all anxious individuals. 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

ISSN 1512-1801

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 and maintains anxiety (Beck & Clark, 1988; Bower, 1981, 1987), a successful modification of the bias reduces anxiety. This intervention, commonly known as the Attentional Bias Modification program, is effective in reducing trait anxiety and a wide variety of anxiety disorders (see Browning, Holmes, & Harmer, 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, we suggest using a similar quadrant to classify participants (see Table 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 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

Summary

The purpose of this paper 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

ISSN 1512-1801

tasks, (b) use GLM or correlation to analyze the data, (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).

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