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Review

A meta-analysis of the relationship between anxiety and attentional control

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HIGHLIGHTS

- A significant negative relationship between anxiety and Attentional Control was found
- Anxiety related deficits found in Attentional Control efficiency but not effectiveness
- Inhibition and switching but not updating was negatively impacted by anxiety
- The negative relationship between anxiety and Attentional Control increased with age on behavioural measures
- Findings largely supported Attentional Control Theory

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ABSTRACT

Attentional Control Theory (ACT) (Eysenck & Derakshan, 2011) proposes that attention control (AC) deficits are central to the development of anxiety. This meta-analysis investigated the size and nature of AC deficits in anxious compared to non-anxious participants. We made the following hypotheses based on ACT: i) anxiety-related AC deficits occur in the AC components of inhibition and switching, but not updating; ii) deficits will be more pronounced for AC efficiency (reaction times) than effectiveness (accuracy); iii) studies with high cognitive load conditions will observe greater deficits than studies with normal cognitive load; iv) age and anxiety level will moderate the effect of anxiety on AC. Fifty-eight studies ($N = 8292$) met inclusion criteria. The meta-analysis revealed a significant AC deficit for high compared to low anxiety participants (Hedges' $g = -0.58$). Overall, results supported assumptions of ACT: anxiety produced significant deficits in AC efficiency but not effectiveness; these deficits occurred in inhibition and switching but not updating and studies with high cognitive load conditions found larger anxiety related AC deficits. Age moderated the relationship between anxiety and AC in behavioural studies and anxiety severity moderated this relationship in self-report studies. Theoretical implications of the results are discussed, and future directions for research are proposed.

This meta-analysis has been registered with PROSPERO in 2016, Registration number: CRD42016036927.

1. Introduction

Anxiety disorders are among the most prevalent forms of mental illness, occurring in 14.4% of the population aged between 16 and 85 years old within a 12-month period in Australia (Tiller, 2013). Rates of remission with first line treatments of Cognitive Behavioural Therapy (CBT) and/or pharmacotherapy have been estimated to be around 50% (Ballenger, 2001; Barlow, Gorman, Shear, & Woods, 2000; Cartwright-Hatton, Roberts, Chitsabesan, Fothergill, & Harrington, 2004; Otte, 2011). More recently, treatments derived from research within cognitive psychology such as Attentional Bias Modification (ABM) and Attentional Control Training (ACT) have emerged with mixed results in terms of efficacy (e.g., Jones & Sharpe, 2017; Mogg et al., 2015; MacLeod & Clarke, 2015; Mogoaşe & Koster, 2014; Hakamata et al., 2010; Sari, Koster, Pourtois, & Derakshan, 2015). More in depth understanding of the theoretical relationship between attentional processes and anxiety may aid in the development of more effective forms of treatment.

Much of the theoretical research conceptually defines anxiety as a motivational state that exists when there is a high level of perceived threat to that individual (Derakshan & Eysenck, 2009). Under such circumstances, state anxiety has been found to impair cognitive performance, in processes such as Working Memory (WM) and allocation of attentional resources. Attentional bias research has found that individuals high in either state or trait anxiety tend to preferentially allocate their attention to threatening stimuli compared to neutral stimuli, and that this bias is greater than that observed in non-anxious individuals or under low anxiety conditions (Bar-Haim, Lamy,

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Pergamin, Bakermans-Kranenburg, & van IJzendoorn, M.H., 2007; Dudeney, Sharpe, & Hunt, 2015; Mogg & Bradley, 1998; Williams, Mathews, & MacLeod, 1996). However, the impact of allocation of attentional resources may vary dynamically with stages of processing (Amir, Foa, & Coles, 1998; Mogg, Bradley, De Bono, & Painter, 1997; Williams, Watts, MacLeod, & Mathews, 1988; Williams, Watts, MacLeod, & Mathews, 1997). Cisler and Koster (2010) argue that attention can be seen as multiple processes. The initial orientation to threatening information, vigilance, is argued to be driven by the "bottom-up" system. However, once threatening information has captured attention, threatening stimuli can either be avoided (fast disengagement) or can continue to capture attention (difficulty disengaging). Avoidance and difficulty disengaging are thought to be controlled by "top-down" processing. According to such accounts, the ability of individuals to control attention, using top-down processes, is likely therefore to impact the degree to which individuals demonstrate an attentional bias, particularly since in some contexts (e.g. where there is a realistic threat) such attentional biases could also be adaptive (Van Ryckeghem, Noel, Sharpe, Pincus & Van Damme, 2019). Given the complexity of how anxiety influences attention to threat, attentional bias may be better understood as an outcome of several processes within an attentional system rather than a singular process.

2. Attentional control theory

One such mechanism that has been proposed to explain how the different attentional processes are regulated within the attentional system is Attentional Control (AC), defined as the ability to flexibly focus and shift attention according to current goals (Muris, Mayer, van Lint, & Hofman, 2008). Attentional Control Theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007) draws on Baddeley's (1986) Working Memory Model (WMM) and the Processing Efficiency Theory (PET; Eysenck & Calvo, 1992), and stipulates that there are two attentional systems that direct selective attention – a bottom up stimulus driven system, and a top down goal directed system analogous to the central executive in the WMM. As such, when there is a threat, threatening stimuli will capture attention and this is adaptive. However, the more state or trait anxiety an individual experiences the more likely ambiguous information will be interpreted in a threatening way and hence capture attention. Attentional control is then necessary to disengage from the threat.

ACT posits that increased anxiety (either state or trait) leads to decreased attentional control (Eysenck et al., 2007), such that the influence of the goal directed system is reduced and the influence of the stimulus driven system is increased through preferential processing of task-irrelevant threat related stimuli (Corbetta & Shulman, 2002). ACT also suggests that poor attentional control can be a risk factor for the development of high trait anxiety, the developmental nature of which is further elaborated by the moderation model (see below). Although the direction of the effect remains debatable, it is likely that there may be bidirectional influences since it is state anxiety at the time of assessment that might most interfere with immediate task performance (e.g. effectiveness and efficiency). To further complicate matters, ACT posits that AC is complex and the effect of anxiety may differentially impact on different AC components and indices (Eysenck & Derakshan, 2011). These predictions are outlined below, and existing evidence is briefly reviewed.

3. Attentional control indices: efficiency vs. effectiveness

ACT argues that under some circumstances, highly trait anxious participants may not show evidence of disrupted attentional control in terms of accuracy of responding, but this comes at a hidden cost and requires greater use of cognitive resources to perform at the same standard as low trait anxious individuals, and is dependent upon the motivation to perform well (Eysenck et al., 2007). Hence, ACT would predict that the attentional deficits associated with anxiety would produce reduced efficiency in the form of slower response rate to cognitive tasks if the person is motivated but will have little impact on effectiveness or accuracy of task response. Although there is some support for this prediction (see Derakshan & Eysenck, 2009, for a review), few studies directly compare task effectiveness and efficiency. Further, the impact of reduced cognitive efficiency may only appear under high cognitive load where opportunities to recruit other cognitive resources are limited (Eysenck et al., 2007). In other words, one can test the degree to which task effectiveness and efficiency is associated with attentional control by varying cognitive load on experimental tasks.

4. Components within attentional control

Three major functions that have been identified as sub-components of the top down executive system within ACT are inhibition, switching and updating (Eysenck et al., 2007; Miyake et al., 2000). Inhibition involves preventing attentional resources from being distributed to task-irrelevant stimuli (Wong, Mahar, Titchener, & Freeman, 2013); this process may include suppressing, interrupting, or delaying a dominant response to salient but task-irrelevant stimuli (Derakshan & Eysenck, 2009; Harnishfeger, 1995). Inhibition is the most studied function in relation to anxiety, and research has generally found that high levels of trait or state anxiety reduces the efficiency of response in a range of tasks including the Emotional Stroop task (e.g., Reinholdt-Dunne, Mogg, & Bradley, 2009; see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007 for a review), the Go/No-Go task (e.g., Gomez, Ratcliff, & Perea, 2007; Johnstone, Pleffer, Barry, Clarke, & Smith, 2005), visual search tasks (e.g., Byrne & Eysenck, 1995), and the Attention Network Task (ANT; Fan, McCandliss, Sommer, Raz, & Pozner, 2002). Perhaps the strongest evidence for this distinction comes from research using the antisaccade task. This paradigm presents a conflict between the reflexive saccade (eye movement) towards a salient but task irrelevant stimulus, and the volitional antisaccade (eye movement in the non-reflexive location) back to the task relevant stimulus. Research has found that state or trait anxiety produces more robust effects on antisaccade efficiency compared to effectiveness (e.g., Derakshan, Ansari, Shoker, Hansard, & Eysenck, 2009; Garner, Ainsworth, Gould, Gardner, & Baldwin, 2009).

The switching function involves controlling attentional resources to remain focused on task relevant stimuli, shifting back and forth between tasks or accommodating mental set changes in task requirements (Miyake et al., 2000). Experimental paradigms in which switching deficits due to elevated state anxiety have been observed include tasks used for neuropsychological assessment of cognitive deficits, such as the Wisconsin Card Sorting Task (e.g., Caselli, Reiman, Hentz, Osbourne, & Alexander, 2004; Goodwin & Sher, 1992) and the Comprehensive Trail Making Test (CTMT; Orem, Petrac, & Bedwell, 2008), as well as tasks more commonly used in research settings such as the Task-Switching paradigm (Johnson, 2009; Kofman, Meiran, Greenberg, Balas, & Cohen, 2006; Miyake et al., 2000). In a review, Eysenck and Derakshan (2011) concluded that the negative effects of high state anxiety have been observed in both inhibition and switching functions under various paradigms.

Finally, few existing studies have explored the effects of state or trait anxiety on the updating function. Updating is thought to involve both monitoring new information and evaluating it in terms of task relevancy, and overwriting old and no longer relevant information (see Miyake et al., 2000 for a review). Some tasks that have been used to investigate the relationship between anxiety and updating include the N-back task (e.g., Vytal, Cornwell, Arkin, & Grillon, 2012; Wong et al., 2013) and the Reading Span task (e.g., Calvo, 1996; Sorg & Whitney, 1992). According to Derakshan and Eysenck (2099), the updating function relies heavily on WM storage and executive manipulation of stored information instead of attention alone, thus it is unlikely to be directly affected by anxiety. However, other studies have found deficits in both N-back task performance efficiency and effectiveness associated with heightened levels of trait anxiety (e.g., Wong et al., 2013).

In summary, ACT assumes that high trait or state anxiety can negatively affect the processing efficiency of the shifting and inhibition functions, and that anxiety is presumed to only influence the updating function under conditions of high cognitive load (see Berggren & Derakshan, 2013 for a discussion). However, the evidence for these predictions has been mixed.

For example, Edwards, Edwards, and Lyvers (2015) conducted a series of experiments that compared high and low trait anxious individuals, under high and low threat (i.e. high or low state anxiety). Trait anxiety was associated with reduced inhibition efficiency and effectiveness but there was no effect of state anxiety. For shifting, both trait anxiety and state anxiety was associated with poorer shifting efficiency but not effectiveness. Finally, no relationship was found between trait or state anxiety and updating. These results are largely in keeping with the predictions from ACT, except that trait anxiety was associated with both efficiency and effectiveness for inhibition. In contrast, Wong et al. (2013) found that participants who scored high on trait anxiety demonstrated impaired processing efficiency but not effectiveness on all three processing tasks. Again, this partially supports the predictions of ACT, although ACT does not predict that anxiety will be associated with deficits in updating. Thus within the limited studies that have directly tested the predictions of ACT, there is mixed evidence for these predictions. Moreover, there has been little effort to consolidate existing research to test the assumptions of ACT.

5. Individual differences within attentional control

It is currently unclear whether AC processes are constant across the lifespan. A recent meta-analysis in attentional bias towards threat in children found that age moderated the relationship between anxiety and attentional bias, such that the difference between anxious and non-anxious youth increased with age (Dudeney et al., 2015). One potential factor that could account for this finding is the development of attentional control. According to Field and Lester's (2010) Moderation Model, attentional control is a skill that develops between early to late childhood. The model assumes that all young children have a predisposed attentional bias towards threat as a result of stimulus driven processing. As children enter into middle childhood, different trajectories in development emerge. Children that develop volitional attentional control processes are less susceptible to developing anxiety; whereas children who fail to develop adequate attentional control remain biased towards threat and are more vulnerable to developing anxiety (Field & Lester, 2010; Kindt & van den Haut, 2001). Moreover, the relationship between AC and anxiety may be bi-directional. AC may underpin development of anxiety, but anxiety may also adversely impact AC. However, there has been little research directly comparing the effect of anxiety on attentional control in adults compared to children, and the timeline of emergent anxiety related AC deficits remain unclear.

6. Research aims and hypotheses

The aim of this meta-analysis is to test predictions arising from ACT and the Moderation Model. The primary aim of the current meta-analysis is to determine whether a significant relationship exists between trait and/or state anxiety and AC deficits in both children and adults. Further secondary analyses aim to test the following hypotheses: i) anxiety related AC deficits will be observed in the AC components of inhibition and switching but not updating; ii) the same deficits will be more prominent in AC efficiency compared to effectiveness; iii) studies that required participants to operate under high cognitive load conditions will observe greater anxiety related AC deficits than studies where participants operated under normal cognitive load; iv) anxiety related AC deficits will be moderated by anxiety level and age, such that AC deficits will be larger for those who are older and who have more severe anxiety levels. Finally, exploratory analyses will test whether anxiety related AC deficits differ between those with clinically significant anxiety compared to non-clinical populations, and between studies that experimentally manipulated anxiety (i.e. manipulated state anxiety) compared to studies that did not.

7. Method

7.1. Search strategy

A study protocol was registered with PROSPERO and can be accessed from http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42016036927. The registration number for the protocol is CRD42016036927.

Potential studies were identified through searches of electronic databases including PsychInfo, Medline Ovid, Scopus and Web of Science. All available records from 1986 up to September 2016 were searched using the following keyword combinations: (*anxiety* OR *panic* OR *agoraphobia* OR *phobia*) AND (*attention** OR "*executive function*" OR "*inhibition* AND *attention**" OR "*anti-saccade*" OR *antisaccade* OR "*Stroop* AND *attention*" OR "*attention network task*" OR "*switching* AND *attention**" OR "*shifting* AND *attention**" OR "*Wisconsin card sorting task*" OR "switching task" OR "*updating* AND *attention**" OR "*N-back*") AND NOT ("*attention deficit hyperactivity disorder*" OR *ADHD* OR *ADD*). The search was limited to publications written in English and using human subjects. This search yielded a total of 13,752 articles (after the removal of duplicates). An ancestry search was performed by consulting the reference sections of several review articles (Berggren & Derakshan, 2013; Derakshan & Eysenck, 2009; Derakshan & Eysenck, 2009; Derryberry & Reed, 2002; Edwards, Edwards, & Lyvers, 2015; Eysenck et al., 2007; Moran, 2016; Muris et al., 2008; Waszczuk, Brown, Eley, & Lester, 2015). This yielded a further 16 unique articles. The articles were then reviewed for appropriateness in two stages.

In Stage 1, 13,768 articles were reviewed by the first author of this paper by reading the title and abstracts to ascertain whether they fulfilled the inclusion and exclusion criteria. Articles were included if the following criteria were satisfied:

a) The study contained original quantitative data from a human population, whether child or adult
b) Participants must be recruited from a normal, anxious or sub-clinical anxious population
c) The study must include at least one measure of both anxiety (e.g., The State-Trait Anxiety Inventory Trait and State scales (STAI-T and STAI-S), Liebowitz Social Anxiety Scale (LSAS), Revised Children's Anxiety and Depression Scale (RCADS) etc.) and AC (following the recommendations of Miyaki et al., 2000. E.g., colour-word Stroop task, antisaccade task, Wisconsin Card Sorting Task (WCST), Attentional Control Scale (ACS) etc.).
d) Articles were excluded if they met the following criteria: The study purposefully recruited participants with a physical health condition, cognitive impairment or samples not representative of the general population due to some special characteristic (genetic factor, race/ethnicity)
e) The purported measure of anxiety is a measure of a similar but different construct such as behavarioural inhibition or negative affect
f) The purported measure of attentional control was identified as a measure of Attentional Bias, WM, Sustained Attention, Divided Attention, Reward or Punishment (incentive) based Attentional Control or other similar but different constructs
g) Stimuli used were emotionally salient

A total of 235 studies survived this process and were read for full

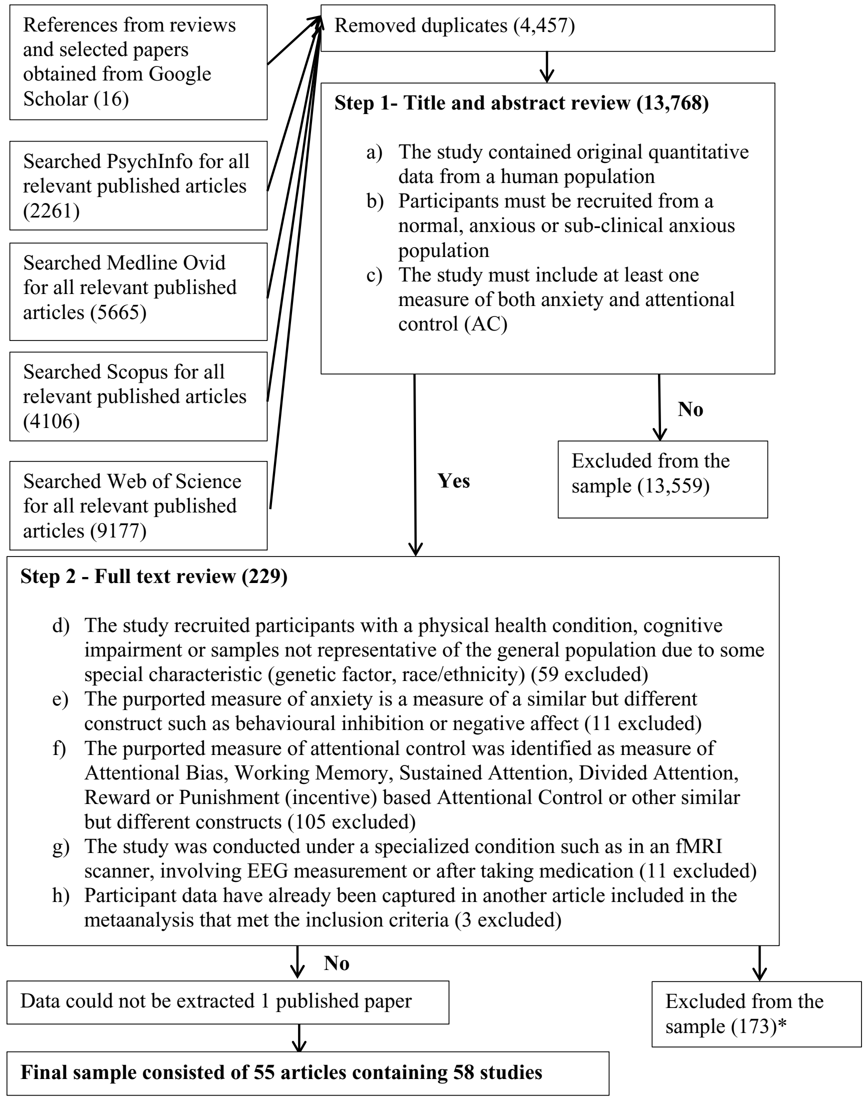

Fig. 1. Flowchart illustrating the literature search and review procedure.
*The sum of the number of articles excluded for each exclusion criteria exceed the number of articles excluded from the sample as some articles met more than one exclusion criteria.

text review in Stage 2. Two raters initially reviewed a randomly selected 20% of these studies based on the following criteria:

a) The method section met the inclusion and exclusion criteria described earlier
b) The difference in AC was either compared across groups that differed in anxiety or correlated with anxiety

The overall inter-rater agreement was high (Cohen's $\kappa = 0.95$). Disagreements were discussed to arrive at a consensual solution. One rater coded the remaining articles. The final sample consisted of 56 articles containing 59 studies. See Fig. 1 for a flowchart of the literature search and review procedure.

7.2. Coding system

A protocol was developed to code basic study information and moderators. Basic information included journal name, its Web of Science database category, publication year, experimental design (between or within groups), sample size, and exclusion criteria used.

We coded eight moderators (See Table 1). The first moderator was AC experimental procedure: whether a self-report or behavioural task was used to measure AC. The second moderator was the component of AC measured. This included four levels of overall AC, inhibition, switching and updating. Coding of this moderator followed the recommendations of Miyake et al. (2000) about criteria with which to distinguish tasks that predominantly measured inhibition, switching or

Table 1
Coding system for moderators.

Variable	Levels
Attentional control	
Experimental procedure	Self-report, behavioural
Component	Overall AC, inhibition, switching, updating
Index	Efficiency, effectiveness
Cognitive load	High cognitive load, normal cognitive load
Anxiety	
Status	Clinically significant, Non-clinical
Induction	Induced anxiety, Non-induced anxiety
Level	Continuous variable
Sample characteristics	
Age	Continuous variable

updating, where possible. Overall AC included only self-report measures (ACS, Attentional Control Scale for Children (ACS−C) and the AC subscale of the Adult Temperament Questionnaire (ATQ)). Inhibition included studies reporting the ACS and ACS-C subscales of focusing, as well as behavioural measures including the Stroop task, antisaccade performance in the antisaccade task, the Attentional Network Task (ANT) and Attentional Network Test-Interaction (ANT-I), the Parametric Go/No-Go (PGNG) task, the irrelevant singleton search task and the odd one out task. Switching included studies reporting the ACS and ACS-C subscales of shifting. The behavioural measures of switching performance include switch trials in the mixed antisaccade task, the Intra/Extradimensional Set Shift (IED) task in the Cambridge Neuropsychological Testing Automated Battery (CANTAB), irrelevant singleton search task, various versions of the switching task, the WCST, and the trail-making test (TMT). Updating included the ACS and ACS-C subscales of updating (where available), and the N-back task. The third moderator of AC index was coded only for behavioural measures of AC and included efficiency and effectiveness. Coding of this moderator followed the recommendations of Eysenck et al. (2007), where *effectiveness* refers to the quality of task performance indexed by response accuracy (calculated from percentage errors where response accuracy was not reported. For the WCST, this was calculated as the inverse of preservative error). In contrast, *efficiency* refers to the relationship between the effectiveness of performance and the effort or resources spent in task performance, typically calculated as the proportion of RT for correct responses in the AC condition (the trials that require attentional control) to RT for correct responses in the non-AC condition (the trials that do not have competing responses and therefore do not require attentional control). Antisaccade task calculations included extraction of RT for correct antisaccades.

Cognitive load indicated whether the studies had participants operating under high cognitive load. This moderator consisted of two categories: high cognitive load and normal cognitive load. For example, participants in one study were asked to complete the Attention Network Task while counting backwards from 100 in 1 s (low cognitive load) or counting backwards from 100 in 3 s (high cognitive load) (Najmi, Amir, Frosio, & Ayers, 2015).

Anxiety was coded in terms of anxiety status, whether anxiety was experimentally induced and anxiety level. Anxiety status referred to clinically significant versus non-clinical comparison groups. Studies were coded as using clinically significant groups if groups were divided based on clinical diagnosis or using a scale with a clinical cut-off and the high anxiety group was above the clinical cut-off. Studies were coded as using non-clinical groups if group division was based on the outcomes of the non-clinical range on relevant scales (e.g. a median split). Anxiety induction referred to whether the study experimentally manipulated anxiety (induced anxiety) or not (non-induced anxiety). Finally, anxiety level and the participant sample characteristic of age were coded as continuous variables, using the mean of the sample as the moderator.

7.3. Coding decisions

Only one effect size could be extracted from a given sample of participants in order to satisfy the requirement of independent effect sizes. Therefore, further coding decisions with regard to the selection of effect sizes were made in cases where it was possible to extract more than one effect size from a study. These decisions were made according to the following:

- For studies using ANT and ANT-I paradigms, executive control or interference was selected over alerting and orientating.
- The colour-word Stroop task was selected over other non-emotional Stroop tasks (e.g., grass-snow Stroop task), which were selected over odd-one-out tasks. The WCST was selected or the TMT.
- If the tasks were given under different conditions of cognitive load, we selected the high cognitive load condition as this is hypothesized to demonstrate stronger anxiety effects on AC.
- When a study reported several measures of anxiety, we preferentially selected the most commonly used measures (thus we selected the STAI-T over the STAI-S, which was in turn selected over the LSAS, the Brief Fear of Negative Evaluation Scale (BFNE) and The Social Phobia and Anxiety Inventory - 23 (SPAI-23)).
- If AC was measured using both behavioural and self-report measures, we selected the behavioural measure over the self-report measure to be included in the overall analysis.
- Where overall AC and components of AC were measured in the same sample, we selected overall AC over AC components. Where several AC components were measured in the same sample, we selected the measure that had the smallest sample to enhance the power of the moderator analysis (in line with Bar-Haim et al., 2000). This resulted in updating being selected over switching, which was in turn selected over inhibition.
- If a study contained several effects (such as two groups of anxiety participants) that were equally valid to the present meta-analysis and none of the previously mentioned criteria applied, we calculated the effect sizes that reflected the average of the reported effects.

7.4. Quality ratings

Methodological quality of all included papers were assessed using criteria based on the Downs and Black (1998) quality rating scale as well as criteria outlined by Dudeney et al.'s (2015) study. The coding system for the methodological quality of the studies related to reporting, bias and internal validity. External validity was not coded for two reasons. First, a minimum standard for external validity was already set by our inclusion criteria. Second, it was difficult to ascertain whether non-reporting of a criterion was due to the quality of reporting or methodological quality that may threaten validity. Thus we chose to code reporting quality rather than external validity. Reporting criteria included eligibility criteria, demographics, types of anxiety, comorbidity, recruitment procedures and location of the study for participants in the anxious and control groups. Bias criteria included data cleaning, analyses consistent with hypotheses, appropriate statistical analyses and reporting of power analyses. Internal validity criteria included valid and reliable anxiety measure, valid and reliable AC measure, participant sampling and adjustment for confounding variables. One rater rated all 58 studies. A second rater coded a randomly selected 25% of the included studies. Inter-rater agreement was high (Cohen's $\kappa = 0.706–1$). Disagreements were discussed to arrive at a consensual decision.

7.5. Meta-analytic procedures

Original datasets were able to be obtained for 98% of the included studies. From these studies, where possible, AC efficiency and effectiveness means and standard deviations for control and anxious groups, correlation between attentional control and anxiety, and sample size were calculated. Where this information was not available, *t*-values and sample size for the comparison between control and anxious groups was extracted. Data from one study (Visu-Petra, Miclea, & Visu-Petra, 2013) was not able to be extracted; the authors were contacted to obtain relevant data, however, no response was received.

The Hedge's *g* was the effect size index that was calculated. Hedge's *g* represents the standardized mean difference between two conditions and is corrected for biases given the sample size. When AC was lower for control than for anxious participants or when the correlation between AC and anxiety was positive, Hedge's *g* was given a positive value. Conversely, when AC was higher for control than for anxious participants or when the correlation between AC and anxiety was negative, Hedge's *g* was given a negative value. Hedge's *g* values of 0.2, 0.5

and 0.8 were interpreted as small, medium and large effect sizes, respectively (Cohen, 1988).

The data was analyzed using a mixed effects model that combines random and fixed effects. The random effects model was used to model total homogeneity and sub-group comparisons, whereas fixed effects models were used for moderator analyses. Moderator analyses were conducted separately for the different subgroups thus large variance was not expected. Tau^2 was estimated across all studies using a pooled within-group estimate. Heterogeneity was assessed using the Q-value significance test, which provides an indicator of whether or not heterogeneity is present. All analyses were computed using Comprehensive Meta-Analysis software, version 3 (CMA3; Borenstein, Hedges, Higgins, & Rothstein, 2014).

7.6. Analysis

Publication bias was tested using funnel plots and Egger's regression test (Egger, Smith, Schneider, & Minder, 1997). Duval and Tweedie's (2000) trim and fill correction method was used to test whether asymmetry had a significant impact on observed effect size. Rosenthal's fail safe N (Rosenthal, 1991) was calculated to estimate the number of null effects that would be required to nullify a significant effect.

Three steps of pre-specified analyses were conducted. First, the overall AC deficit for high compared to low anxious participants was calculated across all studies. Then an exploratory subgroup comparison between behavioural and self-report studies was conducted. Separate planned subgroup analyses were conducted for behavioural and self-report studies to investigate the effect of cognitive load and anxiety status. Planned meta-regressions were conducted to explore the unique contribution of anxiety and age as predictors of AC deficits were conducted separately for self-report and behavioural studies. Further exploratory subgroup analyses were conducted in relation to anxiety status, anxiety induction, and to compare the effect size of anxiety related AC deficits in different AC indices and AC components within behavioural studies. In moderator and sub-group analyses, we only conducted further analyses where at least 2 studies were available for analysis in each group.

8. Results

A final selection of 55 articles reporting 58 studies was included in this meta-analysis. One study (Visu-Petra L, Miclea, & Visu-Petra G, 2013) met the inclusion criteria but could not be included in the final analysis because data could not be extracted from the published paper. The authors were contacted for the data but they did not reply. For an analysis of publication bias, please see Appendix B.

8.1. Descriptive results

There were a total of 58 studies containing a total sample of $N = 8292$. Across all included studies, 46 studies used an adult sample and 12 studies used a child sample; 46 studies used a community sample (including sub-clinical samples) and 12 studies used a clinically anxious sample as the comparison group to normal controls; moreover, 37 studies used behavioural methods to measure AC and 26 studies used self-report methods. A summary of the studies and their characteristics are included in Table 2.

The forest plot (see Fig. 2) was examined for outliers using visual examination of forest plots as recommended by Hedges and Olkin (1985), with no outliers observed.

8.2. Quality ratings

The overall quality of studies is summarized in Supplementary materials. Cross-sectional study ratings ranged from 5 (33.33%) to 14 (93.33%) out of 15 criteria being fulfilled. Reporting quality overall was low to moderate, with reporting and controlling for comorbidity being the least reported criterion (eight studies). Risk of bias criteria generally demonstrated high quality (with all studies demonstrating perfect scores for appropriate statistical analyses and valid and reliable anxiety and AC measure) except for the reporting of power analyses (five studies reported power analyses and followed the recommendations). Finally, internal validity was moderate, with a majority of studies sampling from the same population where applicable, as well as adjusting for potential confounding variables. However, only 19.30% of the studies sampled experimentally manipulated anxiety, while the majority of the studies employed a cross-sectional design in which AC deficits were compared between high- and low-anxious individuals, or examined bivariate correlations between AC and anxiety. There was no evidence that quality affected findings (for self-report studies: $Q_M = 0.12, p > .05$; for behavioural studies: $Q_M = 3.09, p > .05$), but the results were in the direction that better quality studies had larger effects, confirming poor quality studies cannot account for the findings.

8.3. Primary meta-analysis

The primary meta-analysis revealed a significant effect across studies showing that AC is worse for participants who are more anxious (Hedges' $g = -0.58$, confidence interval [CI] = -0.71 to -0.46, $z = -8.37, p < .0001$). There was evidence for a significant variance ($Q_B = 350.10, p < .0001, I^2 = 83.72$) in the sample of effect sizes, thus subgroup and moderator analyses were deemed appropriate. A summary of the findings of the primary meta-analysis as well as the subgroup and moderator analyses can be found in Table 3.

8.4. Behavioural vs. self-report studies

The first exploratory subgroup analysis conducted was between behavioural ($k = 37$) and self-report ($k = 21$) studies. Results revealed a significant difference in effect size ($Q_B = 26.51, p < .0001$) where self-report studies (Hedges' $g = -0.87$, CI = -1.00 to -0.75) produced larger AC differences between low and high anxious participants compared to behavioural studies (Hedges' $g = -0.39$, CI = -0.52 to -0.25) (see Fig. 3a). Thus further moderator analysis was conducted separately for studies that included self-report measures and studies that included behavioural measures.

8.5. Moderator analysis of self-report studies

A total of 26 studies containing 4899 participants were included in the meta-regression for self-report studies. The overall effect size for self-report measures was slightly lower than in the overall analysis but remained significant (Hedges' $g = -0.79$, CI = -0.96 to -0.62, $Q_B = 173.32, p < .0001$).

8.6. Anxiety status

An exploratory subgroup analysis found no differences in effect size for anxiety status ($Q_B = 0.22, p > .05$) (see Fig. 4a.). Studies with a clinically anxious group ($k = 5$, Hedges' $g = -0.87$, CI = -1.08 to -0.65, $p < .0001$) was not significantly different from those with a high but not necessarily clinically anxious group ($k = 26$, Hedges' $g = -0.81$, CI = -0.87 to -0.75, $p < .0001$). That is, high anxious groups (regardless of whether groups had clinically significant levels of anxiety) reported similarly large deficits in attentional control using self-report measures.

8.7. Anxiety induction

An exploratory subgroup analysis found no differences in effect size for induced vs. non-induced anxiety ($Q_B = 0.93$, $p > .05$) (see Fig. 5a.). Studies with induced anxiety ($k = 2$, Hedges' $g = -0.93$,

Table 2
Summary of the characteristics of studies in included in the current meta-analysis.

	Study	N	Study type	AC measure	AC component	AC index	Anxiety measure	Anxiety level	Experimentally induced anxiety	Age	Hedges' g	95% CI	
												Lower limit	Upper limit
1	Affrunti and Woodruff-Borden (2013)	102	Self-report	BRIEF (Shift subscale)	Switching	N/A	BAI-Y	12.78	No	8.1	−0.65	−1.06	−0.24
2	Ansari and Derakshan (2010)	71	Behavioural	Antisaccade task	Inhibition	Efficiency	STAI-T	–	No	27.11	−0.69	−1.19	−0.19
3	Armstrong, Zald, and Olatunji (2011)	29	Self-report	ACS	Ooverall AC	N/A	STAI-T	–	No	38	−1.35	−2.26	−0.44
4	Booth (2014)	97	Behavioural	Switching task	Switching	Efficiency	STAI-T	43.91	No	21.45	−0.28	−0.69	0.12
5	Coy, O'Brien, Tabaczynski, Northern, and Carels (2011)	88	Behavioural	Colour-word Stroop	Inhibition	Effectiveness	RTA	–	Yes	–	−0.79	−1.22	−0.36
6	Derakshan et al. (2009a)[HC]	47	Behavioural	Switching task	Switching	Efficiency	STAI-T	–	No	–	−0.73	−1.32	−0.15
7	Derakshan et al. (2009b)	61	Behavioural	Antisaccade tasks	Inhibition	Efficiency	STAI-T	–	No	29.9	−0.75	−1.38	−0.12
8	Edwards et al. (2015a)	90	Behavioural	WCST	Switching	Efficiency	STICSA	18.4	Yes	24.06	−0.40	−0.83	0.02
9	Edwards et al. (2015b)	70	Behavioural	Irrelevant singleton search task	Switching	Efficiency	STAI-T	39.52	Yes	24.16	−0.55	−1.05	−0.06
10	Fergus and Carleton (2016)	86	Behavioural	ANT	Inhibition	Efficiency	STICSA	32.95	No	18.9	−0.38	−0.82	0.05
11	Fuji et al. (2013)	60	Behavioural	WCST - preservation error (inversed)	Switching	Effectiveness	LSAS	–	No	24.75	−0.62	−1.13	−0.11
12	Gorlin and Teachman (2015a)	150	Behavioural	Colour-word Stroop	Inhibition	Efficiency	LSAS	40.45	Yes	18.7	−0.06	−0.38	0.26
13	Gorlin and Teachman (2015b)	135	Behavioural	Colour-word Stroop	Inhibition	Efficiency	LSAS	40.32	Yes	18.7	−0.20	−0.54	0.14
14	Graver and White (2007)	22	Behavioural	WCST - preservation error (inversed)	Switching	Effectiveness	LSAS	–	Yes	21.46	0.05	−0.75	0.86
15	Healy (2010)	109	Self-report	ACS	Overall AC	N/A	STAI-T	40.06	No	20	−0.95	−1.36	−0.53
16	Healy and Kulig (2006)	69	Self-report	ACS	Overall AC	N/A	BAI	15.4	No	–	−1.14	−1.69	−0.59
17	Healy (2014)	77	Behavioural & Self-report	ACS, Colour-word Stroop	Overall AC	N/A	STAI-T combined with STAI-S	39.57	No	19.19	−0.24	−0.69	0.22
18	Heeren, Mogoaşe, McNally, Schmitz, and Philippot (2015)	50	Behavioural	ANT	Inhibition	Efficiency	STAI-T	40.52	No	47.28	−2.61	−3.36	−1.86
19	Hendrawan, Yamakawa, Kimura, Murakami, and Ohira (2012)	32	Behavioural	Colour-word Stroop	Inhibition	Efficiency	STAI-S (baseline)	–	Yes	19.13	−0.18	−0.89	0.54
20	Jorgenson (1977)	20	Behavioural	Colour-word Stroop	Inhibition	Efficiency	STAI-T	–	No	–	−0.38	−1.00	0.23
21	Melendez, Bechor, Rey, Pettit, and Silverman (2016)	186	Self-report	ACS-C	Overall AC	N/A	RCMAS-C	50.71	No	9.66	−0.84	−1.16	−0.53
22	Mitchell, Mogg, and Bradley (2012)	196	Self-report	ACS	Overall AC	N/A	MASQ–ANX	50.8	No	19.9	−0.58	−0.87	−0.29
23	Mogg et al. (2015)	793	Behavioural	ANT	Inhibition	Efficiency	CBCL (Anxiety subscale)	–	No	–	−0.20	−0.45	0.05
24	Moradi, Fata, Abhari, and Abbasi (2014)	86	Self-report	ACS	Overall AC	N/A	BAI	–	No	31.89	−0.74	−1.19	−0.28
25	Morillas-Romero (2013)	58	Self-report	ATQ (AC subscale)	Overall AC	N/A	STAI-T	24.36	No	25.18	−1.37	−2.01	−0.74
26	Moriya and Tanno (2009)	43	Behavioural	ANT	Inhibition	Efficiency	STAI-T	46.86	No	–	−0.17	−0.78	0.44
27	Moser, Becker, and Moran (2012)	51	Behavioural	Irrelevant singleton search task	Inhibition	Efficiency	STAI-T	40.7	No	–	−0.94	−1.55	−0.32
28	Muris et al. (2008)	82	Self-report	ACS	Overall AC	N/A	RCADS	14.95	No	10.72	−0.86	−1.34	−0.39
29	Muris, Meesters, and Rompelberg (2007)	145	Self-report	ACS	Overall AC	N/A	RCADS	14.2	No	10.9	−0.92	−1.28	−0.56
30	Najmi (2015; Study 1) [HC]	58	Behavioural	ANT	Inhibition	Efficiency	STAI-T	54.13	No	37.03	−1.27	−1.83	−0.71
31	Najmi (2015; Study 2) [HC]	108	Behavioural	ANT	Inhibition	Efficiency	STAI-T	–	No	19.63	−0.17	−0.55	0.20
32	O'Carroll and Fisher (2013)	240	Self-report	ACS	Inhibition	N/A	PTA	49.58	No	19.6	−0.56	−0.82	−0.30
33	Olafsson et al. (2011)	728	Self-report	ACS	Inhibition	N/A	HADS	–	No	24.7	−1.01	−1.17	−0.84
34	Pacheco-Unguetti, Acosta, Marques, and Lupianez (2011)	26	Behavioural & Self-report	ANT-I task, ACS	Inhibition	Efficiency	STAI-T	22	No	34.73	−1.45	−2.44	−0.46
35	Pacheco-Unguetti et al. (2010; Study 1)	48	Behavioural	ANT-I task	Inhibition	Efficiency	STAI-T	–	No	–	−0.49	−1.06	0.07

(continued on next page)

Table 2 (*continued*)

	Study	N	Study type	AC measure	AC component	AC index	Anxiety measure	Anxiety level	Experimentally induced anxiety	Age	Hedges' *g*	95% CI	
												Lower limit	Upper limit
36	Pacheco-Unguetti et al. (2010; Study 2)	64	Behavioural	ANT-I task	Inhibition	Efficiency	STAI-S	–	No	–	−0.23	−0.72	0.25
37	Ramirez, Ortega, and Reyes Del Paso (2015)	45	Behavioural	ANT	Inhibition	Efficiency	STAI-T	–	No	–	−1.10	−1.72	−0.48
38	Rebega & Benga (2013; Study 2b)	30	Behavioural	ANT	Inhibition	Efficiency	RCADS-P	–	No	10.6	0.02	−0.68	0.72
39	Reinholdt-Dunne et al. (2009)	56	Behavioural & Self-report	ANT, ACS	Inhibition	Efficiency	STAI-T	–	No	–	0.83	0.29	1.37
40	Reinholdt-Dunne et al. (2013; Study 1)	165	Behavioural & Self-report	ANT, ACS	Inhibition	Efficiency	STAI-T	13.7	No	20.9	−0.14	−0.45	0.17
41	Reinholdt-Dunne et al. (2013; Study 2)	193	Behavioural & Self-report	ANT, ACS	Inhibition	N/A	MASQ–ANX	28.5	No	19.9	−0.60	−0.90	−0.31
42	Richey et al. (2016; Study 1)	219	Self-report	ACS	Overall AC	N/A	STAI-T	–	Yes	18.42	−1.12	−1.43	−0.82
43	Richey et al. (2016; Study 2)	129	Self-report	ACS	Overall AC	N/A	STAI-T	37.93	Yes	18.96	−0.65	−1.01	−0.28
44	Richey, Keough, and Schmidt (2012)	128	Self-report	ACS	Overall AC	N/A	STAI-T	37.24	No	19.4	−1.06	−1.45	−0.66
45	Spada, Georgiou, and Wells (2010)	142	Self-report	ACS	Inhibition	N/A	STAI-S	35.6	No	24.6	−0.87	−1.23	−0.51
46	Sportel, Nauta, de Hullu, de Jong, and Hartman (2011)	1086	Self-report	ATQ (AC subscale)	Overall AC	N/A	RCADS –C	25.95	No	13.6	−1.28	−1.42	−1.14
47	Stefanopoulou, Hirsch, Hayes, Adlam, and Coker (2014)	34	Behavioural	N-Back task	Updating	Effectiveness	PSWQ	–	Yes	–	0.09	−0.57	0.74
48	Susa, Pitica, Benga, and Miclea (2012)	161	Self-report	ACS-C	Overall AC	N/A	SCAS	28.96	No	11.5	−0.87	−1.21	−0.53
49	Sutterby and Bedwell (2012)	50	Behavioural	TMT	Switching	Efficiency	STAI-T	49.76	No	38.32	−0.17	−0.72	0.38
50	Taylor, Cross, and Amir (2016)	75	Self-report	ACS	Inhibition	N/A	LSAS	44.58	No	20.66	−0.79	−1.28	−0.30
51	Tincas et al. (2007)	78	Behavioural	CANTAB (IED)	Switching	Effectiveness	SPAS-P	33.53	No	4.978	−0.44	−0.89	0.00
52	Tortella-Feliu et al. (2014)	132	Behavioural & Self-report	ANT, ACS	Inhibition	Efficiency	STAI-T	–	No	29.67	−0.41	−0.76	−0.06
53	Ursache and Raver (2014)	320	Behavioural	Colour-word Stroop	Inhibition	Efficiency	STAI-T	1.85	No	10.6	−0.18	−0.40	0.04
54	Verstraeten, Vasey, Claes, and Bijttebier (2010)	280	Self-report	ACS	Inhibition	N/A	RCMAS	–	No	12.28	−0.82	−1.07	−0.57
55	Visu-Petra, Stanciu, Benga, Miclea, and Cheie (2014)	68	Behavioural	Verbal memory updating task	Updating	Efficiency	SPAS	28.5	No	4.67	0.18	−0.30	0.66
56	Waszczuk et al. (2015)	61	Behavioural	Irrelevant singleton search task	Inhibition	Efficiency	STAIC-T	33.18	No	9.23	−0.55	−1.08	−0.03
57	White, McDermott, Degnan, Henderson, and Fox (2011)	291	Behavioural	DCCS	Switching	Effectiveness	CBCL (Anxiety subscale)	2.92	No	4	0.02	−0.21	0.25
58	Wong et al. (2013)	75	Behavioural	PG/NG task (set shifting accuracy)	Updating	Effectiveness	STAI-T	–	Yes	24.45	0.03	−0.42	0.48

Note. ACS = Attentional Control Scale, ACS-C = Attentional Control Scale for Children, ATQ (AC subscale) = Adult Temperament Questionnaire (Attentional Control subscale), ANT = attentional network task, ANT-I = attentional network task of interactions, WCST = Wisconsin card sorting task, TMT = trail making task, CANT (IED) = Cambridge Neuropsychological Testing Automated Battery Intra/Extradimensional Set Shift task, DCCS = Dimensional Change Card Sort task, PGNG = Parametric Go/No-Go task. ^{HC} indicates that the study was conducted under conditions of high cognitive load. All other studies were conducted under low cognitive load.

Study	Hedges' g	Standard error	Variance	95% CI		Z-value	p-value
				Lower limit	Upper limit		
Affrunti & Woodruff-Borden (2013)	-0.65	0.21	0.04	-1.06	-0.24	-3.08	0.00
Ansari & Derakshan (2010)	-0.69	0.25	0.06	-1.19	-0.19	-2.70	0.01
Armstrong et al. (2011)	-1.35	0.46	0.22	-2.26	-0.44	-2.91	0.00
Booth (2014)	-0.28	0.21	0.04	-0.69	0.12	-1.36	0.17
Coy et al. (2011)	-0.79	0.22	0.05	-1.22	-0.36	-3.58	0.00
Derakshan et al. (2009a)	-0.73	0.30	0.09	-1.32	-0.15	-2.47	0.01
Derakshan et al. (2009b)	-0.75	0.32	0.10	-1.38	-0.12	-2.34	0.02
Edwards et al. (2015a)	-0.40	0.22	0.05	-0.83	0.02	-1.87	0.06
Edwards et al. (2015b)	-0.55	0.25	0.06	-1.05	-0.06	-2.21	0.03
Fergus & Carleton (2016)	-0.38	0.22	0.05	-0.82	0.05	-1.73	0.08
Fuji et al. (2013)	-0.62	0.26	0.07	-1.13	-0.11	-2.38	0.02
Gorlin & Teachman (2015a)	-0.06	0.16	0.03	-0.38	0.26	-0.36	0.72
Gorlin & Teachman (2015b)	-0.20	0.17	0.03	-0.54	0.14	-1.15	0.25
Graver & White (2007)	0.05	0.41	0.17	-0.75	0.86	0.13	0.90
Healy (2010)	-0.95	0.21	0.05	-1.36	-0.53	-4.43	0.00
Healy & Kulig (2006)	-1.14	0.28	0.08	-1.69	-0.59	-4.06	0.00
Healy (2014)	-0.24	0.23	0.05	-0.69	0.22	-1.03	0.30
Heeren et al. (2015)	-2.61	0.38	0.15	-3.36	-1.86	-6.84	0.00
Hendrawan et al. (2012)	-0.18	0.36	0.13	-0.89	0.54	-0.48	0.63
Jorgenson (1977)	-0.38	0.31	0.10	-1.00	0.23	-1.23	0.22
Melendez et al. (2016)	-0.84	0.16	0.03	-1.16	-0.53	-5.28	0.00
Mitchell et al. (2012)	-0.58	0.15	0.02	-0.87	-0.29	-3.89	0.00
Mogg et al. (2015)	-0.20	0.13	0.02	-0.45	0.05	-1.56	0.12
Moradi et al. (2014)	-0.74	0.23	0.05	-1.19	-0.28	-3.19	0.00
Morillas-Romero (2013)	-1.37	0.32	0.11	-2.01	-0.74	-4.23	0.00
Moriya & Tanno (2009)	-0.17	0.31	0.10	-0.78	0.44	-0.54	0.59
Moser et al. (2012)	-0.94	0.31	0.10	-1.55	-0.32	-2.98	0.00
Muris et al. (2008)	-0.86	0.24	0.06	-1.34	-0.39	-3.56	0.00
Muris et al. (2007)	-0.92	0.18	0.03	-1.28	-0.56	-5.00	0.00
Najmi (2015; Study 1)	-1.27	0.19	0.04	-1.83	-0.71	-0.91	0.36
Najmi (2015; Study 2)	-0.17	0.28	0.08	-0.55	0.20	-4.46	0.00
O'Carroll & Fisher (2013)	-0.56	0.13	0.02	-0.82	-0.30	-4.16	0.00
Olafsson et al. (2011)	-1.01	0.08	0.01	-1.17	-0.84	-12.12	0.00
Pacheco-Unguetti et al. (2011)	-1.45	0.50	0.25	-2.44	-0.46	-2.88	0.00
Pacheco-Unguetti et al. (2010; Study 1)	-0.49	0.29	0.08	-1.06	0.07	-1.70	0.09
Pacheco-Unguetti et al. (2010; Study 2)	-0.23	0.25	0.06	-0.72	0.25	-0.94	0.35
Ramirez et al. (2015)	-1.10	0.32	0.10	-1.72	-0.48	-3.48	0.00
Rebega & Benga (2013; Study 2b)	0.02	0.36	0.13	-0.68	0.72	0.06	0.95
Reinholdt-Dunne et al. (2009)	0.83	0.16	0.02	0.29	1.37	-0.89	0.37
Reinholdt-Dunne et al. (2013; Study 1)	-0.14	0.15	0.02	-0.45	0.17	-4.00	0.00
Reinholdt-Dunne et al. (2013; Study 2)	-0.60	0.27	0.08	-0.90	-0.31	3.01	0.00
Richey et al. (2016; Study 1)	-1.12	0.16	0.02	-1.43	-0.82	-7.20	0.00
Richey et al. (2016; Study 2)	-0.65	0.19	0.03	-1.01	-0.28	-3.48	0.00
Richey et al. (2012)	-1.06	0.20	0.04	-1.45	-0.66	-5.25	0.00
Spada et al. (2010)	-0.87	0.18	0.03	-1.23	-0.51	-4.72	0.00
Sportel et al. (2011)	-1.28	0.07	0.01	-1.42	-1.14	-17.77	0.00
Stefanopoulou et al. (2014)	0.09	0.34	0.11	-0.57	0.74	0.26	0.79
Susa et al. (2012)	-0.87	0.17	0.03	-1.21	-0.53	-5.03	0.00
Sutterby & Bedwell (2012)	-0.17	0.28	0.08	-0.72	0.38	-0.61	0.54
Taylor et al. (2016)	-0.79	0.25	0.06	-1.28	-0.30	-3.14	0.00
Tincas et al. (2007)	-0.44	0.23	0.05	-0.89	0.00	-1.95	0.05
Tortella-Feliu et al. (2014)	-0.41	0.18	0.03	-0.76	-0.06	-2.27	0.02
Ursache & Raver (2014)	-0.18	0.11	0.01	-0.40	0.04	-1.60	0.11
Verstraeten (2010)	-0.82	0.13	0.02	-1.07	-0.57	-6.32	0.00
Visu-Petra et al. (2014)	0.18	0.25	0.06	-0.30	0.66	0.73	0.47
Waszczuk et al. (2015)	-0.55	0.27	0.07	-1.08	-0.03	-2.06	0.04
White et al. (2011)	0.02	0.12	0.01	-0.21	0.25	0.17	0.87
Wong et al. (2013)	0.03	0.23	0.05	-0.42	0.48	0.14	0.89
Fixed	**-0.64**	**0.02**	**0.00**	**-0.69**	**-0.59**	**-26.12**	**0.00**
Random	**-0.58**	**0.06**	**0.00**	**-0.71**	**-0.46**	**-9.04**	**0.00**

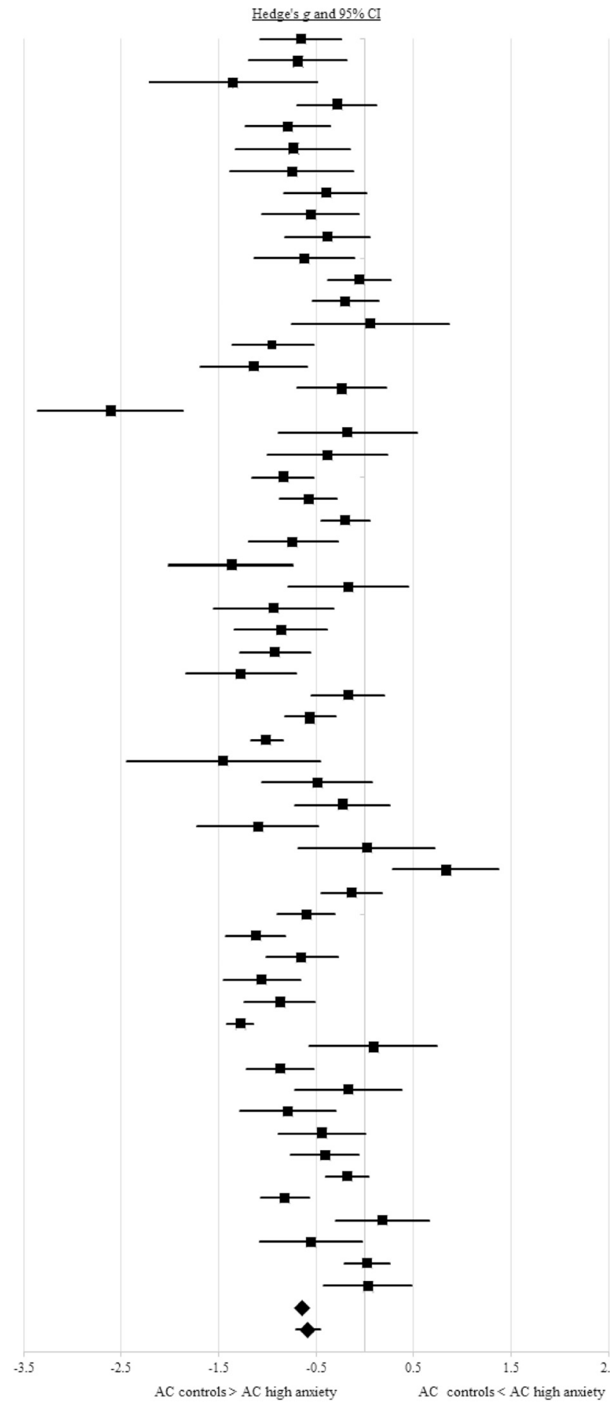

Fig. 2. Forest plot of effect sizes in Hedge's *g*.

CI = −1.17 to −0.70, $p < .0001$) were not significantly different from those with non-induced anxiety ($k = 26$, Hedges' $g = -0.81$, CI = −0.87 to −0.74, $p < .0001$). That is, studies that experimentally manipulated anxiety reported similarly large deficits in attentional control using self-report measures as studies that did not experimentally manipulate anxiety.

8.8. Anxiety

A planned meta-regression tested the moderating effects of mean anxiety score. The anxiety measure that was used most frequently in this sample of studies was the STAI; nine studies used the Trait version of this measure and an additional study used the State version. A decision was made to include both State and Trait versions of this scale to maximise the power of the analysis, as both versions were based on the same norms. The model was approaching significance ($Q_M = 3.81$, $p = .05$), with anxiety accounting for 60% of the variance within the model (see Fig. 6c.). Only eight studies reported both age and anxiety level as measured by the STAI, thus there were insufficient studies to complete an interaction analysis.

Table 3
Summary of the subgroup and meta-regression results of the moderators between attentional control and anxiety.

Variable		k	Hedges' g	95% CI	R^2	Q_W/Q_R	Q_B/Q_M
Overall analysis		58	−0.58***	−0.71 to −0.46		350.10***	
Experimental procedure		58					37.52***
	Self-report	21	−0.87***	−1.00 to −0.75		57.99***	
	Behavioural	37	−0.34***	−0.46 to −0.22		87.04***	
Self-report studies		26	−0.82***	−0.88 to −0.76		173.14***	
Anxiety status		26					0.23
	Clinical significance	5	−0.87***	−1.08 to −0.65		2.86	
	Non-clinical	21	−0.81***	−0.87 to −0.75		170.23***	
Anxiety induction		26					0.93
	Induced anxiety	2	−0.93***	−1.17 to −0.70		3.75	
	Non-induced anxiety	24	−0.81***	−0.87 to −0.75		168.47***	
Age		24			0.15	138.91***	0.12
Anxiety		10			0.60	15.43*	3.81†
Behavioural studies		37	−0.26***	−0.33 to −0.19		110.10***	
AC index		37					11.33***
	Effectiveness	8	−0.08	−0.21 to 0.05		24.27**	
	Efficiency	29	−0.34***	−0.00 to −0.26		74.50***	
AC component		37					34.79***
	Inhibition	24	−0.31***	−0.40 to −0.22		64.25***	
	Switching	9	−0.53***	−0.69 to −0.37		10.11	
	Updating	4	0.10	−0.05 to 0.24		1.06	
Anxiety status		37					3.87*
	Clinical significance	10	−0.38***	−0.51 to −0.24		33.10***	
	Non-clinical	27	−0.22***	−0.30 to −0.14		73.09***	
Anxiety induction		37					0.03
	Induced anxiety	9	−0.25**	−0.40 to −0.10		12.48	
	Non-induced anxiety	28	−0.26***	−0.34 to −0.19		97.60***	
Cognitive load		37					5.29*
	High cognitive load	3	−0.57***	−0.85 to −0.30		10.77**	
	Normal cognitive load	27	−0.24***	−0.31 to −0.17		94.04***	
Age		26			0.35	48.86**	13.76***
Anxiety		15			0.00	56.46***	2.33

Note. k values are the number of effect sizes; Hedges' g values are the standardized differences of attentional control between high and low anxiety participants; CI = confidence interval; Q_W/Q_R values represent the within group homogeneity statistic in group and subgroup comparisons and residual variability in the meta-regressions, respectively; Q_B/Q_M values represent the between group homogeneity statistic in group and subgroup comparisons and the model homogeneity statistic in meta-regressions, respectively.
† $p < .1$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

8.9. Age

Next, age was entered into a planned meta-regression model using studies from where this information could be extracted ($k = 24$, $N = 4774$). Age in the univariate analysis was not a significant predictor of the effect of anxiety on AC ($Q_M = 0.12$, $p > .05$) (see Fig. 6a.).

8.10. Moderator analysis of behavioural studies

A total of 37 studies ($N = 3772$) were included in the moderator analyses. First, the effect of AC indices and components were examined using subgroup analyses, then age and anxiety were examined in moderator analyses. Finally, the interaction between anxiety and index was explored.

8.11. Component

A planned subgroup analysis demonstrated that AC components were significantly different in effect size ($Q_B = 110.07, p < .001$). Both inhibition ($k = 24$) and switching ($k = 9$) produced significant effect sizes (Hedges' $g = -0.31$, CI = −0.40 to −0.22, $p < .0001$; and Hedges' $g = -0.53$, CI = −0.69 to −0.37, $p < .0001$ respectively) while updating ($k = 4$) did not (Hedges' $g = 0.10$, CI = −0.05 to 0.24, $p > .05$). Specific contrasts revealed that inhibition and switching were not significantly different from each other, but both had significantly larger effect sizes compared to Updating ($Q_B = 9.23$, $p < .01$; and $Q_B = 9.23, p < .01$) (see Fig. 3c). Only the component of switching contained enough studies of each index to allow further analysis.

8.12. Index

A planned subgroup analysis revealed a significant difference in effect size between AC indices ($Q_B = 11.33$, $p < .001$); efficiency ($k = 29$) produced a significant difference between those with high and low anxiety favouring those with low anxiety (Hedges' $g = -0.34$, CI = −0.43 to −0.26, $p < .0001$) but effectiveness ($k = 8$) did not (Hedges' $g = -0.08$, CI = −0.21 to 0.05, $p > .05$) (see Fig. 3b.).

8.13. Efficiency vs. effectiveness within switching

In terms of studies that measured switching, an exploratory subgroup analysis revealed that effect sizes for efficiency ($k = 5$) and effectiveness ($k = 4$) were not different to each other ($Q_B = 9.96$, $p > .05$). Both indices produced a significant effect size (Hedges' $g = -0.59$, CI = −0.78 to −0.40, $p < .0001$; and Hedges' $g = -0.40$, CI = −0.69 to −0.11, $p < .01$ respectively).

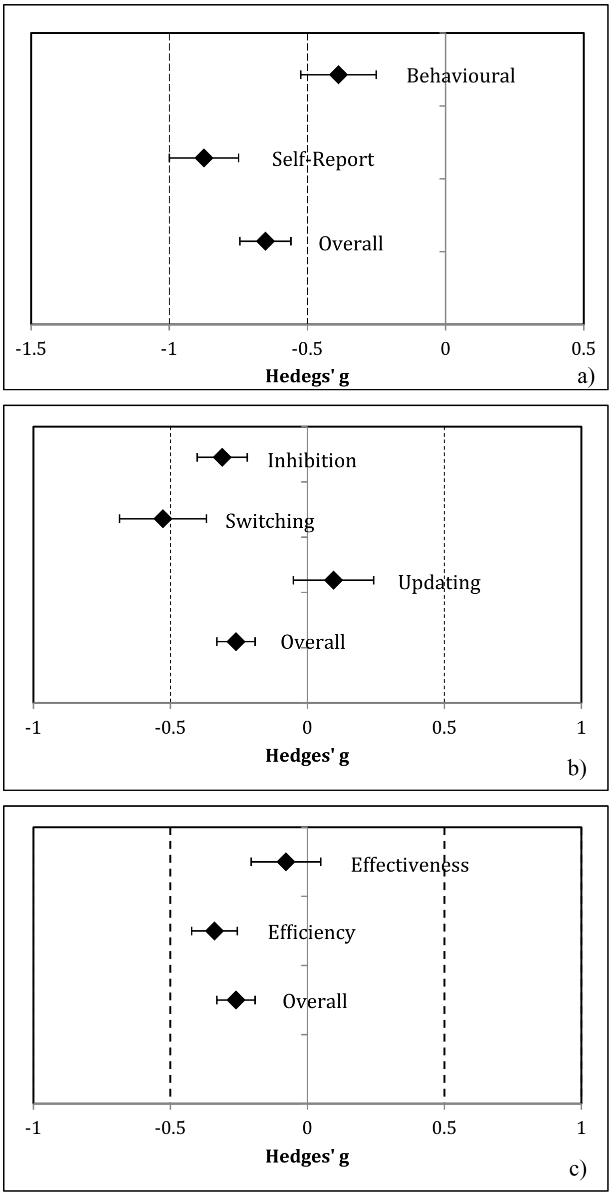

Fig. 3. Forest plot showing the subgroup ahavioural and self-report studies; b) inhibition vs. switching vs. updating components in behavioural studies; c) effectiveness vs. efficiency indices in behavioural studies.

8.14. Cognitive load

A planned subgroup analysis found significant differences in effect size depending on cognitive load (Q_B = 5.29, $p > .05$) (see Fig. 7). Studies with high cognitive load (k = 3, Hedges' $g = -0.57$, CI = −0.85 to −0.30, $p < .0001$) obtained larger effect sizes compared to studies with normal cognitive load (k = 34, Hedges' $g = -0.24$, CI = −0.31 to −0.17, $p < .0001$). All studies with high cognitive load conditions reported the AC index of efficiency. One study examined the AC component of switching and two studies examined the AC component of inhibition.

8.15. Anxiety status

An exploratory subgroup analysis found significant effect size differences in anxiety type (Q_B = 3.87, $p < .05$) (see Fig. 4b). Studies that had clinically significant anxiety groups (k = 10, Hedges' $g = -0.38$, CI = −0.51 to −0.24, $p < .0001$) produced significantly larger effect

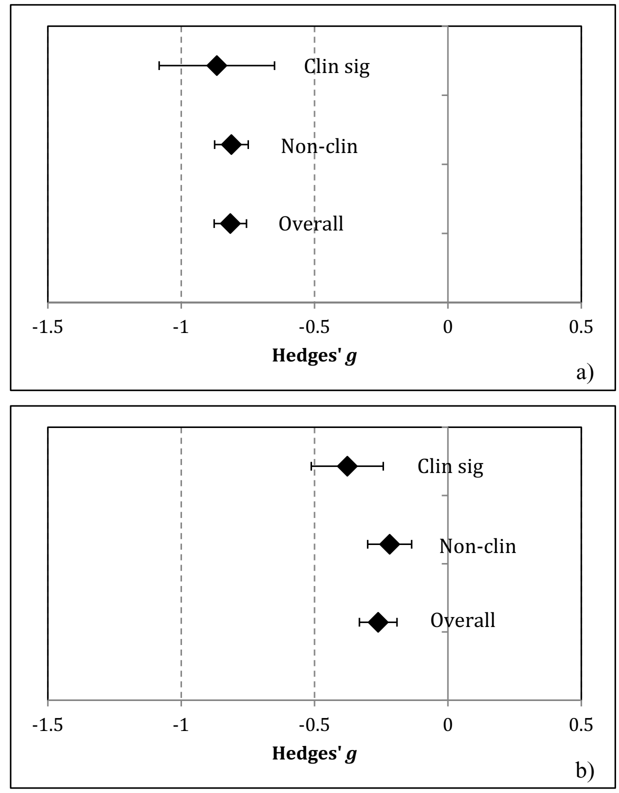

Fig. 4. Forest plots of anxiety status for a) self-report studies and b) behavioural studies.

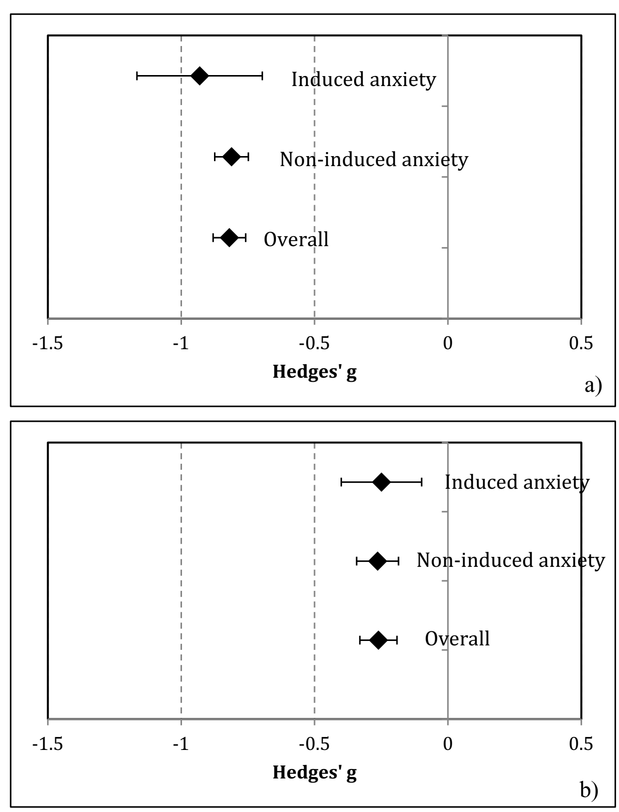

Fig. 5. Forest plots of anxiety induction for a) self-report studies and b) behavioural studies.

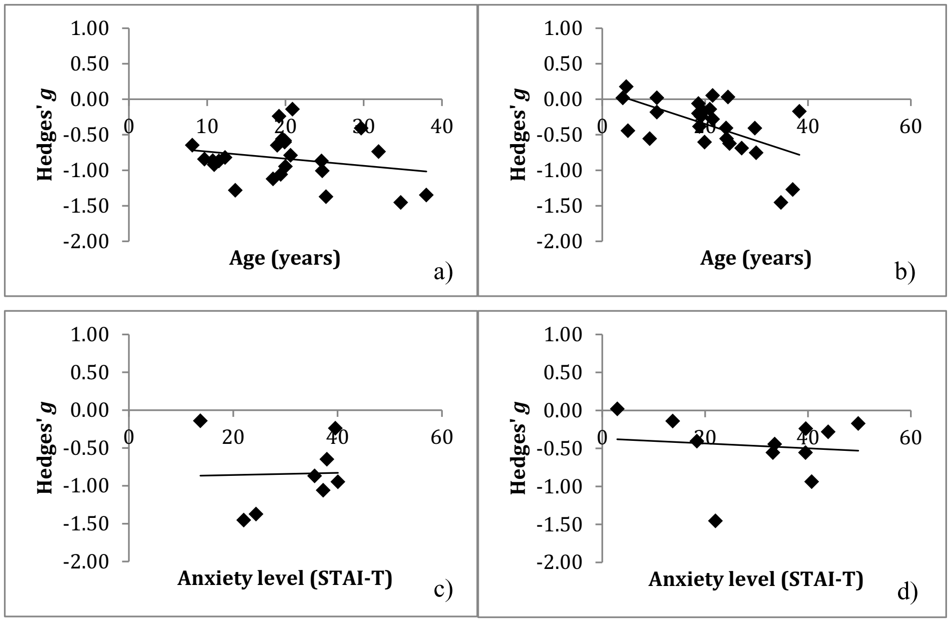

Fig. 6. a) Scatterplots for Hedges' *g* and age for self-report studies; b) Hedges' *g* and age for behavioural studies; c) Hedges' *g* and anxiety level for self-report studies; d) Hedges' *g* and anxiety level for behavioural studies.

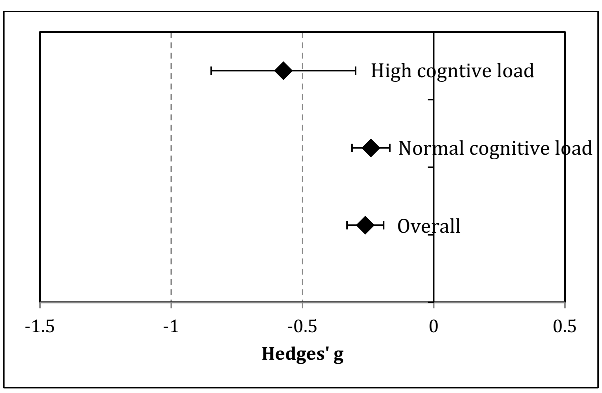

Fig. 7. Forest plot of cognitive load in behavioural studies.

sizes than those with high but not necessarily clinical anxiety groups ($k = 27$, Hedges' $g = -0.22$, CI = -0.36 to -0.14, p < .001). In other words, the deficits observed in anxiety groups on behavioural tasks were larger in clinically anxious samples than in community samples with high anxiety.

8.16. Anxiety induction

An exploratory subgroup analysis found no differences in effect size for induced vs. non-induced anxiety ($Q_B = 0.03, p > .05$) (see Fig. 5b). Studies with induced anxiety ($k = 9$, Hedges' $g = -0.25$, CI = -0.40 to -0.10, $p < .005$) was not significantly different from those with non-induced anxiety ($k = 28$, Hedges' $g = -0.26$, CI = -0.34 to -0.19, $p < .0001$). That is, studies that experimentally manipulated anxiety found similarly large deficits in attentional control using behaviour measures as studies that did not experimentally manipulate anxiety.

8.17. Anxiety

When mean anxiety score was entered into a planned meta-regression model alone using studies that reported scores on the STAI-T (the most frequent anxiety measure; $k = 16$), anxiety was not a significant predictor ($Q_M = 2.22, p > .05$) (see Fig. 6d). Only 12 studies reported both age and anxiety as measured by the STAI and as such there were insufficient studies for an interaction effect between age and anxiety level to be tested.

8.18. Age

Twenty-seven studies reported mean age. When age was entered into a planned meta-regression model alone, the model was significant ($Q_M = 9.72, p < .01$); age was able to account for 35% of the variance within the model (see Fig. 6d). The anxiety-related deficits in attentional control were greater with increasing age.

9. Discussion

The major aim of this study was to determine whether predictions based on ACT and the Moderation Model were supported when considering the available literature. To this end, we made four hypotheses and predictions of ACT were generally supported, with more mixed support for the Moderation Model. Our first hypothesis was that anxiety related AC deficits would be larger for AC efficiency compared to effectiveness. The prediction of anxiety producing deficits in processing efficiency rather than effectiveness has been a core assumption of ACT (Eysenck & Derakshan, 2011). The current meta-analysis supported this prediction across a variety of behavioural tasks, where small but significant deficits were observed for efficiency but not effectiveness. However, when switching studies were examined alone, both efficiency and effectiveness indices produced significant, and comparable anxiety related AC deficits. It has been suggested that several factors may jointly determine the costs associated with task-switching, including task-set activation and inhibition (see Monsell, 2003, for a review). If effective switching places more demands on the recruitment of resources, anxiety may be more likely to produce deficits in switching effectiveness compared to the effectiveness score of inhibition and updating, neither of which resulted in anxiety-related deficits.

Our second hypothesis was that anxiety related deficits would be observed in inhibition and switching but not updating. This hypothesis was supported, with clear evidence that overall attentional control is impaired for patients with high anxiety, and that deficits are present in inhibition and shifting but not updating. The significant AC deficits found within tasks measuring inhibition and switching in contrast with a lack of an effect in studies that measured updating aligns with the predictions of ACT; however, this cannot be used as conclusive evidence for the absence of anxiety related deficits in updating. Eysenck and Derakshan (2011) suggested that of the three executive functions outlined by Miyake et al. (2000), inhibition and switching involved greater attentional control. In contrast, the updating function involves monitoring and updating the information currently within working memory, and as such may involve less active control processes. In addition, tasks used to measure updating such as the N-back task (all updating studies in the current meta-analysis used the N-back task) may reflect WM capacities more than AC processes (Eysenck et al., 2007).

While Eysenck et al. (2007) argue that WM may be less vulnerable to the deleterious effects of anxiety compared to executive attention, a recent meta-analysis by Moran (2016) found that dynamic WM tasks including the N-back task showed reliable anxiety related deficits ($k = 20$, Hedges' $g = -0.44$), with an effect size that is comparable to the effect sizes of Inhibition and Switching found in the current study. It may be possible that the relatively small sample of updating studies included in the current analysis ($k = 4$) did not provide sufficient power to detect a significant effect. Future studies would benefit from the use of alternative measures such as the automated operation span task in order to provide further evidence to determine whether or not updating is also negatively impacted by anxiety (Unsworth, Heitz, Schrock, & Engle, 2005).

Our third hypothesis was that studies requiring participants to operate under high cognitive load conditions will observe greater anxiety related AC deficits than studies where participants operated under normal cognitive load conditions. This hypothesis was supported in behavioural studies. There were no self-report studies where participants operated under high cognitive load, as might be expected, given that high cognitive load is not a suitable condition for participants answering self-report questions. This finding is a novel and important finding in support of the predictions of ACT. However, the current meta-analysis also identified a comparatively small number of studies ($k = 3$) that contained a high cognitive load condition. Given that ACT stipulates that the impact of reduced cognitive efficiency may only appear under high cognitive load conditions (Eysenck et al., 2007), future studies should focus on testing this prediction. The current meta-analysis was not able to test whether high cognitive load conditions differentially impacted on cognitive efficiency versus effectiveness, as all three studies with high cognitive load conditions captured the AC index of efficiency, thus this should be considered as a direction for future research.

Our fourth hypothesis was that anxiety related AC deficits would be moderated by age and anxiety level, as predicted by the Moderation Model. There was some support for this hypothesis in that we found that increased age was predictive of larger effect sizes in behavioural studies (but not self-report studies). The Moderation Model (Field & Lester, 2010) predicts that the effect of anxiety on AC emerges as developmental trajectories start to diverge between anxious and non-anxious children, such that the detrimental effects of anxiety on AC become more pronounced across middle and then later childhood. Some recent empirical evidence suggests that differences in AC due to anxiety can be observed in children as young as 9 years of age (Waszczuk et al., 2015). Thus, the strongest differences should be observed when comparing children younger than nine years of age and adults, however, no study has directly made this comparison. The current finding of age being a significant predictor in behavioural but not self-report studies supports this prediction.

We also had an exploratory research question as to whether clinically significant anxiety was associated with increased deficits in attentional control. We found that higher levels of anxiety were predictive of larger effect sizes in self-report studies, as predicted (but not behavioural studies). Inconsistencies in the predictive value of anxiety level provide inconclusive evidence for the Moderation Model. That is, although attentional control was different between high and low trait anxious groups, the severity of anxiety in the sample did not predict performance on behavioural tasks. It is possible that age and anxiety level or anxiety status will have an interaction effect on AC. Specifically it might be expected that the impact of anxiety status or severity on attentional control would increase with increased age. Unfortunately, due to a small sample of studies reporting both age and anxiety the analysis of an interaction effect was unable to be carried out. This highlights the need for more studies investigating the development of AC in early to late childhood. Differences between self-report and behavioural studies may at least in part be due to differences in sampling. The self-report studies had somewhat restricted participant age range, ranging between 8.1 and 38 years of age, hence missing early to early-middle childhood where the greatest increase in attentional control occurs. Behavioural studies captured a wider age range in participants included, with participants ranging between 4 and 38.32 years. This could be due to age restrictions on self-report AC measures (for example, the child version of the ACS has been validated for 6 to 17 year olds but to date no measure exists for children under 6) and/or the lack of child focused studies using self-report measures to date (5 studies were identified and included in this meta-analysis). Differences in sampling were present in anxiety level as well, with wider ranging STAI scores of 13.70 to 44.47 in self-report studies ($M = 33.62$) and a narrower range of 20 to 46.65 in behavioural studies (M = 38.38), which also had higher overall means in anxiety.

Effect size did not differ for self-report studies with comparison groups differing by clinical status, however, for behavioural studies, those that used a clinically significant comparison group produced larger anxiety related AC deficits than those that included a non-clinical comparison group. This does suggest that attentional control deficits might be particularly relevant to those whose anxiety difficulties are sufficiently severe that they are clinically significant. Current results suggest that anxiety related AC deficits may be more prominent when comparing non-anxious individuals and those with clinically significant levels of anxiety.

It must be noted, however, that non-clinical anxiety groups included participants from at risk or subclinical populations, who scored highly on self-report measures of anxiety such as the STAI ($k = 2$ and 9 in self-report and behavioural studies, respectively). Due to the inconsistencies in how studies defined subclinical populations (e.g. the majority used median or tertile split designs resulting in the "high" and "low" anxious groups having different cut-offs between studies), a decision was made to not code this as a separate level. This means that differences in effect size due to anxiety status may be underestimated. Thus, further research is needed to investigate differences in AC deficits between normal, subclinical and clinical populations.

Finally, the exploratory research question as to whether effect sizes would be different for studies that did or did not experimentally induce anxiety yielded non-significant results. Thus it appears that regardless of how anxiety occurs, the deleterious effects of anxiety (level and status) on AC is the same.

9.1. Methodological implications for measuring attentional control

The current meta-analysis found that studies using self-report measures of AC produced greater effect size than those using behavioural measures. There are a number of reasons why self-report measures would produce a greater effect. First, the majority of self-report studies ($k = 16$ out of a total of 21) measured overall AC, whereas all behavioural studies were only able to capture a component of AC. It is possible that anxiety has the strongest impact on AC processes in general and a weaker effect on AC components. Second, behavioural measures tend to produce greater variability due to other factors unrelated to AC such as motor planning and processing speed and individual differences in the speed accuracy trade-off, which may dilute the effect size. In addition, the majority of behavioural measures have sub-optimal reliability (see Kane, Conway, Miura, & Colflesh, 2007), largely due to the reliance on difference scores based on highly correlated reaction times (see McNally, 2019 for a discussion), which could explain the larger effects observed in self-report measures. For this reason, it would be useful for this area of research to expand and include studies that measured efficiency using functional magnetic resonance imaging (fMRI) or electroencephalogram (EEG). Using neuroimaging measures in conjunction with behavioural data would increase reliability and add converging evidence. Due to a limited number of studies that used both self-report and behavioural measures in the current meta-analysis ($k = 8$), a meaningful correlational analysis between the effect sizes found using these different approaches could not be conducted. However, this should be considered for future research.

The AC processes proposed by ACT may be outside of conscious awareness or may impact on an individual's insight and conscious control of their own attentional resources. Therefore, it remains questionable whether self-report measures of AC are able to fully capture AC. Although Derryberry and Reed (2001) reported that scores on the Attentional Control Scale (ACS) were positively related to indices of positive emotionality such as extraversion ($r = 0.40$) and inversely related to aspects of negative emotionality such as trait anxiety ($r = -0.55$), they did not report the correlations with measures that are more conceptually relevant to AC such as executive function. A study by Judah, Grant, Mills, and Lechner (2013) found small but significant positive correlations (r ranged between 0.32 and 0.35) for the focusing subscale scores with antisaccade performance and pro-saccade latency and between the shifting subscale scores with switch trial performance in an antisaccade task, as well as a letter-number sequencing task. This provides preliminary evidence that the ACS is able to tap into the same AC processes as some behavioural tasks, but more studies investigating the correlations of self-report and behavioural measures of AC is warranted.

Despite the attenuated effect of anxiety on behavioural measures of AC, there are several advantages of behavioural measures. Behavioural measures are able to differentiate between processing efficiency and processing effectiveness, and are able to capture specific AC components. Behavioural studies also produced a significant difference in anxiety status, where studies with clinically significant comparison groups produced larger effects than those with non-clinical comparison groups. It is possible that behavioural tasks may be more sensitive to finely graded levels of AC deficits. Finally, self-report measures of AC have slightly more limited age restrictions than behavioural measures that makes them unsuitable for testing attentional control processes in very young children. Thus, behavioural measures are necessary for investigating important theoretical issues surrounding AC indices, component functions, clinical status, and the developmental trajectory of AC in anxious compared to non-anxious individuals.

9.2. Limitations

Overall, the quality of the studies reviewed varied from low to high quality. Publication bias is a common limitation in meta-analytic studies (Borenstein et al., 2011; Rosenthal, 1991). In the current meta-analysis, we observed evidence for a small publication bias effect, but a large fail-safe number, indicating strong reliability for the current results. However, the current meta-analysis only included studies published in peer reviewed journals, and did not include any unpublished data or data from grey literature, such as dissertations or conference presentations. Thus the current findings of publication bias may be an underestimate of true publication bias.

The current study was unable to ascertain the causal direction of the relationship between anxiety and AC deficits, as studies included were either correlational or between subjects in design. Although AC theories such as ACT propose that AC deficits occur as a result of anxiety, the same deficits may also lead to decreased ability to regulate emotional processing and serve to maintain anxiety. The current finding that age was able to predict the effect of anxiety on AC, especially when young children were included in the analysis, provides preliminary evidence that anxiety impairs the development of AC processes. Prospective studies in the development of AC processes in anxious and non-anxious children, especially during middle childhood are needed to more comprehensively understand the direction of causality in terms of anxiety and AC deficits.

These limitations notwithstanding, the current meta-analysis had a number of strengths. We excluded behavioural measures that used emotionally salient stimuli. This decision was made to differentiate AC tasks from tasks that capture attentional bias. Thus the results of this meta-analysis may in fact underestimate the true effect size if AC deficits become more prominent in emotionally salient contexts. However, the fact that an effect was still reliably observed in behavioural studies with neutral stimuli provides strong support for general AC deficits associated with anxiety. Whether emotionally salient stimuli further exacerbates the anxiety-related AC deficits is an important area for future research, as it will be able to disentangle the likely direction(s) of causality. The antisaccade task can be used with and without emotional stimuli and there is some evidence that the anxiety-related AC deficits may be increased when emotionally salient stimuli is used (Derakshan, Ansari, et al., 2009).

9.3. Clinical implications

The robust and reliable negative effect of anxiety on AC when participants are presented with non-emotional stimuli supports an underlying AC deficit in anxious participants. Current psychotherapeutic treatments of anxiety such as CBT tend to focus on challenging the content of anxious thoughts. These findings suggest that interventions that target improved control of cognitive processes may be worthy of further investigation. An example of this is the attention training technique (ATT), which was first developed by Wells (1990) as a component of metacognitive therapy for emotional disorders (Siegle, Thompson, Carter, Steinhauer, & Thase, 2007). ATT aims to limit excessive conceptual processing of threat in the form of worry and rumination and improve attentional control through auditory monitoring exercises (Wells & Simons, 2009), and has been found to be a possibly efficacious treatment for emotional disorders including anxiety disorders, depression, OCD and PTSD (see Fergus & Bardeen, 2016 for a review). Another treatment that has been shown to improve attention control is mindfulness (Watier & Dubois, 2016). It may be for those with anxiety and poor attentional control, regular mindfulness practice may be particularly useful, consistent with meta-analyses confirming the efficacy of mindfulness for reducing stress and anxiety (Blanck et al., 2018). Similarly, attentional control processes may also underlie cognitive bias modification. A study by Salemink and Wiers (2012) found that attentional control as measured by the colour-word Stroop task moderated both threat related interpretive bias and the efficacy of cognitive modification of interpretive biases in adolescents.

AC has been suggested to be the underlying mechanism of attentional bias (e.g., Cisler & Koster, 2010; Derryberry & Reed, 2002). There is some evidence suggesting that AC moderates the relationship between attentional bias and anxiety in adults, such that the relationship is greater between attentional bias and anxiety among those with better attentional control (Bardeen & Orcutt, 2011; Peers & Lawrence, 2009) and AC similarly moderates the relationship between attentional bias and negative affect in children and adolescents (Lonigan & Vasey, 2009). A recent study by Clarke et al. (2017) found that ABM under high working memory load led to significantly greater reductions in negative attentional bias for participants who were trained to avoid negative stimuli, suggesting that increased effortful control may be important in the modification of attentional biases. Understanding the relationship between attentional control, attention bias and the development of anxiety disorders would help in efforts to prevent and treat anxiety disorders.

9.4. Conclusions

The current meta-analysis conducted a large and thorough review of the current literature and found that there is a reliable anxiety related deficit in AC, across both self-report and a variety of experimental paradigms. Consistent with ACT, the current findings show a significant anxiety related deficit in processing efficiency but not effectiveness overall, although for switching attention both effectiveness and efficiency appear to be compromised in people with anxiety compared to those without. AC deficits, as predicted, were observed in the component functions of inhibition and switching but not updating. There was some support for the Moderation Model, in that younger age predicted fewer differences between people high versus low in anxiety on behavioural measures, but not self-report measures. Conversely, anxiety severity predicted poorer self-reported ACdeficits among those high in anxiety compared to those low in anxiety, but did not predict performance on behavioural tasks. The current findings provide broad support for the ACT, and some support for the moderation model.

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Contributors

Professor Louise Sharpe, Assoc. Professor Maree Abbott and Dr. Ran Shi designed the study and consulted on the protocol. Dr. Shi conducted literature searches, identified relevant studies according to title and abstract review, and evaluated the studies based on inclusion and exclusion criteria based on full text review. Assoc. Professor Abbott also rated of a proportion of the identified relevant papers on the inclusion and exclusion criteria to generate inter-rater reliability. Dr. Shi extracted the data from the final set of studies and conducted the statistical analysis in consultation with Professor Sharpe. Dr. Shi wrote the first draft of the manuscript and all authors contributed to and have approved the final manuscript.

Declaration of Competing Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property. We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). She is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author and which has been configured to accept email from: louise.sharpe@sydney.edu.au

Appendix A. Quality ratings

Quality ratings based on quality assessment criteria

	Study	Quality assessment criteria																
		Reporting								Bias							Internal validity	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Sum
1	Affrunti and Woodruff-Borden (2013)	0	1	N/A	0	1	0	0	1	1	1	0	1	1	1	1	0	9 / 15
2	Ansari and Derakshan (2010)	1	1	N/A	0	1	1	1	1	1	1	0	1	1	0	0	0	10 / 15
3	Armstrong et al. (2011)	1	1	1	0	1	0	0	0	1	1	0	1	1	1	0	0	9 / 16
4	Booth (2014)	0	1	N/A	0	0	0	0	0	1	1	0	1	1	1	0	0	6 / 15
5	Coy et al. (2011)	1	1	N/A	0	1	1	1	0	1	1	0	1	1	0	1	1	10 / 15
6	Derakshan, Smyth, and Eysenck (2009a)	0	1	N/A	0	1	1	1	1	1	1	0	1	1	1	0	0	10 / 15
7	Derakshan, Smyth, and Eysenck (2009b)	0	0	N/A	0	1	1	1	0	1	1	0	1	1	1	0	0	8 / 15
8	Edwards, Edwards, and Lyvers (2015)	1	1	N/A	0	1	1	1	1	1	1	0	1	1	1	1	1	12 / 15
9	Edwards, Moore, Champion, and Edwards (2015)	0	1	N/A	0	1	0	0	1	1	1	0	1	1	1	1	1	9 / 15
10	Fergus and Carleton (2016)	0	1	N/A	0	0	1	1	0	1	1	0	1	1	1	1	0	9 / 15
11	Fujii et al. (2013)	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	14 / 16
12	Gorlin and Teachman (2015a)	1	1	N/A	0	1	0	0	1	1	1	0	1	1	1	1	1	10 / 15
13	Gorlin and Teachman (2015b)	1	1	N/A	0	1	0	0	1	1	1	0	1	1	1	1	1	10 / 15
14	Graver and White (2007)	1	1	1	1	1	0	0	1	1	1	0	1	1	0	1	1	11 / 16
15	Healy (2010)	0	1	N/A	0	0	1	1	0	1	1	1	1	1	1	1	0	10 / 15
16	Healy and Kulig (2006)	0	1	N/A	0	1	0	0	1	1	1	1	1	1	1	1	0	10 / 15
17	Healy (2014)	1	1	N/A	1	1	1	1	1	1	1	1	1	1	1	1	0	14 / 15
18	Heeren et al. (2015)	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	13/15
18	Hendrawan et al. (2012)	1	1	N/A	0	0	0	0	0	1	1	0	1	1	1	1	1	8 / 15
19	Jorgenson (1977)	1	0	N/A	0	0	0	0	0	1	1	0	1	1	0	0	0	5 / 15
20	Melendez et al. (2016)	0	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	11 / 16
21	Mitchell et al. (2012)	1	1	N/A	0	1	1	1	1	1	1	0	1	1	1	0	0	11 / 15
22	Mogg et al. (2015)	1	1	1	0	0	0	0	0	1	1	0	1	1	0	1	0	8 / 16
23	Moradi et al. (2014)	1	1	1	0	1	0	0	0	1	1	0	1	1	0	1	0	9 / 16
24	Morillas-Romero, Tortella-Feliu, Bornas, and Aguayo-Siquier (2013)	0	1	N/A	0	0	0	0	1	1	1	0	1	1	1	0	0	7 / 15
25	Moriya and Tanno (2009)	1	1	N/A	0	0	0	0	0	1	1	0	1	1	1	0	0	7 / 15
26	Moser et al. (2012)	1	0	N/A	0	0	1	1	0	1	1	0	1	1	1	0	0	8 / 15
27	Muris et al. (2008)	0	1	N/A	0	0	1	1	0	1	1	0	1	1	0	1	0	8 / 15
28	Muris et al. (2007)	0	1	N/A	0	1	1	1	1	1	1	0	1	1	1	1	0	11 / 15
29	(Najmi et al., 2015; Study 2)	1	1	1	0	1	1	1	1	1	1	0	1	1	1	0	0	12 / 16
30	(Najmi et al., 2015; Study 1)	1	0	N/A	0	1	0	0	1	1	1	0	1	1	1	0	0	8 / 15
31	O'Carroll and Fisher (2013)	1	1	N/A	0	0	0	0	1	1	1	0	1	1	1	0	0	8 / 15

32	Olafsson et al. (2011)	0	1	N/A	0	0	0	0	0	1	1	0	1	1	0	0	0	5 / 15
33	Pacheco-Unguetti et al. (2011)	1	1	1	0	1	1	1	1	1	1	0	1	1	1	0	0	12 / 16
34	Pacheco-Unguetti et al. (2010; Study 1)	1	1	N/A	0	0	0	0	0	1	1	0	1	1	1	0	0	7 / 15
35	Pacheco-Unguetti et al. (2010; Study 2)	1	1	N/A	0	0	0	0	0	1	1	0	1	1	1	0	0	7 / 15
36	Ramirez et al. (2015)	1	1	N/A	1	1	1	1	0	1	1	0	1	1	0	1	0	11 / 15
37	Rebega & Benga (2013; Study 2b)	1	1	N/A	0	0	1	1	0	1	1	0	1	1	0	0	0	8 / 15
38	Reinholdt-Dunne et al. (2009)	1	1	N/A	0	0	0	0	1	1	1	0	1	1	0	1	0	8 / 15
39	Reinholdt-Dunne et al. (2013; Study 1)	1	1	N/A	0	1	0	0	1	1	1	0	1	1	1	0	0	9 / 15
40	Reinholdt-Dunne et al. (2013; Study 2)	1	1	N/A	0	1	0	0	1	1	1	0	1	1	1	0	0	9 / 15
41	Richey et al. (2016; Study 1)	1	1	N/A	0	0	0	0	1	1	1	1	1	1	1	0	1	9 / 15
42	Richey et al. (2016; Study 2)	1	1	N/A	0	0	0	0	1	1	1	1	1	1	1	0	1	9 / 15
43	Richey et al. (2012)	1	1	N/A	1	1	1	1	1	1	1	0	1	1	1	1	0	13 / 15
44	Spada et al. (2010)	1	1	N/A	0	1	0	0	1	1	1	0	1	1	1	1	0	10 / 15
45	Sportel et al. (2011)	0	1	N/A	0	1	1	1	1	1	1	0	1	1	1	1	0	11 / 15
46	Stefanopoulou et al. (2014)	1	1	1	1	1	0	0	0	1	1	0	1	1	1	1	1	11 / 16
47	Susa et al. (2012)	1	1	N/A	1	0	1	1	1	1	1	0	1	1	1	0	0	11 / 15
48	Sutterby and Bedwell (2012)	1	1	1	1	1	0	0	0	1	1	0	1	1	1	1	0	11 / 16
49	Taylor et al. (2016)	0	1	N/A	0	1	0	0	1	1	1	0	1	1	1	1	0	9 / 15
50	Tincas, Dragos, Ionescu, and Benga (2007)	0	1	N/A	0	1	1	1	0	1	1	0	1	1	1	1	0	10 / 15
51	Tortella-Feliu et al. (2014)	1	1	N/A	0	1	0	0	1	1	1	0	1	1	1	1	0	10 / 15
52	Ursache and Raver (2014)	1	1	N/A	0	0	0	0	1	1	1	0	1	1	1	1	0	9 / 15
53	Verstraeten (2010)	0	1	N/A	0	0	0	0	1	1	1	0	1	1	1	1	0	8 / 15
54	Visu-Petra et al. (2014)	0	1	N/A	0	1	1	1	1	1	1	0	1	1	1	1	0	11 / 15
55	Waszczuk et al. (2015)	0	1	N/A	0	1	1	1	1	1	1	0	1	1	1	1	0	11 / 15
56	White et al. (2011)	1	1	N/A	0	1	0	0	0	1	1	0	1	1	1	1	0	9 / 15
57	Wong et al. (2013)	0	1	N/A	0	0	1	1	0	1	1	0	1	1	1	0	1	8 / 15

Items: (1) Is the eligibility criteria clearly described? (2) Are the demographics of participants reported? (3) Are the types of anxiety specified? (4) Is comorbidity assessed and controlled for? (5) Is the recruitment procedure reported? (6) Is the location of testing of participants in the anxious group reported? (7) Is the location of testing of participants in the control group reported? (8) Is the data cleaning procedure and its criteria clearly described? (9) Are hypotheses and analyses consistent? (10) Is the statistical analysis appropriate? (11) Is the power analysis reported and were recommendations followed? (12) Is the anxiety measure used valid and reliable? (13) Is the AC measure used valid and reliable? (14) Are high and low anxious groups matched? (15) Are adjustments made for potential confounding variables? (16) Was anxiety experimentally manipulated?

Appendix B. Statistical analysis

B.1. Publication bias

An examination of the funnel plot where the effect size of the individual studies were plotted against the SE revealed a slight asymmetry (see Fig. B1), with the Egger's test indicating a potential bias of studies with small sample sizes ($t(56) = 1.66, p = .05$). Applying Duval and Tweedie's (2000) trim and fill correction (one hypothetical study was imputed) resulted in negligible change in the overall effect size (Hedges' $g = -0.55$, CI $= -0.68$ to -0.43). Rosenthal's fail safe N was 7368, indicating that there would need to be > 7000 hypothetical null effects with an effect size of zero added to the meta-analysis to make the difference across all studies statistically non-significant. This effect is 23 times larger than Rosenthal's (1991) recommended critical threshold ($5\,k + 1$).

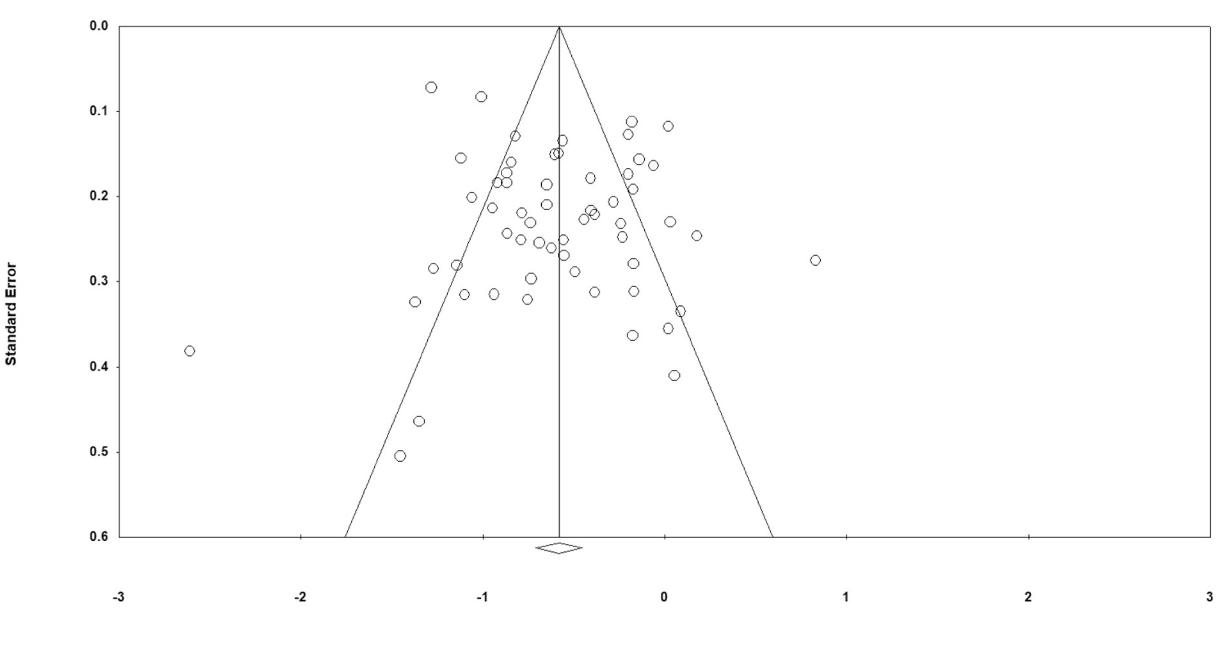

Fig. B1. Funnel plot of standard error by Hedges' *g*.

B.2. Overall analysis

1. Effect size of anxiety related AC deficits across all studies.

k	Effect size	95% Confidence interval		*z*-value	*p*-value	Heterogeneity		
	Hedges' *g*	Lower	Upper			*Q*-value	df (Q)	*p*-value
58	−0.58	−0.71	−0.46	−9.04	> 0.001	3350.10	57	> 0.001

2. Effect size of anxiety related AC deficits as a function of study type.

Groups	*k*	Effect size	95% Confidence interval		*z*-value	*p*-value	Heterogeneity		
		Hedges' *g*	Lower	Upper			*Q*-value	df (Q)	*p*-value
Behavioural	37	−0.39	−0.52	−0.25	−5.56	> 0.001	123.72	36	> 0.001
Self-report	21	−0.87	−1.00	−0.75	−13.68	> 0.001	58.00	20	> 0.001
Overall	58	−0.65	−0.74	−0.56	−13.84	> 0.001	350.10	57	> 0.001
Between groups effect							26.51	1	> 0.001

B.3. Self-report studies

3. Effect size of anxiety related AC deficits for self-report studies.

k	Effect size	95% Confidence interval		*z*-value	*p*-value	Heterogeneity		
	Hedges' *g*	Lower	Upper			*Q*-value	df (Q)	*p*-value
26	−0.82	−0.88	−0.76	−26.38	> 0.001	173.32	25	> 0.001

4. Effect size of anxiety related AC deficits for self-report studies as a function of anxiety status.

Groups	*k*	Effect size	95% Confidence interval		*z*-value	*p*-value	Heterogeneity		
		Hedges' *g*	Lower	Upper			*Q*-value	df (Q)	*p*-value
Clin sig	5	−0.87	−1.08	−0.65	−7.86	> 0.001	2.86	4	0.5820
Non-clin	21	−0.81	−0.87	−0.75	−25.19	> 0.001	170.23	20	> 0.001
Overall	26	−0.82	−0.88	−0.76	−26.38	> 0.001	173.32	25	> 0.001
Between groups effect							0.23	1	0.63

Note. Clin sig = comparison group based on clinical significance; Non-clin = comparison group is non-clinical.

5. Effect size of anxiety related AC deficits for self-report studies as a function of anxiety induction.

Groups	*k*	Effect size	95% Confidence interval		*z*-value	*p*-value	Heterogeneity		
		Hedges' *g*	Lower	Upper			*Q*-value	df (Q)	*p*-value
Induced	2	−0.93	−1.17	−0.70	−7.76	> 0.001	3.75	1	0.529
Non-induced	24	−0.81	−0.87	−0.75	−25.24	> 0.001	168.47	23	> 0.001
Overall	26	−0.82	−0.88	−0.76	−26.38	> 0.001	173.14	25	> 0.001
Between groups effect							0.93	1	0.34

Note. Induced = anxiety is experimentally induced; Non-induced = anxiety is not experimentally induced.

6. Meta-regression testing age as a predictor of effect size for self-report studies.

	k		95% confidence interval		*z*-value	*p*-value	Test of the model		
		Coefficient	Lower	Upper			Q-value	Tau^2	R^2 analog
Intercept		−0.86	−1.35	−0.37	−3.43	> 0.001			
Age	24	0.004	−0.02	0.03	0.35	0.73	0.12	0.14	0.15

7. Meta-regression testing anxiety level (STAI scores) as a predictor of effect size for self-report studies.

	k		95% confidence interval		z-value	p-value	Test of the model		
		Coefficient	Lower	Upper			Q-value	Tau2	R2 analog
Intercept		−0.18	−0.91	0.54	−0.5	0.62			
Anxiety level	10	−0.03	−0.04	0.0001	−1.95	0.051	3.81	0.05	0.59

B.4. Behavioural studies

8. Effect size of anxiety related AC deficits for behavioural studies.

k	Effect size	95% Confidence interval		z-value	p-value	Heterogeneity		
	Hedges' g	Lower	Upper			Q-value	df (Q)	p-value
37	−0.34	−0.47	−0.21	−5.11	> 0.001	110.10	36.00	> 0.001

9. Effect size of anxiety related AC deficits for behavioural studies as a function of anxiety status.

Groups	k	Effect size	95% Confidence interval		z-value	p-value	Heterogeneity		
		Hedges' g	Lower	Upper			Q-value	df (Q)	p-value
Clin sig	10	−0.38	−0.51	−0.24	−5.48	> 0.001	33.10	9	> 0.001
Non-clin	27	−0.22	−0.30	−0.14	−5.20	> 0.001	73.09	26	> 0.001
Overall	37	−0.26	−0.33	−0.19	−7.29	> 0.001	110.07	36	> 0.001
Between groups effect							3.88	1	0.049

Note. Clin sig = comparison group based on clinical significance; Non-clin = comparison group is non-clinical.

10. Effect size of anxiety related AC deficits for behaviourial studies as a function of anxiety induction.

Groups	k	Effect size	95% Confidence interval		z-value	p-value	Heterogeneity		
		Hedges' g	Lower	Upper			Q-value	df (Q)	p-value
Induced	9	−0.25	−0.40	−0.10	−3.24	> 0.005	12.48	8	0.13
Non-induced	28	−0.26	−0.34	−0.19	−6.58	> 0.001	97.60	27	> 0.001
Overall	37	−0.26	−0.33	−0.19	−7.33	> 0.001	110.10	36	> 0.001
Between groups effect							0.03	1	0.87

Note. Induced = anxiety is experimentally induced; Non-induced = anxiety is not experimentally induced.

11. Effect size of anxiety related AC deficits for behavioural studies as a function of cognitive load.

Groups	k	Effect size	95% Confidence interval		z-value	p-value	Heterogeneity		
		Hedges' g	Lower	Upper			Q-value	df (Q)	p-value
High cog load	3	−0.57	−0.85	−0.30	−4.08	> 0.001	10.77	2	> 0.005
Normal cog load	34	−0.24	−0.31	−0.17	−6.51	> 0.001	94.04	33	> 0.001
Overall	37	−0.26	−0.33	−0.19	−7.33	> 0.001	110.10	36	> 0.001
Between groups effect							5.29	1	> 0.05

Note. High cog load = the study required participants to complete tasks under conditions of high cognitive load; Normal cognitive load = the study did not require participants to complete tasks under conditions of high cognitive load.

12. Meta-regression testing age as a predictor of effect size for behavioural studies.

	k		95% confidence interval		z-value	p-value	Test of the model		
		Coefficient	Lower	Upper			Q-value	Tau^2	R^2 analog
Intercept		0.07	−0.19	0.34	0.55	0.58			
Age	27	−0.02	−0.03	−0.00	−3.12	> 0.005	9.72	0.05	0.53

13. Meta-regression testing anxiety level (STAI scores) as a predictor of effect size for behavioural studies.

	k		95% confidence interval		*z*-value	*p*-value	Test of the model		
		Coefficient	Lower	Upper			Q-value	Tau2	R2 analog
Intercept		−1.57	−3.03	−0.12	−2.12	0.03			
Anxiety level	16	0.03	−0.01	0.06	1.49	0.13	2.22	0.18	0.00

14. Effect size of anxiety related AC deficits for behavioural studies as a function of AC index.

Groups	*k*	Effect size	95% Confidence interval		*z*-value	*p*-value	Heterogeneity		
		Hedges' *g*	Lower	Upper			*Q*-value	df (Q)	*p*-value
Effectiveness	8	−0.08	−0.21	0.05	−1.21	0.23	24.28	7	0.001
Efficiency	29	−0.34	−0.42	−0.26	−7.98	> 0.001	74.50	28	> 0.001
Overall	37	−0.26	−0.33	−0.19	−7.33	> 0.001	110.10	36	> 0.001
Between groups effect							11.33	1	> 0.001

15. Effect size of anxiety related AC deficits for behavioural studies as a function of AC component.

Groups	*k*	Effect size	95% Confidence interval		*z*-value	*p*-value	Heterogeneity		
		Hedges' *g*	Lower	Upper			*Q*-value	df (Q)	*p*-value
Inhibition	24	−0.31	−0.40	−0.22	−6.66	> 0.001	64.27	23	> 0.001
Switching	9	−0.53	−0.69	−0.37	−6.51	> 0.001	10.11	8	0.26
Updating	4	0.10	−0.05	0.24	1.28	0.20	1.06	3	0.79
Overall	37	−0.26	−0.33	−0.19	−7.33	> 0.001	110.10	36	> 0.001
Between groups effect							34.69	2	> 0.001

16. Effect size of anxiety related AC deficits for behavioural studies measuring switching as a function of AC index.

Groups	*k*	Effect size	95% Confidence interval		*z*-value	*p*-value	Heterogeneity		
		Hedges' *g*	Lower	Upper			*Q*-value	df (Q)	*p*-value
Effectiveness	4	−0.40	−0.69	0.11	−2.72	0.007	2.89	3	0.41
Efficiency	5	−0.59	−0.78	−0.40	−6.07	> 0.001	5.95	4	0.20
Overall	9	−0.53	−0.69	−0.37	−6.52	> 0.001	9.96	7	0.27
Between groups effect							1.13	1	0.29

Appendix C. PRISMA checklist

Section/topic	#	Checklist item	Reported on page #
Title			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Cover page p.2
Abstract			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known.	6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	6–7
Methods			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	7
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7–9
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	7

Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	10–12
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	10–11
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	12–13
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	13
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	13–14
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	14
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	14
Results			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	9
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	16–18
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	19 Appendix A
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	18
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	19–20
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	53 (Appendix B)
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	21–28
Discussion			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	28–32
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	33–34
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	34–35
Funding			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	35

Appendix D. References included in meta-analysis

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