Acta Psychologica 238 (2023) 103973

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Trait anxiety slows speed of processing but does not affect specific components of executive control

Daniel Adrover-Roig *, Victor Sanchez-Azanza, Lucía Buil-Legaz, Raúl López-Penadés, Eva Aguilar-Mediavilla

Department of Pedagogy and Educational Psychology, Institute of Research and Innovation in Education (IRIE), University of the Balearic Islands, Spain

ARTICLE INFO

Keywords:
Anxiety
Cognitive control
Self-reported assessment
Speed

ABSTRACT

The present work aimed to establish the influence of self-reported trait anxiety on computerized and self-reported measures of executive control, and speed of processing in young adults using latent variable modeling. One hundred and six participants completed the State-trait anxiety questionnaire (STAI-t), the Attentional Control Scale (ACS), and a set of computerized tasks of executive control, tapping into the updating, inhibition, and shifting components. Higher scores in the latent variable of trait anxiety were negatively associated with the self-reported latent variable of attentional control. Notably, self-reported and performance-based indicators of executive control showed no associations at the latent level. Contrary to our hypotheses, higher trait anxiety did not affect any performance-based executive component but was associated with an increase in response times. We show that self-reported trait anxiety is related to a lower self-perceived sense of attentional control and does not affect executive functioning in non-clinical samples. In turn, trait anxiety is mainly associated with a slowed speed of processing. In conclusion, the tendency to experience a negative mood is related with cognitive processing by reducing its speed even in the absence of threatening stimuli.

1. Introduction

Anxiety can be defined as an aversive emotional and motivational state occurring in threatening circumstances (Eysenck et al., 2007). Research on anxiety has traditionally differentiated between state anxiety—the current experienced level of anxiety— and trait anxiety—stable anxiety proneness and a part of a personality dimension related to emotional instability (Eysenck, 2000). In the present study, we mainly focus on trait anxiety, the personality dimension that involves a characteristic style or temperamental tendency to experience a negative mood in different stressful and non-stressful circumstances.

1.1. *Trait anxiety and executive control*

Several studies have reported higher levels of anxiety are associated with dysfunctional executive functioning (EF) (Castaneda et al., 2008; see Shields et al., 2016, for a meta-analysis of stress and EF). In terms of behavioral performance-based EF, anxiety can differently modulate the three major attentional networks, as proposed by Posner et al. (2007). In parallel, Eysenck et al. (2007) based their Attentional Control Theory (ACT) on the assumption that anxiety is divergently associated with the two attentional systems proposed by Corbetta and Shulman (2002). In this vein, anxiety decreased the influence of the top-down goal-directed system while increasing the relevance of the bottom-up system responsible for detecting unattended but relevant stimuli. In line with these theoretical postulates, Pacheco-Unguetti et al. (2010) found that state anxiety was associated with an over-functioning of the bottom-up system while trait anxiety was related to deficiencies in top-down executive control using a modified version of the attention network test.

Specifically, trait anxiety has been studied in relation to the three major components of EF: updating, inhibition, and switching between task sets (Miyake et al., 2000). First, Eysenck and Calvo (1992) proposed that trait anxiety impairs the efficiency of the central executive, restraining the attention-like component of the working memory model explained by Baddeley (1986). Instead, only modest effects of trait anxiety were found on the phonological loop and the visuospatial sketchpad (Christopher & MacDonald, 2005; Eysenck et al., 2005). Nevertheless, trait anxiety has been shown to be associated with worse

* Corresponding author at: University of the Balearic Islands, Edifici Guillem Cifre de Colonya # A-204, Ctra. de Valldemossa, Km. 7.5, 07122 Palma de Mallorca, Spain.

E-mail address: daniel.adrover@uib.es (D. Adrover-Roig).

https://doi.org/10.1016/j.actpsy.2023.103973
Received 21 October 2022; Received in revised form 20 April 2023; Accepted 20 June 2023
Available online 24 June 2023

working memory in children, independent of state anxiety levels (Ng & Lee, 2016). However, Visu-Petra et al. (2013) found that high trait-anxious participants scored better on working memory tasks. These counterintuitive findings have been further qualified by a recent work showing that updating working memory representations mediates the relation between trait anxiety and academic outcomes, meaning that trait anxiety may enhance working memory (Alfonso & Lonigan, 2021).

Regarding the other two components of EF, anxiety impairs both inhibition and switching (Visu-Petra et al., 2013). Concerning inhibition, high-anxious participants are more susceptible to distraction than low-anxious people (Pacheco-Unguetti et al., 2010, 2009; Snyder et al., 2014). In addition, previous studies that used the antisaccade task showed significantly more eye-movement errors in participants with high anxiety than low-anxious individuals, suggesting that anxiety influences the response suppression component of inhibition (Derakshan, Ansari, et al., 2009; Garner et al., 2009; Wieser et al., 2009).

In terms of the switching ability, Caselli et al. (2004) reported an association of trait anxiety with a larger number of total errors and perseverations in the Wisconsin Card Sorting Test (WCST), indicative of poorer shifting. Ansari et al. (2008) examined the task-switching ability in a mixed antisaccade task as a function of trait anxiety and concluded that high-anxious participants use the shifting process less efficiently, showing greater switch costs. The very few studies that have explored the association between task-set shifting and trait anxiety with a typical task-switching cuing paradigm have shown mixed results. Whereas the first conducted study did not find a negative association between trait anxiety and shifting ability (Bunce et al., 2008). Gustavson et al. (2017) reported that trait anxiety affects the switching ability depending on task demands when switching away from an established task set.

In consequence, not all studies have been able to report a negative effect of trait anxiety on EF, leading to inconclusive results. These divergent outcomes have suggested that self-reported anxiety might have not only a very little effect on cognitive performance in healthy adults (Visu-Petra et al., 2013; Waldstein et al., 1997), but even a positive influence (Demetriou et al., 2021). These results have been interpreted with the revised ACT suggesting that, when challenged with demanding tasks, highly-anxious participants are more prone to engage in compensatory strategies to improve performance (Berggren & Derakshan, 2013). It is also worth noting that previous findings have shown that self-reported measures of executive control do not reflect executive performance, but instead other aspects such as general personality traits (Buchanan, 2016).

In addition, we also aimed to study the influence of trait anxiety on processing speed, which is entwined with basic and higher-order cognitive control processes (Salthouse, 1996).

1.2. Trait anxiety and processing speed

Attentional control and processing efficiency models pose that heightened negative affect consumes working memory resources (Baddeley, 2003; Etkin et al., 2015) and impacts negatively both processing speed and task accuracy (Eysenck et al., 2007). Labad et al. (2020) reported that not only higher trait anxiety was related to a poorer cognitive functioning in visual memory, speed of processing, and executive control, but also that cortisol levels during the day were associated with poorer processing speed. A possible explanation for the interfering role of anxiety in cognition is that the presence of worries about task performance in highly-anxious individuals leads to an increase in the allocation of inefficient processing resources (Eysenck & Calvo, 1992). Several authors have proposed that selective attentional biases occur in high-anxious individuals at an early stage of processing, suggesting a link between anxiety and dysfunctional thoughts emerging independently of later strategic processes (Capitão et al., 2014). Despite the negative role of trait anxiety on cognition, previous works have yielded opposite results, from faster detection RTs in the olfactory domain in high-anxious individuals (La Buissonnière-Ariza et al., 2013), to a faster response speed when detecting fear in comparison to happy faces (Byrne & Eysenck, 1995). Moreover, high trait-anxious individuals are slower detecting happy faces than low trait-anxious ones when the distractor faces are angry, revealing that their response speed is facilitated by threatening target stimuli but impaired by threatening distractors (Byrne & Eysenck, 1995). These results indicate that early processing biases are related to a stable personality dimension of anxiety, rather than to a situational variation in this measure.

In sum, although there are discordant results in terms of faster RTs in high trait-anxious individuals found by some studies (Byrne & Eysenck, 1995; Capitão et al., 2014; La Buissonnière-Ariza et al., 2013), we expected that trait anxiety will be associated with the slowed speed of processing as a consequence of a heightened consumption of cognitive resources (Baddeley, 2003; Eysenck et al., 2007; Labad et al., 2020).

It is also important to note here that studies examining the associations of trait anxiety with EF are more frequently conducted with clinical samples. Studying this aspect in a non-clinical sample might contribute to clarifying the association between negative affect on potential divergent contributions to deficits in EF or its components. We predicted that higher levels of trait anxiety would be related to lower self-reported attentional control, poorer general performance-based EF (in inhibition, and switching, but better updating abilities following Alfonso & Lonigan, 2021 and Visu-Petra et al., 2013), and a slower speed of processing.

2. Method

2.1. Participants

A total of 111 participants were recruited from the University of the Balearic Islands. After applying the exclusion criteria (see below the description of computerized tasks for details), 106 undergraduate students took part in this study (*M* age = 20.56 years; *SD* = 2.14; 86 females). Educational level was measured using a five-point Likert-like scale (0 = *without undergraduate studies*, 1 = *one year of undergraduate studies*, 2 = *two years of undergraduate studies*, 3 = *three years of undergraduate studies*, 4 = *four years of undergraduate studies*), being the mean of the education level in the sample 2.24 and the standard deviation 1.42. All participants had normal or corrected-to-normal vision and audition, and none reported psychiatric or pharmacological treatment.

2.2. Measures

2.2.1. State-trait anxiety inventory (STAI-t)

The trait version of the State-Trait Anxiety Inventory (STAI-t; Spielberger et al., 1983) is a 20-item scale designed to measure cognitive and somatic components of anxiety as a general personality trait. It has been claimed that the STAI-t does not assess solely anxiety, since it includes items related to depression (Endler et al., 1992). Accordingly, the STAI-t shows a high correlation with several measures of depression (Spielberger & Reheiser, 2009).

Both the anxiety and depression subscales were computed as well as a total score (Bieling et al., 1998). Seven statements like “Some unimportant thought runs through my mind and bothers me” and “I worry too much over something that really doesn't matter” are included in the anxiety subscale. Thirteen statements like “I am happy” and “I feel satisfied with myself” are included in the depression subscale. All items are rated on a four-point Likert scale from 1 (*almost never*) to 4 (*almost always*). Cronbach's α in this study was 0.79 for the anxiety subscale, 0.84 for the depression subscale, and 0.87 for the total score.

2.2.2. Attentional control scale (ACS)

The Attentional control scale (ACS; Derryberry & Reed, 2002) is a self-reported questionnaire created to measure individual differences in attentional control. The questionnaire includes two subscales: Attentional focusing, assessing the capacity to intentionally maintain the attentional focus and resist unintentional distraction, and Attentional shifting, evaluating the capacity to deliberately switch the attentional focus and avoid unintentional focusing on particular channels (Derryberry & Rothbart, 1988; see Ólafsson et al., 2011 for a factorial analysis in the adult population). The ACS includes 20 items. Ten items are expressed as statements like 'When working on something, still get distracted by events around me' and are included in the focusing subscale, while ten items are expressed as statements like "Hard to break from one way of thinking to another" and are included in the shifting subscale. All items are rated on a four-point Likert scale with 1 = *almost never*, 2 = *sometimes*, 3 = *often*, and 4 = *always* as possible answers. Cronbach's α in this study was 0.79 for the focusing subscale, 0.60 for the shifting subscale, and 0.82 for the total score.

2.2.3. Block-tapping task

We administered a computerized version of the Corsi (1972) block-tapping task (Croschere et al., 2012) to evaluate the updating of working memory representations, the updating component of EF. This task assesses the range of visuospatial working memory and consists of a display of nine blue squares in a black screen that light up one by one in a sequence where each square lits up for 1000 ms (see Fig. 1A).

Participants had to remember the sequence in which the squares had lighted up and then click each one in the same order. The difficulty of the sequence increased progressively, starting with two squares illuminated, increasing one square at a time when two consecutive trials of the same length were correctly remembered, until a total of nine. When the participant failed in one sequence, the next one was presented with the same number of elements. If the participant failed two consecutive sequences of the same length of squares to remember, the task finished. Before the experimental block, participants performed a practice block of three sequences of three squares length. For each participant, we recorded the total score as the product of the length of the last pair of correct sequences (block span) and the number of correctly remembered sequences. The total score considers the performance on both trials of an equal length and thus it could be considered more reliable than the block span alone (Kessels et al., 2000).

2.2.4. Flanker task

We administered a modified version of the original flanker task

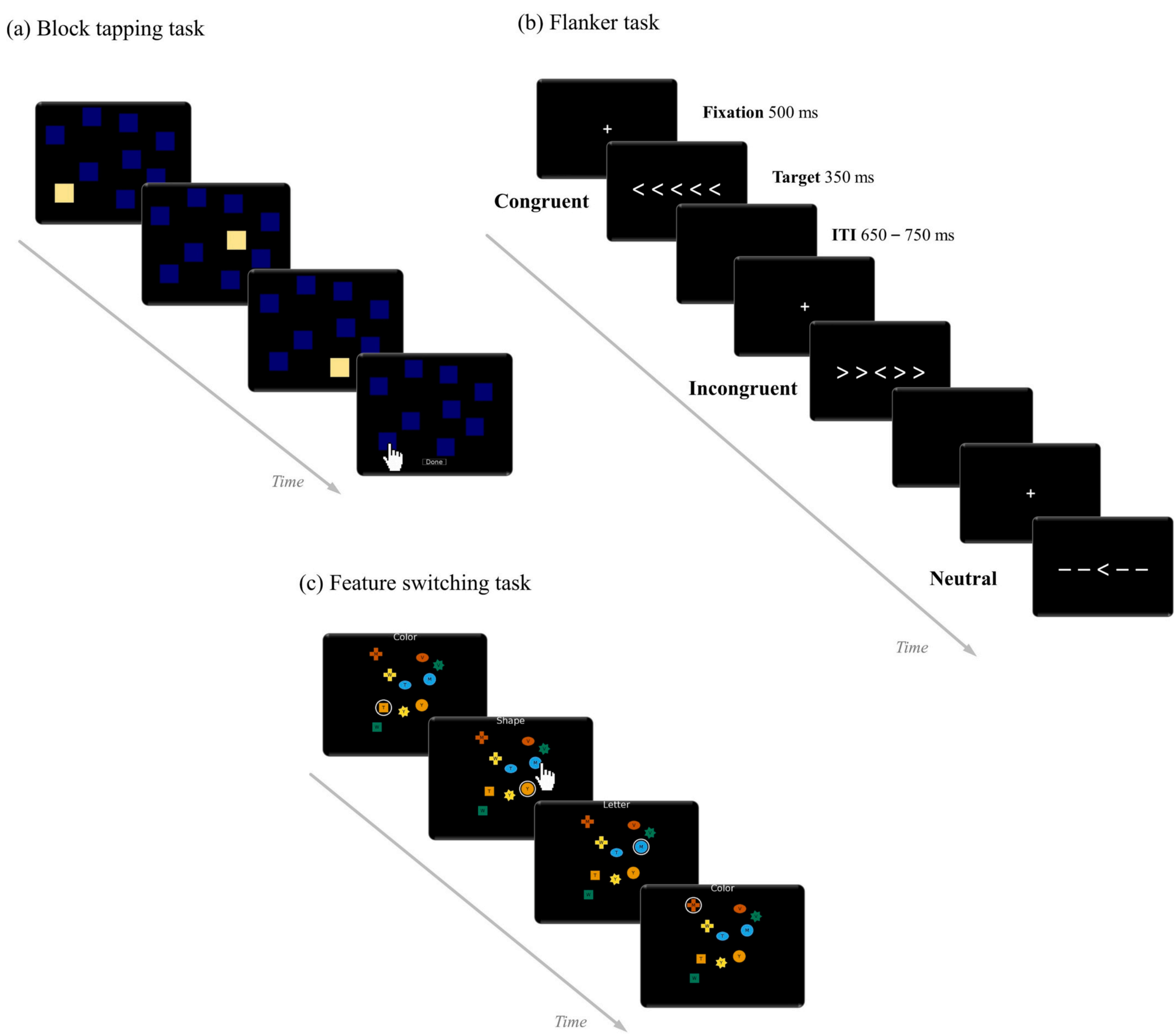

Fig. 1. Graphical representation of the tasks administered, including (a) the Block-tapping task, (b) the Flanker task, and (c) the Feature-switching task. Note: "ITI" refers to the inter-trial interval, "ms" to milliseconds.

(Eriksen & Eriksen, 1974), which explores resistance to distractor interference and inhibition-related processes. In this task, a central arrow (target) appears in the middle of a black screen surrounded by other arrows or lines. The participant had to indicate which side the central arrow points to by pressing with the left or the right index finger the appropriate keyboard button (Z or M key on a Spanish keyboard) by the direction of the central arrowhead. We presented 240 randomized trials without rest, where 80 of them were either congruent (target and flanking arrows pointed in the same direction), incongruent (target and flanking arrows pointed in different directions), or neutral (distractors were horizontal lines instead of arrows; see Fig. 1B). Each trial started with the appearance of a fixation cross during 500 ms followed by the target and the distractors, which were presented for 350 ms, and ended with a black screen (inter-trial interval; ITI) randomized between 650 and 750 ms. Before the experimental block, participants performed a practice block of 24 trials that were not analyzed. Response accuracies and response times (RTs) were recorded and averaged for each experimental condition and participant. RTs shorter than 50 ms (anticipation) or >1000 ms (timeout) were excluded from the analysis. Furthermore, one participant with <50 % of correct responses was not included in the analyses. Proportional flanker costs were computed as follows for incongruent–congruent proportional flanker costs (FCIC) and incongruent–neutral (FCIN) proportional flanker costs, respectively: [(RTincongruent –RTcongruent)/ RTincongruent]^2 and [(RTincongruent – RTneutral)/ RTincongruent]^2 (de Bruin & Della Sala, 2018). Moreover, the inverse efficiency score was computed by dividing the mean RT of correct trials for both congruent and incongruent trials by the overall proportion of corrects (Pcor), separately for each condition. Then, we subtracted the congruent inverse efficiency score from the incongruent one to achieve the FIES measure, that is, flanker costs in terms of inverse efficiency scores: (RTincongruent/Pcor) – (RTcongruent /Pcor) (Bruyer & Brysbaert, 2011). Note that we reversed these score's values (ρs original Flanker scores, reversed Flanker scores = −1) to provide a unified scale among EC latent variables, in which larger values revealed a better performance in EC. Thus, larger incongruent–congruent proportional flanker costs, incongruent–neutral proportional flanker costs, and incongruent–congruent flanker inverse efficiency score values (i.e., lesser interference or cost, reversed) reflected better performance.

2.2.5. Feature switching task

A computerized version of the feature-switching task (Anderson et al., 2012) was administered to evaluate the flexibility to switch back and forth between tasks and mental sets (Friedman & Miyake, 2004) to measure the switching component of EF. The task consisted of a presentation of ten objects on a black screen, each of them characterised as a function of three features: shape (circle, square, ellipse, plus or star), color (green, red, orange, yellow, or blue), and the letter appearing inside the shape (ranging from A to Z). Each object matched another single object on only one feature. In each trial, one object was signalled by a white circle surrounding the object, which remained until a response was given. In addition, a feature was written at the top of the screen (see Fig. 1C). Participants had to select the object that matched the one circled, based on the displayed target feature. Each trial presented a different feature, according to which the participant had to match the circled object, organised into nine blocks of twelve trials. In the first three blocks, participants had to switch between two of the three features repeatedly (two-predictable features condition, FS2P). In the next three blocks, they had to switch between all three features in a consistent order that differed between blocks (three-predictable features condition, FS3P). Finally, in the last three blocks, participants had to switch between target features that randomly alternated after each correct response. In these last blocks, participants could not anticipate the feature target before responding (three-unpredictable features condition, FS3U). A total of 108 trials were presented in the entire experimental block. Before the experimental block, participants performed a practice block of six trials. We recorded RTs and the number of errors for each trial and averaged for each of the three experimental conditions. RTs shorter than 200 ms (anticipation) or further than 3 *SD*s from the mean (timeout) were excluded from the analysis. No participants met the criterion for exclusion according to a 50 % accuracy or below.

2.3. Procedure

The research design was approved by the Committee on Research Ethics of the University of the Balearic Islands, code 2647. All participants were informed about the nature of the study and provided informed consent following the Declaration of Helsinki. All participants answered the self-reported questionnaires prior to the EF tasks. The experimental session was conducted in a computer room, in which EF measures were collected throughout computerized tasks, including a block-tapping, a modified flanker and a feature-switching task. Both the first and the latter tasks were presented using the Psychology Experiment Building Language (PEBL; Mueller & Piper, 2014), while the flanker task was the SiF task used in Sanchez-Azanza et al. (2020). This session lasted about 60 min, and all participants were rewarded with a USB memory stick and snacks after completion.

2.4. Data analysis

First, to quantify a potential common method bias (CMB) induced by the use of self-reported measures of both anxiety and attentional control, we performed Harman's single factor test (Podsakoff et al., 2003). The test consisted in loading all items of self-reported scales in an exploratory factor analysis with the principal components method of extraction fixing the number of factors to one. This test assumes that, if a large amount of common method variance is present, most of the covariance among measures (> 50 %) will be accounted by a single factor. Second, we performed a series of central tendency descriptive statistics for self-reported measures (STAI-t, ACS), as well as with computerized measures of EF. Third, a latent variable approach was adopted to explore the influence of both ACS and STAI-t on the target cognitive processes through Structural Equation Modeling (SEM). SEM combines factor analysis and multiple regression allowing to test the hypothesized covariation among latent variables (Morrison et al., 2017) and to inspect whether the interrelations among the measured variables, clustered in latent variables, behave like in a given specific theoretical model.

Thus, we specified four independent models, one for each executive control subcomponent: Updating (Model 1, with the results of the block-tapping task), Inhibition (Model 2, with the results of the flanker task), Switching (Model 3, with the results of the Feature-switching task), and Speed of Processing (Model 4, with the time of response in the feature-switching and flanker tasks using trials without incongruence); in the same way it was done previously (Sanchez-Azanza et al., 2020). According to previous literature, every model was specified in such a manner each of the subcomponents of EF and speed of processing was influenced by both self-perceived trait anxiety (i.e., STAI) and self-assessed attentional control (i.e., ACS), which, in turn, would be correlated with each other.

A significance level of $p < .05$ was used for all structural analyses in the models. SEM model fit (i.e., the extent to which any given theoretical model fits the actual data) was assessed by comparing the values of each fit index of every model with their respective standard thresholds (Schermelleh-Engel et al., 2003; Schreiber et al., 2006).

All data are freely available at Open Science Framework (https://osf.io/9rhz6/). SPSS Statistics software (version 22, IBM) was used for descriptive and correlational analyses. SPSS AMOS software (version 21, IBM) was used for SEM estimation.

3. Results

Descriptive statistics of the main variables of the present study can be consulted in Table 1.

Table 1
Descriptive statistics of the main measures in the present study ($N = 106$).

	M	(*SD*)	Min	Max
Trait anxiety (STAI)				
Total	23.12	(8.53)	12	39
STAI_a (anxiety)	7.49	(3.83)	2	16
STAI_d (depression)	15.63	(5.77)	7	26
Attentional control (ACS)				
Total	52.02	(7.89)	30	63
ACS_f (focusing)	23.31	(4.65)	9	31
ACS_s (shifting)	26.73	(3.83)	18	32
Updating				
BTTS	61.87	(21.54)	24	126
Inhibition				
Flanker task: mean RT	402.41	(38.36)	324.65	511.71
Flanker task: error %	8.27	(5.60)	0.42	30.42
FCIC	0.02	(0.01)	$3.261e^{-5}$	0.06
FCIN	0.02	(0.01)	$1.172e^{-7}$	0.08
FIES	62.78	(26.52)	−3.06	163.52
Switching				
FS2P	2170.35	(318.98)	1559.81	3368.47
FS3P	2151.03	(335.52)	1412.61	3215.6
FS3U	2194.85	(34.74)	1592.56	3.357.28
Feature switching task: error %	2.51	(3.15)	0	16.41
Speed of processing				
FRTn	384.28	(35.03)	313.03	477.03
FRTc	384.61	(39.90)	311.01	516.57
FSRT	2172.02	(297.07)	1585	3235.89

Note. M: Mean; *SD*: Standard Deviation; Min: minimum; Max: maximum; STAI-a: STAI anxiety trait subscale; STAI-d: STAI depression trait subscale; ACS Total: Attention Control Scale total score; ACS-f: Attentional Control focusing scale; ACS-s: Attentional Control shifting scale; BTTS: Block-tapping total score; RT: Response Time in milliseconds; FCIC: incongruent–congruent proportional flanker costs; FCIN: incongruent–neutral proportional flanker costs; FIES: incongruent–congruent flanker inverse efficiency score; FS2P: feature-switching two-predictable features RT; FS3P: feature-switching three-predictable features RT; FS3U: feature-switching three-unpredictable features RT; FRTn: flanker task neutral condition RT; FRTc: flanker task congruent condition RT; FSRT: Feature Switching task mean RT.

To ascertain that the associations between self-reports were not due to the method of assessment, we first report the results of the CMB analysis. The Harman's single-factor test showed that a single factor would account for 19.1 % of variance, which is far below the cut-off of 50 % that would indicate an inadequate CMB. These results show that the variance attributable to a common method of assessment (self-report) is acceptable, thus not substantially influencing the conclusions of the study.

3.1. Influence of attentional control and trait anxiety on the specific components of executive control

Following Table 2, all models showed an overall good fit to the data according to the standard cut-off criteria used in SEM. Specifically, each model's χ^2 *p*-value was non-significant, all CFI and NFI values were over 0.95 and the RMSEA statistic below 0.08. Furthermore, the subscales of both ACS ($ps < 0.0001$) and STAI ($ps < 0.002$) showed significant loadings on their respective factors (for a graphical depiction, see Fig. 2). The same outcome was found for the Inhibition ($ps < 0.0001$), the Switching ($ps < 0.0001$) and the Speed of Processing ($ps < 0.003$) latent variables. Moreover, the strength of the correlation between the factors ACS and STAI ($p = 0.005$) was greater for the latent factors than for the observable measures ($r_{\text{latent}} = -0.46$; $r_{\text{observable}} = -0.31$).

Regarding the structural results of the models, none of the associations of STAI or ACS latent variables was significant for neither Updating ($ps > 0.867$), Inhibition ($ps > 0.332$) or Switching ($ps > 0.745$) when Models 1 to 3, respectively, were estimated. However, even though Attentional Control did not relate with the latent variable of Speed of Processing in Model 4, a significant association between the latter and trait anxiety was found ($p = 0.033$). That is, it seems that higher levels of anxiety appear to increase the time required to process information, thus slowing down responses (Figs. 2 and 3).

4. Discussion

The main aim of this work was to study the associations between trait anxiety and both self-assessed and computerized measures of EF. We presented a set of experimental tasks tapping the three major dimensions of executive functions (Miyake et al., 2000) and two self-reported questionnaires to assess trait anxiety and attentional control. The main hypothesis was that trait anxiety would be negatively associated with both self-reported attentional control and the distinct components of performance-based EF (except for updating, which was supposed to follow the opposite direction). Therefore, we expected that individuals with high levels of trait anxiety would show lower scores in overall EF, with negative associations between the ability to inhibit information and to effectively switch between sets of tasks, but positive with the capacity to update working memory representations.

In the same line as Pacheco-Unguetti et al. (2010), Derryberry and Reed (2002), and Demetriou et al. (2021), self-reported trait anxiety was negatively associated with self-reported attentional control. This association held even after ensuring that the self-reported method of assessment for both questionnaires did not affect the results. Thus, in general, self-perceived levels of trait anxiety were associated with a lower sense of attentional control capacity.

To assess whether this finding extended to computerized tasks of EF, participants carried out a set of tasks consisting of a block-tapping, a flanker, and a feature-switching task. Contrary to our expectations and in contrast to previous studies (Ansari et al., 2008; Bishop, 2009; Pacheco-Unguetti et al., 2010) our results do not provide support that trait anxiety is associated with EF in general, nor with a deficiency in the top-down executive performance-based tasks in a community sample of

Table 2
Model fit indices regarding the influence of both Attentional Control and Trait Anxiety on either Updating (Model 1), Inhibition (Model 2), Switching (Model 3), and Speed of Processing (Model 4) latent variables.

Model	χ^2				Other			
	Statistic	df	*p*	χ^2/df	NFI	CFI	RMSEA	AIC
1	2.7	3	0.447	0.888	0.973	1	0	26.7
2	15.4	11	0.167	1.396	0.977	0.993	0.061	49.4
3	6.9	11	0.808	0.626	0.974	1	0	40.9
4	11.4	11	0.411	1.036	0.966	0.999	0.018	45.4

Note. df: degrees of freedom; χ^2/df: chi-square/degrees of freedom ratio; NFI: normed fit index; CFI: comparative fit index; RMSEA: root mean square error of approximation; AIC: Akaike information criterion.

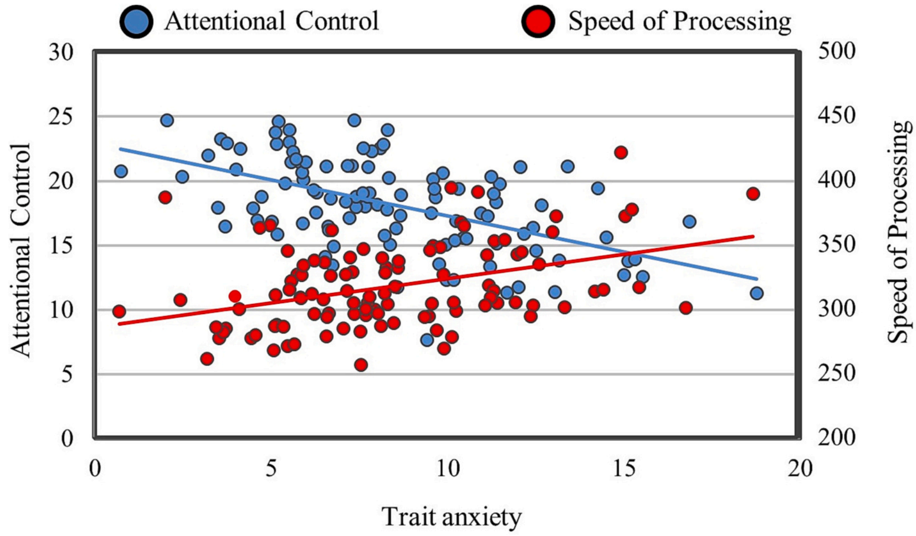

Fig. 2. Scatterplot showing the associations between the latent factor scores on Trait anxiety and self-reported Attentional control, and between Trait anxiety and Speed of Processing.

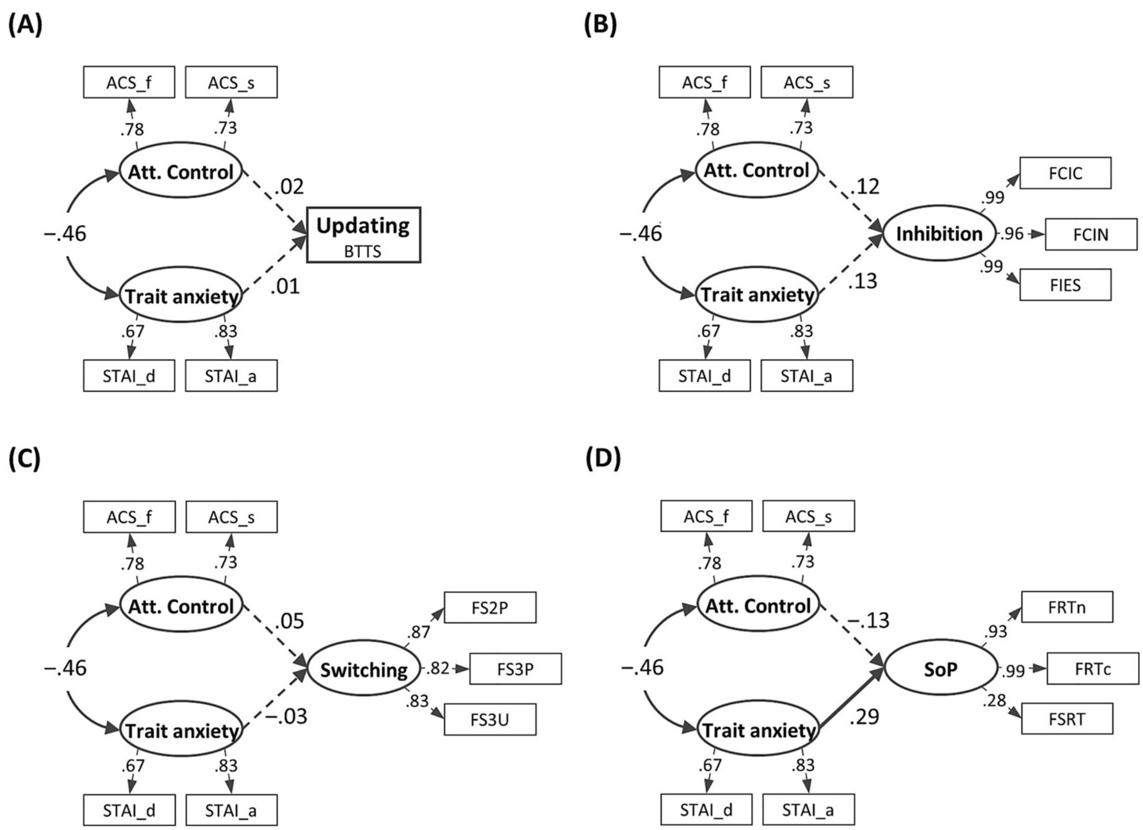

Fig. 3. Graphical representation of the results exploring the conjoined associations between Attentional control and Trait anxiety with (A) Updating, (B) Inhibition, (C) Switching, and (D) Speed of Processing (SoP). Ellipses indicate latent variables and rectangles show observable measures. Numbers alongside arrows represent the standardized direct effects (β). Arrows' dotted lines indicated non-significant ($p > 0.05$) associations, while continuous lines show significant associations ($p < 0.05$).

Note. Att. Control: self-perceived attentional control; ACS_f: ACS's focusing subscale; ACS_s: ACS's shifting subscale; STAI_d: STAI's depression subscale; STAI_a: STAI's anxiety subscale; BTTS: block-tapping total score; FCIC: incongruent–congruent proportional flanker costs; FCIN: incongruent–neutral proportional flanker costs; FIES: incongruent–congruent flanker inverse efficiency score; FS2P: feature-switching two-predictable features RT; FS3P: feature-switching three-predictable features RT; FS3U: feature-switching three-unpredictable features RT. SoP: Speed of Processing; FRTn: flanker task neutral condition RT; FRTc: flanker task congruent condition RT; FSRT: feature-switching mean RT.

young students (Ansari et al., 2008; Bishop, 2009; Pacheco-Unguetti et al., 2010). Regarding the block-tapping task, our results are inconsistent with previous works showing that working memory (as assessed by the Corsi block-tapping task) was associated with trait anxiety (Christopher & MacDonald, 2005; Eysenck et al., 2005). As stated earlier, visuospatial working memory tasks, such as the Corsi block-tapping task used here, might be resistant to the negative effects of trait anxiety, since the influence of anxiety on this component is modest (Christopher & MacDonald, 2005; Eysenck et al., 2005) or even positive when cognitive load is challenging for high anxious individuals (Demetriou et al., 2021).

In the same line, our results do not support the negative relation between trait anxiety and the interference control component of inhibition, contrary to previous reports (Bishop, 2009; Pacheco-Unguetti et al., 2010, 2009; Snyder et al., 2014; Visu-Petra et al., 2013). A potential reason for this may lie in the fact that our task was not demanding enough to capture a potential negative association with trait anxiety. For instance, Pacheco-Unguetti et al. (2010) presented a task that combined in a single experiment alerting tones and spatial cues before the target stimuli to explore the alerting, orienting, and executive networks. We believe this might have made their task more difficult, as their RTs to congruent and incongruent trials (Experiment 1) took over 200 ms longer (over 50 % slower) than those in the present study. Thus, a higher task difficulty in Pacheco-Unguetti et al.'s study might partially account for this discrepancy. Additionally, they tested participants with extreme scores in trait anxiety, which were above the 80th and below the 15th percentile for high and low-anxiety participants (scores ≥ 34 and ≤ 14, respectively). This may have yielded larger values in Pacheco-Unguetti et al.'s study in the 80th percentile, as compared to those in the present study (scores ≥ 30 and ≤ 14, respectively), which is another potential reason for the divergence with the present results. Another possible source for the discrepant results between both studies may lie in their use of an independent samples analytic approach, rather than the associative one adopted here. Following previous reports, extreme group categorization can inflate effect sizes (Fisher et al., 2020), which might misrepresent the relations between variables in the real world, can lead to the illusion of experimental control in designs that lack it (Humphreys, 1978), can diminish the accuracy of the estimated relations (Cohen, 1983) and is more prone to produce false-positive results (Vargha et al., 1996).

In terms of the switching ability, the lack of association between trait anxiety and shifting found in the present study might reveal that there is indeed no relation between both constructs, in line with previous reports (Bunce et al., 2008; Pacheco-Unguetti et al., 2010). However, it may also suggest that the feature-switching task used in the present study might not be the best candidate to measure task-switch costs. In this regard, our switching task only involves the continuous shifting between task sets and does not contain pure repetition trials, as other works include (Ansari et al., 2008; Derakshan, Smyth, & Eysenck, 2009). Gustavson et al. (2017) found that the association between shifting and trait anxiety depended on task demands, in particular when trying to switch away from an established task set. Given that our shifting paradigm forced participants to switch on every trial, it did not allow us to measure RTs to repeat trials and prevented us to quantify how established the task set was. In consequence, it was not possible to disentangle the cost of switching away from an established task set from the cost of reconfiguring the current task set. Additionally, the switcher task in the present study did not include trials with distinct anticipatory periods, which might have caused the absence of an association with anxiety, as greater switch costs are found in high trait-anxious individuals when time or preparation is short (Ansari et al., 2008).

Despite these results, we found that another non-executive broader component, speed of processing, showed a significant negative association with trait anxiety, which was restricted to slower overall RTs, while some previous works yielded opposite results in this regard (La Buissonnière-Ariza et al., 2013). A possible explanation for these opposite results could be that highly-anxious individuals show a high concern about task performance, and this could even lead to an increase in the allocation of processing resources, which might be inefficient for optimal task performance (Eysenck & Calvo, 1992). However, our results indicate that a stable temperamental predisposition to anxiety is associated with a slower speed of processing, in line with other previous studies (Eysenck et al., 2007; Labad et al., 2020). Task performance concerns are likely to lead to a larger and inefficient deployment of processing resources (Eysenck & Calvo, 1992). In this vein, high trait-anxious individuals might consume additional cognitive and emotional resources, which shall interfere with the performance of the task at hand (Baddeley, 2003; Eysenck et al., 2007), leading to overall slower task performance. Therefore, we show through a latent variable approach, that speed of processing is negatively influenced by high levels of negative affect in healthy young adults, in line with previous reports (Eysenck et al., 2007).

Nevertheless, the present work has several limitations. The first one concerns sample size. Although it is sufficient to carry out the analytic approach conducted (Gana & Broc, 2019), a larger sample would allow to improve the robustness of the structural models tested. The second limitation concerns the lack of a situational measure of anxiety, which would have helped to better discern its contribution to the results presented here. In this regard, further works might benefit from the inclusion of both self-reported and objective measures of state anxiety, such as cardiac or electrodermal indicators. Another potential limitation of the present study involves the use of a single working memory task in the visuospatial domain; it would be desirable to include a wider range of working memory tasks that permit a wider range of tasks assessing the updating component of EF. We also believe that the inclusion of a cued task-shifting paradigm with different anticipatory periods would add a valuable piece of evidence, as it would allow the calculation of a purer measure of switch costs under different preparatory temporal windows. Finally, although averaged RTs are reliable measures for the estimation of speed of processing, other performance-based indicators, such as the number of items completed in a given time, might be also useful to estimate the latent construct of processing speed.

In conclusion, the present study shows that a stable response style associated with a higher vulnerability to anxiety might reflect a slowed speed of processing. Furthermore, our results do not support a relation between trait anxiety and the updating of information in working memory, the capacity for interference control, and the ability to switch between task sets. We believe this study complements findings on the role of trait anxiety in a community sample of young adults tested with measures of performance-based EF other than self-reports (Bjelland et al., 2009).

Credit authorship contribution statement

All data and analysis script can be accessed at https://osf.io/9rhz6/. Daniel Adrover-Roig contributed to the conceptualization and wrote the original draft; Victor Sanchez-Azanza contributed to the formal analysis, reviewed and edited the draft; Lucía Buil-Legaz contributed to the conceptualization, reviewed and edited the draft; Raúl López-Penadés contributed to the conceptualization, methodology, reviewed and edited the draft; Eva María Aguilar-Mediavilla contributed to the conceptualization, reviewed and edited the draft.

Declaration of competing interest

The authors declare that they had no conflicts of interests with respect to their authorship and/or the publication of this article.

Data availability

Data will be made available on request.

Acknowledgments

This study received the support of Grants EDU2017-85909-P funded by MCIN/AEI/10.13039/501100011033 and by "ERDF A way of making Europe", grant PID2021-123770OB-I00, funded by MCIN/AEI/10.13039/501100011033 and by "ERDF A way of making Europe", and a predoctoral grant to the second author; grant BES-2014-069063 funded by MCIN/AEI/10.13039/501100011033 and by "ESF Investing in your future".

References

Alfonso, S. V., & Lonigan, C. J. (2021). Trait anxiety and adolescent's academic achievement: The role of executive function. *Learning and Individual Differences, 85* (December 2020), Article 101941. https://doi.org/10.1016/j.lindif.2020.101941

Anderson, K., Deane, K., Lindley, D., Loucks, B., & Veach, E. (2012). The effects of time of day and practice on cognitive abilities: The PEBL tower of London, trail-making, and switcher tasks. In *PEBL Technical Report Series*. Michigan Technological University. https://sites.google.com/site/pebltechnicalreports/home/2012/pebl-technical-report-2012-04.

Ansari, T. L., Derakshan, N., & Richards, A. (2008). Effects of anxiety on task switching: Evidence from the mixed antisaccade task. *Cognitive, Affective, & Behavioral Neuroscience, 8*(3), 229–238. https://doi.org/10.3758/CABN.8.3.229

Baddeley, A. (2003). Working memory: Looking back and looking forward. *Nature Reviews Neuroscience, 4*(10). https://doi.org/10.1038/nrn1201

Baddeley, A. D. (1986). *Working memory*. Clarendon Press.

Berggren, N., & Derakshan, N. (2013). Attentional control deficits in trait anxiety: Why you see them and why you don't. *Biological Psychology, 92*(3), 440–446. https://doi.org/10.1016/j.biopsycho.2012.03.007

Bieling, P. J., Antony, M. M., & Swinson, R. P. (1998). The state-trait anxiety inventory, trait version: Structure and content re-examined. *Behaviour Research and Therapy, 36* (7–8), 777–788. https://doi.org/10.1016/S0005-7967(98)00023-0

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience, 12*(1). https://doi.org/10.1038/nn.2242

Bjelland, I., Lie, S. A., Dahl, A. A., Mykletun, A., Stordal, E., & Kraemer, H. C. (2009). A dimensional versus a categorical approach to diagnosis: Anxiety and depression in the HUNT 2 study. *International Journal of Methods in Psychiatric Research, 18*(2), 128–137. https://doi.org/10.1002/mpr.284

Bruyer, R., & Brysbaert, M. (2011). Combining speed and accuracy in cognitive psychology: Is the inverse efficiency score (IES) a better dependent variable than the mean reaction time (RT) and the percentage of errors (PE)? *Psychologica Belgica, 51* (1). https://doi.org/10.5334/pb-51-1-5

Buchanan, T. (2016). Self-report measures of executive function problems correlate with personality, not performance-based executive function measures, in nonclinical samples. *Psychological Assessment, 28*(4), 372–385. https://doi.org/10.1037/pas0000192

Bunce, D., Handley, R., & Gaines, S. O. (2008). Depression, anxiety, and within-person variability in adults aged 18 to 85 years. *Psychology and Aging, 23*(4). https://doi.org/10.1037/a0013678

Byrne, A., & Eysenck, M. W. (1995). Trait anxiety, anxious mood, and threat detection. *Cognition and Emotion, 9*(6), 549–562. https://doi.org/10.1080/02699939508408982

Capitão, L. P., Underdown, S. J. V., Vile, S., Yang, E., Harmer, C. J., & Murphy, S. E. (2014). Anxiety increases breakthrough of threat stimuli in continuous flash suppression. *Emotion, 14*(6). https://doi.org/10.1037/a0037801

Caselli, R. J., Reiman, E. M., Hentz, J. G., Osborne, D., & Alexander, G. E. (2004). A distinctive interaction between chronic anxiety and problem solving in asymptomatic APOE e4 homozygotes. *Journal of Neuropsychiatry and Clinical Neurosciences, 16*(3). https://doi.org/10.1176/jnp.16.3.320

Castaneda, A. E., Tuulio-Henriksson, A., Marttunen, M., Suvisaari, J., & Lönnqvist, J. (2008). A review on cognitive impairments in depressive and anxiety disorders with a focus on young adults. *Journal of Affective Disorders, 106*(1–2), 1–27. https://doi.org/10.1016/j.jad.2007.06.006

Christopher, G., & MacDonald, J. (2005). The impact of clinical depression on working memory. *Cognitive Neuropsychiatry, 10*(5), 379–399. https://doi.org/10.1080/13546800444000128

Cohen, J. (1983). The cost of dichotomization. *Applied Psychological Measurement, 7*(3). https://doi.org/10.1177/014662168300700301

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*(3), 201–215. https://doi.org/10.1038/nrn755

Corsi, P. M. (1972). *Human memory and the medial temporal region of the brain*. McGill University.

Croschere, J., Dupey, L., Hilliard, M., Koehn, H., & Mayra, K. (2012). The effects of time of day and practice on cognitive abilities: Forward and backward Corsi block test and digit span. In *PEBL technical report series*. https://sites.google.com/site/pebltechnicalreports/home/pebl-technical-report-2012-03.

de Bruin, A., & Della Sala, S. (2018). Effects of age on inhibitory control are affected by task-specific features. *Quarterly Journal of Experimental Psychology, 71*(5), 1219–1233. https://doi.org/10.1080/17470218.2017.1311352

Demetriou, E. A., Park, S. H., Pepper, K. L., Naismith, S. L., Song, Y. J., Thomas, E. E., … Guastella, A. J. (2021). A transdiagnostic examination of anxiety and stress on executive function outcomes in disorders with social impairment. *Journal of Affective Disorders, 281*(November 2019), 695–707. https://doi.org/10.1016/j.jad.2020.11.089

Derakshan, N., Ansari, T. L., Hansard, M., Shoker, L., & Eysenck, M. W. (2009). Anxiety, inhibition, efficiency, and effectiveness. *Experimental Psychology, 56*(1), 48–55. https://doi.org/10.1027/1618-3169.56.1.48

Derakshan, N., Smyth, S., & Eysenck, M. W. (2009). Effects of state anxiety on performance using a task-switching paradigm: An investigation of attentional control theory. *Psychonomic Bulletin & Review, 16*(6), 1112–1117. https://doi.org/10.3758/PBR.16.6.1112

Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology, 111*(2), 225–236. https://doi.org/10.1037/0021-843X.111.2.225

Derryberry, D., & Rothbart, M. K. (1988). Arousal, affect, and attention as components of temperament. *Journal of Personality and Social Psychology, 55*(6), 958–966. https://doi.org/10.1037/0022-3514.55.6.958

Endler, N. S., Cox, B. J., Parker, J. D., & Bagby, R. M. (1992). Self-reports of depression and state-trait anxiety: Evidence for differential assessment. *Journal of Personality and Social Psychology, 63*(5). https://doi.org/10.1037//0022-3514.63.5.832

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon identification of a target letter in a non-search task. *Perception & Psychophysics, 16*(1), 143–149. https://doi.org/10.3758/bf03203267

Etkin, A., Büchel, C., & Gross, J. J. (2015). The neural bases of emotion regulation. In. *Nature Reviews Neuroscience, 16*(11). https://doi.org/10.1038/nrn4044

Eysenck, M. W. (2000). A cognitive approach to trait anxiety. *European Journal of Personality, 14*(5), 463–476. https://doi.org/10.1002/1099-0984(200009/10)14:5<463::AID-PER393>3.0.CO;2-3

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition & Emotion, 6*(6), 409–434. https://doi.org/10.1080/02699939208409696

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*(2), 336–353. https://doi.org/10.1037/1528-3542.7.2.336

Eysenck, M. W., Payne, S., & Derakshan, N. (2005). Trait anxiety, visuospatial processing, and working memory. *Cognition & Emotion, 19*(8), 1214–1228. https://doi.org/10.1080/02699930500260245

Fisher, J. E., Guha, A., Heller, W., & Miller, G. A. (2020). Extreme-groups designs in studies of dimensional phenomena: Advantages, caveats, and recommendations. *Journal of Abnormal Psychology, 129*(1). https://doi.org/10.1037/abn0000480

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General, 133*, 101–135. https://doi.org/10.1037/0096-3445.133.1.101

Gana, K., & Broc, G. (2019). *Structural equation modeling with lavaan*. Wiley. https://doi.org/10.1002/9781119579038

Garner, M., Ainsworth, B., Gould, H., Gardner, H., & Baldwin, D. (2009). Impaired attentional control in high and low anxious healthy volunteers: Evidence from the antisaccade task. *European Neuropsychopharmacology, 19*, S599. https://doi.org/10.1016/S0924-977X(09)70960-5

Gustavson, D. E., Altamirano, L. J., Johnson, D. P., Whisman, M. A., & Miyake, A. (2017). Is set shifting really impaired in trait anxiety? Only when switching away from an effortfully established task set. *Emotion, 17*(1), 88–101. https://doi.org/10.1037/emo0000212

Humphreys, L. G. (1978). Research on individual differences requires correlational analysis, not ANOVA. *Intelligence, 2*(1). https://doi.org/10.1016/0160-2896(78)90010-7

Kessels, R. P. C., van Zandvoort, M. J. E., Postma, A., Kappelle, L. J., & de Haan, E. H. F. (2000). The Corsi block-tapping task: Standardization and normative data. *Applied Neuropsychology, 7*(4), 252–258. https://doi.org/10.1207/S15324826AN0704_8

La Buissonnière-Ariza, V., Lepore, F., Kojok, K. M., & Frasnelli, J. (2013). Increased odor detection speed in highly anxious healthy adults. *Chemical Senses, 38*(7). https://doi.org/10.1093/chemse/bjt028

Labad, J., Salvat-Pujol, N., Armario, A., Cabezas, Á., de Arriba-Arnau, A., Nadal, R., … Soria, V. (2020). The role of sleep quality, trait anxiety and hypothalamic-pituitary-adrenal axis measures in cognitive abilities of healthy individuals. *International Journal of Environmental Research and Public Health, 17*(20). https://doi.org/10.3390/ijerph17207600

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100. https://doi.org/10.1006/cogp.1999.0734

Morrison, T. G., Morrison, M. A., & McCutcheon, J. M. (2017). Best practice recommendations for using structural equation modelling in psychological research. *Psychology, 08*(09). https://doi.org/10.4236/psych.2017.89086

Mueller, S. T., & Piper, B. J. (2014). The psychology experiment building language (PEBL) and PEBL test battery. *Journal of Neuroscience Methods, 222*, 250–259. https://doi.org/10.1016/j.jneumeth.2013.10.024

Ng, E. L., & Lee, K. (2016). Test anxiety and children's working memory task performance: Does trait or state anxiety matter more? *Journal of Experimental Psychopathology, 7*(3). https://doi.org/10.5127/jep.054115

Ólafsson, R. P., Smári, J., Guðmundsdóttir, F., Ólafsdóttir, G., Harðardóttir, H. L., & Einarsson, S. M. (2011). Self reported attentional control with the Attentional Control Scale: Factor structure and relationship with symptoms of anxiety and depression. *Journal of Anxiety Disorders, 25*(6), 777–782. https://doi.org/10.1016/j.janxdis.2011.03.013

Pacheco-Unguetti, A. P., Acosta, A., Callejas, A., & Lupiáñez, J. (2010). Attention and anxiety. *Psychological Science, 21*(2), 298–304. https://doi.org/10.1177/0956797609359624

Pacheco-Unguetti, A. P., Lupiáñez, J., & Acosta, A. (2009). Atención y ansiedad : Relaciones de la alerta y el control cognitivo con la ansiedad rasgo. *Psicológica, 30* (January), 1–25. https://www.redalyc.org/pdf/169/16911973001.pdf.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology, 88*(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Posner, M., Rueda, M. R., & Kanske, P. (2007). Probing the mechanism of attention. In J. T. Cacioppo, J. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (Third edit, pp. 410–432). Cambridge University Press.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*(3). https://doi.org/10.1037//0033-295x.103.3.403

Sanchez-Azanza, V. A., López-Penadés, R., Aguilar-Mediavilla, E., & Adrover-Roig, D. (2020). Latent variable evidence on the interplay between language switching frequency and executive control in Spanish-Catalan bilinguals. *International Journal of Bilingualism, 24*(5–6). https://doi.org/10.1177/1367006920902525

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online, 8*(2).

Schreiber, J. B., Stage, F. K., King, J., Nora, A., & Barlow, E. (2006). Reporting structural equation modeling and confirmatory factor analysis results: A review. *The Journal of Educational Research, 99*(6), 323–338.

Shields, G. S., Sazma, M. A., & Yonelinas, A. P. (2016). The effects of acute stress on core executive functions: A meta-analysis and comparison with cortisol. *Neuroscience and Biobehavioral Reviews, 68*, 651–668. https://doi.org/10.1016/j.neubiorev.2016.06.038

Snyder, H. R., Kaiser, R. H., Whisman, M. A., Turner, A. E. J., Guild, R. M., & Munakata, Y. (2014). Opposite effects of anxiety and depressive symptoms on executive function: The case of selecting among competing options. *Cognition & Emotion, 28*(5), 893–902. https://doi.org/10.1080/02699931.2013.859568

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the state-trait anxiety inventory*. Consulting Psychologists Press.

Spielberger, C. D., & Reheiser, E. C. (2009). Assessment of emotions: Anxiety, anger, depression, and curiosity. *Applied Psychology. Health and Well-Being, 1*(3). https://doi.org/10.1111/j.1758-0854.2009.01017.x

Vargha, A., Rudas, T., Delaney, H. D., & Maxwell, S. E. (1996). Dichotomization, partial correlation, and conditional Independence. *Journal of Educational and Behavioral Statistics, 21*(3). https://doi.org/10.3102/10769986021003264

Visu-Petra, L., Miclea, M., & Visu-Petra, G. (2013). Individual differences in anxiety and executive functioning: A multidimensional view. *International Journal of Psychology, 48*(4). https://doi.org/10.1080/00207594.2012.656132

Waldstein, S. R., Ryan, C. M., Jennings, J. R., Muldoon, M. F., & Manuck, S. B. (1997). Self-reported levels of anxiety do not predict neuropsychological performance in healthy men. *Archives of Clinical Neuropsychology, 12*(6). https://doi.org/10.1016/S0887-6177(97)00013-9

Wieser, M. J., Pauli, P., & Mühlberger, A. (2009). Probing the attentional control theory in social anxiety: An emotional saccade task. *Cognitive, Affective, & Behavioral Neuroscience, 9*(3), 314–322. https://doi.org/10.3758/CABN.9.3.314