No Trait Anxiety Linked Differences in Affective and Non-Affective Task Switching

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Abstract

Elevated levels of trait anxiety are argued to interfere with the ability to shift attention between different task sets, yet empirical support for this hypothesis is scarce. Using a task-switching paradigm in two separate studies, we compared high and low trait anxious participants' ability to switch from non-affective, positive, and negative tasks to different non-affective tasks. In Study 1 (N = 59 high and low trait anxious undergraduate students), we found that non-affective-to-non-affective switch costs were smaller than both positive-to-non-affective and negative-to-non-affective switch costs, and positive-to-non-affective switch costs were smaller than negative-to-non-affective switch costs. In Study 2 (N = 97 high and low trait anxious community members), we found that non-affective-to-non-affective switch costs and positive-to-non-affective switch costs were both smaller than negative-to-non-affective switch costs, but positive-to-non-affective and non-affective-to-non-affective switch costs did not differ. Crucially, none of the switch costs in either of the studies or in an analysis of the combined data differed between high and low trait anxious groups. While we cannot exclude the possibility that anxiety linked differences in task-switching do exist when switching from more demanding to less demanding tasks, our studies found no evidence for the general idea that elevated trait anxiety interferes with attentional shifting.

Keywords: Task-switching, Attentional shifting, Attentional Control Theory, Trait anxiety.

Highlights

- Two studies assessed trait anxiety (TA) linked differences in task switching (TS)
- No TA-linked differences in overall TS ability
- No TA-linked differences in positive-neutral, negative-neutral, neutral-neutral TS
- Similar findings in reaction times and errors
- Overall no evidence for TA-linked impaired attentional shifting

No Trait Anxiety Linked Differences in Affective and Non-Affective Task-Switching

1. Introduction

Trait anxiety refers to the stable tendency to experience heightened levels of anxiety in a broad range of situations. Elevated levels of trait anxiety are associated with an increased risk of developing clinical anxiety (Chambers et al., 2004), making a thorough understanding of the processes associated with elevated trait anxiety imperative. According to the influential Attentional Control Theory (ACT; Eysenck et al., 2007), elevated trait anxiety increases the amount of attention given to threat and impairs attentional control. Attentional control is a key executive function and includes the ability to shift and switch attention between different task sets or task demands. Impaired attentional shifting may leave high trait anxious individuals vulnerable to maladaptive attentional processes which may further exacerbate anxiety and impair wellbeing. For example, impairments in shifting away from negative materials may facilitate repetitive negative thinking, which is associated with heightened anxiety (Spinhoven et al., 2018). Attentional shifting is often assessed using task-switching paradigms (for reviews, see Monsell, 2003; Vandierendonck et al., 2010), in which participants are required to either repeat the same task as on the previous trial (repetition trials) or switch to a different task (switch trials). Reaction times (RTs) on switch trials are typically longer than RTs on repetition trials, and the difference between these two trial types is referred to as the switch cost, with higher switch costs indicating poorer attentional shifting.

While ACT predicts that elevated trait anxiety should be associated with greater switch costs, studies investigating the relation between trait anxiety and attentional shifting between *affectively neutral* tasks have thus far yielded inconclusive or mixed results (Kofman et al., 2006; Visu-Petra et al., 2013). For example, Derakshan et al. (2009) used a task which could repeat or alternate between different tasks and found that high state anxious participants showed higher switch costs than low state anxious participants, but they did not compare high and low *trait* anxious groups. Bunce et al. (2008) found no association between trait anxiety and RTs on switch trials, but they did not report the correlations between trait anxiety and *switch costs*. More recently, Gustavson et al. (2017) developed a task in which participants had to switch between easy and more demanding non-affective tasks. Larger switch costs were found only when switching from the more demanding task to the less demanding task and this was exaggerated for those reporting high trait anxiety. This suggests that there is no anxiety-related deficit in general task-switching, but rather a specific difficulty when shifting away from attentionally demanding tasks.

Given that high trait anxiety is associated with a tendency to attend to valenced, and in particular negatively valenced stimuli (Bar-Haim et al., 2007), trait anxiety linked task-switching deficits may only be apparent when switching away from affective tasks to non-affective tasks. This hypothesis would be consistent with earlier studies showing that high trait anxious participants take longer than their low trait anxious counterparts to shift attention away from threat-related stimuli (Fox et al., 2002). It is also consistent with clinical reports suggesting that anxious clients tend to perseverate on negative thoughts (Clark, 2001). Few studies have directly addressed the relation between trait anxiety and attentional shifting between tasks involving an affective judgement, although some studies have examined the association between such affective task-switching and constructs related to anxiety. For example, smaller switch costs when shifting from affective to non-affective aspects of negative stimuli is associated with increased effectiveness of reappraisal (Malooly et al., 2013) and decreased rumination (Genet et al., 2013). Twivy et al. (2021) measured trait anxiety at two different time points (T1 and T2) with seven weeks in between, and they measured the cost of attentional shifting between tasks involving affective judgments and affective materials at T1. They found that more efficient shifting away from the affective aspects of negative stimuli was predictive of *increased* anxiety over time (i.e., trait anxiety at T2 correcting for trait anxiety at

T1), while more efficient shifting of attention towards affective aspects of positive stimuli predicted smaller increases in trait anxiety over time. However, Twivy et al. found no significant correlations between any of their switch costs and trait anxiety, either T1 or T2. Finally, Johnson (2009) asked participants to respond to either the emotional expressions of happy, angry, or neutral face pictures (affective task) or to shapes that were presented between the faces' eyes (neutral task). They found that high trait anxiety was associated with larger switch costs when switching from the neutral to the affective task, but not when switching from the affective to the neutral task.

Johnson's (2009) results thus appear to contradict the hypothesis that trait anxiety is associated with a task-switching deficit specifically when switching away from affective tasks to non-affective tasks. However, the number of trials in each of the different trial types in Johnson´s study was not balanced. While they presented a limited number of affective-to-non-affective switches, non-affective-to-affective switches, and non-affective repetitions, a large majority of trials consisted of affective repetitions. This overrepresentation of affective repetitions likely resulted in increased practice effects on this task set, leading to faster RTs on affective repetitions and slower RTs on affective-to-non-affective switches, and may thus have distorted the resulting switch costs. To thoroughly test the hypothesis that trait anxiety is associated with deficits switching away from affective tasks to non-affective tasks, equal number of switch and repetition trials should be used in each condition. In addition, their affective task included both positive and negative stimuli. However, their analyses did not differentiate between switch costs associated with shifting from the positive versus the negative stimulus dimension in the affective task. Given that high trait anxiety is associated with a disproportionate tendency to allocate attention to negative information in particular (Bar-Haim et al., 2007), anxiety linked switching deficits towards non-affective tasks may be only apparent when switching away from negative affective tasks.

In the current study, groups of high and low trait anxious participants completed a task-switching paradigm involving non-affective tasks that were preceded by either the same non-affective task (non-affective repetitions), or by a positive affective task, i.e. a task that required judging whether or not a stimulus was positive in valence (positive-to-non-affective switches), a negative affective task, i.e. a task that required judging whether or not a stimulus was negative in valence (negative-to-non-affective switches), or a different non-affective task (non-affective-to-non-affective switches). The design was balanced such that there were equal numbers of trials in each condition. Our main aim was to test the veracity of three alternative hypotheses. A first possibility is that – in line with the ACT – switching from any task to a different task should be impaired in high anxious participants, and thus all switch costs should be larger in high compared to low trait anxious groups. Alternatively, high trait anxiety may impair only the ability to shift away from attentionally demanding stimuli (Gustavson et al., 2017). If this is true, only switching from the affective tasks to a non-affective task should be affected, and both the positive-to-non-affective and the negative-to-non-affective switch costs (but not the non-affective-to-non-affective switch cost) should be larger in high compared to low trait anxious groups. Finally, high trait anxiety may impair specifically shifting away from negative tasks. If this is true, only switching from the negative task to a non-affective task should be affected, and thus only the negative-to-non-affective switch costs should be larger in high compared to low trait anxious groups.

2. Study 1

2.1. Method

2.1.1. Participants

A total of 60 participants (48 women, age *M* = 19.47, *SD* = 3.85), recruited from the University of Western Australia’s undergraduate research participant pool, took part in this study in exchange for course credits. Our sample size was based on the sample size of

Derakshan et al. (2009). A sensitivity analysis with G*Power (Faul et al., 2007), with a conventional value of .80 for statistical power, 60 participants divided over two groups, and three repeated measurements with an estimated correlation between repeated measures of .50 showed that our sample was large enough to detect minimal effect sizes of f = .17, corresponding with small to medium sized effects. To obtain subsamples of high trait anxious (HTA) and low trait anxious (LTA) participants, we invited students who scored in the top (scores > 50) and bottom (scores < 38) tertiles on the trait version of the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983; see below) during a screening at the start of the semester.

2.1.2. State-Trait Anxiety Inventory (Spielberger et al., 1983).

The trait and state versions (STAI-T and STAI-S) of the STAI were used to assess dispositional and current anxiety, respectively. Both questionnaires consist of 20 statements, and each statement is scored on a 4-point Likert scale. Cronbach's alphas in our sample were .95 for the STAI-T and .96 for the STAI-S. Because we recruited HTA and LTA groups based on screening scores, both anxiety measures only served to describe our sample and to check whether our recruitment procedure did indeed result in high versus low anxious groups.

2.1.3. Materials

For the task-switching paradigm, a total of 96 pictures were selected from the International Affective Picture System (Lang et al., 2008). Of these 96 pictures, 16 pictures were positive (valence M = 7.89, SD = 0.32; arousal M = 4.81, SD = 0.78) and 16 pictures were negative (valence M = 2.67, SD = 0.42; arousal M = 4.76, SD = 0.47). The remaining 64 pictures were emotionally neutral (valence M = 5.30, SD = 0.13; arousal M = 3.63, SD = 0.76). The neutral pictures depicted either indoor versus outdoor scenes and either involved people versus no people, with 16 pictures for each combination of these two dimensions. Valence ratings differed significantly for all sets, all ts > 24.65, all ps < .001. Arousal ratings for the neutral set differed significantly from the arousal ratings of both the positive and the negative set, both *t*s > 5.50, both *p*s < .001, with no difference in arousal between the positive and negative sets, $t < 0$, $p = .83$. Emotional pictures equally often contained people versus no people and depicted equally often indoor versus outdoor scenes. Pictures were presented in their original size (maximum size of 1024 x 768 pixels).

2.1.4. Measure of Affective and Non-Affective Attentional Shifting: Task-Switching Paradigm

We developed a task-switching paradigm to measure both affective and non-affective attentional shifting within a single paradigm (Figure 1). It involved four different task sets: Judging whether or not a picture was positive (positive affective task set), judging whether or not a picture was negative (negative affective task set), judging whether or not a picture presented an outdoor scene (non-affective task set 1), or judging whether or not a picture contained people (non-affective task set 2). For trials involving the positive (or negative) affective task sets, pictures could be either positive (or negative) or neutral. For the non-affective task sets, only neutral pictures were presented. To obtain an equal amount of observations in each cell of the design, we grouped trials into pairs, and we only analysed the RTs to the second trial in each pair. There were 6 different types of trial pairs: (1) positive-to-positive repetition pairs, (2) positive-to-non-affective switch pairs, (3) negative-to-negative repetition pairs, (4) negative-to-non-affective switch pairs, (5) non-affective-to-non-affective repetition pairs, and (6) non-affective-to-non-affective switch pairs.

From responses on the second trial of these trial pairs, we calculated three different switch cost indices. First, reflecting *positive attentional shifting*, positive-to-non-affective switch costs were calculated by subtracting the average RTs on non-affective-to-non-affective repetitions from the average RTs on positive-to-non-affective switch trials. Second, reflecting *negative attentional shifting*, negative-to-non-affective switch costs were calculated by subtracting average RTs on non-affective-to-non-affective repetitions from average RTs on negative-to-non-affective switch trials. Third, reflecting *non-affective attentional shifting*, non-affective-to-non-affective switch costs were calculated by subtracting average RTs on non-affective-to-non-affective repetitions from average RTs on non-affective-to-non-affective switch trials. These calculations ensured that there were no differences in affectivity between the two RTS that were compared (both were for non-affective tasks). As such, the switch cost only reflects the impairment in RT when switching away from another task to a non-affective task, relative to repeating a non-affective task. For the analyses of the error rates, we calculated the equivalent scores.

Each trial started with the presentation of a 500ms white fixation cross on a black background. Next, a picture and a task-cue were presented simultaneously. The task-cues were audio files consisting of a single word ('positive', 'negative', 'outside', 'people'), presented through headphones, and indicated which task set was to be used on any given trial. Participants classified pictures according to the current task set using the y-key (yes) and the n-key (no) on a standard QWERTY keyboard. Pictures remained on the screen until a response was registered. Correct responses were followed by a 500ms inter-trial interval, after which the next trial started. Incorrect responses were followed by a 3000ms error message to not adversely affect RTs on the next trial, after which the 500ms inter-trial interval started. Participants were asked to respond as accurately as possible.

The task consisted of 288 trial pairs in total, distributed over 6 blocks of 48 trial pairs each. After each block, participants could take a self-paced break. The 6 different types of trial pairs were distributed evenly across blocks and presented in a random order, and each picture was presented once per block. Prior to the test block, participants completed a practice block consisting of 24 trial pairs in which feedback was provided on both correct and incorrect responses. Each task set was practiced in 6 randomly ordered trial pairs, using pictures from a separate picture set.

2.1.5. Procedure

Participants were informed of the general nature of the task and stimuli prior to providing written informed consent. Next, participants completed the questionnaires and the task-switching paradigm.[1] Participants were debriefed after completing the study. The procedure was approved by the Human Research Ethics Office of the University of Western Australia (ref. number RA/4/1/5243).

2.1.6. Outlier Analysis and Scoring

The task-switching paradigm data of one participant were removed prior to all further analyses because their error rate deviated more than 3 *SD*s from the group mean (M = 95.69% correct, SD = 3.24, participant's score = 83.68% correct. We then removed the first trial of each trial pair, and we calculated the error rates for each trial type. Next, we removed errors (3.63%) and outlying RTs, identified for each task set separately, following the absolute deviation around the median procedure described by Leys et al. (2013) with a moderately conservative threshold of 2.5. This resulted in the removal of 11.00%, 11.09%, 10.70%, and 10.43% of trials for the people, outside, positive, and negative task sets, respectively.[2]

2.2. Results

Table 1 presents descriptive statistics for all variables of interest. The HTA and LTA groups did not differ in age, $t < 1$, or gender distribution, $\chi^2(1) = 3.75$, $p > .05$. Reflecting our recruitment procedure, the HTA group had higher trait and state anxiety scores at the time of testing than the LTA group, both ts > 6.00, both ps < .001. Trait and state anxiety were strongly positively correlated, Spearman's $\rho = .78$, $p < .001$.

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[1] The procedure also included three additional questionnaires that were used for exploratory purposes and that are not included in this manuscript. These were the Coping Flexibility Scale (Kato, 2013), the Penn State Worry Questionnaire (Meyer et al., 1990), and the Cognitive Flexibility Inventory (Dennis & Vander Wal, 2010).

[2] More details on outlier treatment, as well as the raw and transformed data and output files, are available on https://osf.io/n2k9b

Our study's crucial tests addressed the differences between HTA and LTA groups in attentional shifting. We ran a 2 (Anxiety Group: HTA vs. LTA) x 3 (Valence: positive-to-non-affective vs. negative-to-non-affective vs. non-affective-to-non-affective) mixed-measures ANOVA on the RT switch costs, with Anxiety Group as a between subjects factor and Valence as a within subjects factor. This analysis revealed a significant main effect of Valence, $F(2, 56) = 5.89$, $p = .005$, $f = 0.40$, but no significant main effect of Anxiety Group, $F(1, 57) = 1.06$, $p = .31$, nor a significant interaction, $F < 1$, $p = .40$, $f = 0.18$. The main effect of Valence indicated that, irrespective of Anxiety Group, the cost associated with switching to a non-affective task depended on the nature of the preceding task. Non-affective-to-non-affective switch costs ($M = 69.31$, $SD = 62.95$) were smaller than both negative-to-non-affective switch costs ($M = 97.19$, $SD = 72.83$), $F(1, 58) = 12.10$, $p = .001$, $f = 0.46$, and positive-to-non-affective switch costs ($M = 85.30$, $SD = 65.74$), $F(1, 58) = 6.30$, $p = .015$, $f = 0.33$, suggesting that switching from affective to neutral tasks is more demanding. Positive-to-non-affective switch costs were also smaller than negative-to-non-affective switch costs, $F(1, 58) = 5.31$, $p = .025$, $f = 0.30$. An identical analysis of the switch costs from the error rates revealed neither significant main effects (Valence: $F(2, 56) = 2.66$, $p = .079$, $f = 0.31$; Anxiety Group: $F(1, 57) < 1$, $p = .562$, $f = 0.08$) nor a significant interaction, $F(2, 56) < 1$, $p = .488$, $f = 0.16$.

In order to assess the degree to which the data supported the null hypothesis (switch costs are not affected by trait anxiety) versus the alternative hypothesis (switch costs are affected by trait anxiety), we used JASP (2020) to run Bayesian mixed measures ANOVAs with default priors, again with Valence as within and Anxiety Group as between subjects factors. For the RTs, compared to the null model, this analysis provided very strong support favouring the model including the main effect of Valence, $BF_{10} = 91.92$. After adding the main effect of Valence to the null model, we found anecdotal evidence against the model including the main effect of Anxiety Group, $BF_{10} = 0.56$, and strong evidence against the model including the main effect of Anxiety Group and the interaction between Anxiety Group and Valence, BF_{10} = 0.09. As such, these analyses further support the conclusion that while switch costs to non-affective tasks are affected by the valence of the preceding task, high and low trait anxious groups did not differ in their ability to switch from either positive, negative, or non-affective tasks sets to a (different) non-affective task set. In the equivalent analysis on the switch costs from the errors, we found anecdotal evidence against the model with the main effect of Valence (BF_{10} = 0.52), moderate evidence against the model with the main effect of Anxiety Group (BF_{10} = 0.33), and strong evidence against the model with both main effects and the interaction (BF_{10} = 0.03). In other words, also in the analysis of the errors did HTA and LTA groups not differ in their task-switching ability.

2.3. Discussion

The results of Study 1 are easily summarized: While we found that the nature of the preceding task affected the cost of switching to a subsequent non-affective task, we found no trait anxiety linked differences in either overall switch costs or valence-specific switch costs. As such, our findings are in conflict with one of the central assumptions of the ACT, according to which elevated trait anxiety impairs attentional control and thus hampers one's ability to switch between tasks. However, as our sample size was relatively small, we cannot exclude the possibility that relatively small anxiety linked differences in task-switching do exist. To counter this limitation and because replications are paramount for the transparency and verifiability of findings (Cumming, 2014; Pashler & Wagenmakers, 2012), we conducted a second study, in which we replicated the procedure of Study 1 in a larger community sample. In line with the hypotheses following from the ACT (and the hypotheses tested in Study 1), we predicted impaired switching in high compared to low anxious participants, and we assessed whether such anxiety linked differences in switch costs were affected by the nature of the preceding task.

3. Study 2

3.1. Method

3.1.1. Participants

We invited 100 participants (48 women, 50 men, 2 non-binary, age *M* = 43.92, *SD* = 12.67) from MTurk to participate in our study in exchange for USD10 (median duration was 45 minutes). Workers scoring in the top (scores > 48) and bottom (scores < 35) tertiles on the STAI-Trait during a large screening conducted in the year previous to when testing took place were invited for the HTA and LTA groups, respectively. A sensitivity analysis using G*Power (Faul et al., 2003), with two groups, three repeated measures, conventional values of .05 for alpha and .80 for power, and a correlation between repeated measures of .63 (i.e., the smallest correlation between repeated measures in Study 1), showed that our sample size was large enough to detect relatively small effects (with *f*s of 0.11 and larger).

3.1.2. Procedure

All measures and the general procedure were identical to the measures and procedure adopted in Study 1, except (1) Study 2 was conducted online, (2) we reduced the number of trial pairs in the practice phase of the task-switching paradigm from 24 to 12, and (3) we removed the exploratory questionnaires from the procedure. Cronbach's alpha's for the STAI-T and STAI-S in our sample were both .98. Upon completion of the study, participants were debriefed and received compensation. The procedure was approved by the Human Research Ethics Office of the University of Western Australia (ref. number RA/4/1/5243).

3.1.3. Outlier Analysis and Scoring

Our approach to outliers and scoring was identical to the one used in Study 1. The task-switching paradigm data of three participants were removed prior to all further analyses because their error rates deviated more than 3 *SD*s from the group mean (*M* = 95.35% correct, *SD* = 3.58, participant's scores = 81.77, 82.64, and 83.16% correct. Next, we removed the first trial of each trial pair, errors (3.53%), and 6.11%, 6.79%, 7.43%, and 7.42% of trials with outlying RTs for the people, outside, positive, and negative task sets, respectively (more details are provided in the data cleaning protocol, available on the study's OSF-page).

3.2. Results

Descriptive statistics for all variables of interest are presented in Table 2. The HTA and LTA groups did not differ in age, $t(98) = 1.80$, $p = .074$, but the LTA group had more male and less female participants (vice-versa for the HTA group), $\chi^2(2) = 16.33$, $p < .001$. In line with recruitment strategy, the HTA group had higher trait and state anxiety scores at the time of testing than the LTA group, both *t*s > 13.54, both *p*s < .001. Trait and state anxiety were strongly positively correlated, Spearman's $\rho = .89$, $p < .001$.

As in Study 1, our second study's crucial tests addressed HTA versus LTA group differences in attentional shifting. The 2 (Anxiety Group: HTA vs. LTA) x 3 (Valence: positive-to-non-affective vs. negative-to-non-affective vs. non-affective-to-non-affective) mixed-measures ANOVA on the switch costs revealed only a significant main effect of Valence, $F(2, 94) = 6.93$, $p = .002$, $f = 0.38$. Neither the main effect of Anxiety Group nor the interaction approached significance, both *F*s < 1, both *p*s > .47, both *f*s < 0.08. The main effect of Valence indicated that the magnitude of the cost of switching to a non-affective task depended on the nature of the preceding task, but the absence of a significant interaction indicated that these effects did not differ between HTA and LTA groups. Non-affective-to-non-affective switch costs ($M = 69.58$, $SD = 48.50$) were smaller than negative-to-non-affective switch costs ($M = 79.78$, $SD = 45.82$), $F(1, 96) = 13.58$, $p < .001$, $f = 0.38$, but they did not differ from positive-to-non-affective switch costs ($M = 71.53$, $SD = 43.46$), $F < 1$, $p = .54$, $f = 0.06$. Positive-to-non-affective switch costs were smaller than negative-to-non-affective switch costs, $F(1, 96) = 5.81$, $p = .018$, $f = 0.25$. These results thus indicate that switching to a non-affective task is most demanding when it was preceded by the negative task. As in Study 1, an identical analysis of the switch costs from the error rates revealed neither significant main effects (Valence: $F(2, 94) = 1.74$, $p = .181$, $f = 0.19$; Anxiety Group: $F(1, 95) < 1$, $p = .645$, $f = 0.04$) nor a significant interaction, $F(2, 94) < 1$, $p = .629$, $f = 0.10$.

As in Study 1, we also ran a Bayesian repeated measures ANOVA with default priors to assess the degree to which the data supported the null hypothesis (switch costs are not affected by trait anxiety) versus the alternative hypothesis (switch costs are affected by trait anxiety). Compared to the null model, the analysis of RTs provided moderate support favouring the model including the main effect of Valence, $BF_{10} = 7.39$. As in Study 1, after adding the main effect of Valence to the null model, we found anecdotal evidence against the model including the main effect of Anxiety Group, $BF_{10} = 0.44$, and very strong evidence against the model including the main effect of Anxiety Group and the interaction, $BF_{10} = 0.03$. These analyses thus further indicate that the valence of a preceding task affects the cost of switching to a non-affective task, but that HTA and LTA groups do not differ in their ability to switch from either positive, negative, or non-affective tasks sets to (different) non-affective task sets. In the equivalent analysis on the switch costs from the errors, we found moderate evidence against the model with the main effect of Anxiety Group ($BF_{10} = 0.15$) and the model with the main effect of Valence ($BF_{10} = 0.13$), and very strong evidence against the model with both main effects and the interaction ($BF_{10} = 0.002$). Thus, HTA and LTA groups did again not differ in their task-switching ability.

Finally, to further increase our sample size and thus increase the power of our analyses, we merged the datasets of both studies, and conducted the critical repeated measures ANOVAs on the data of all participants. In order to account for potential differences between student and MTurk samples, we also included Study (study 1 versus study 2) as a between subjects factor in this analysis. The RT analysis revealed a significant main effect of Valence, $F(2, 151) = 14.05$, $p < .001$, $f = 0.43$, which was qualified by the Valence x Study interaction, $F(2, 151) =$

3.36, p = .037, f = 0.21. This interaction indicated only that the main effect of Valence differed between the two studies, in the manner which is described above. The main effect of Anxiety Group and the interactions involving Valence and Anxiety Group were all non-significant, all Fs < 1, all ps > .46, all fs < 0.08. The equivalent analysis of error switch costs revealed only a significant main effect of Valence, $F(2, 151) = 4.226$, p = .016, f = 0.243. All other effects were non-significant, all Fs < 1.08, all ps > .34, all fs < 0.12. The main effect of Valence indicated that, in the two studies combined, negative-to-non-affective switch costs (M = -0.53, SD = 2.68) were smaller than positive-to-non-affective switch costs (M = -0.01, SD = 2.86), $F(1, 155) = 5.30$, p = .023, f = 0.18, but neither negative-to-non-affective switch costs nor positive-to-non-affective switch costs differed from non-affective-to-non-affective switch costs (M = 0.09, SD = 2.75), $F(1, 155) = 3.86$, p = .051, f = 0.16, and $F(1, 155) < 1$, p = .772, f = 0.03, respectively. In sum, even in a sample of 156 participants, we found no evidence to support the hypothesis that HTA and LTA people differ in their task-switching abilities.[3]

3.3. Discussion

In line with our findings from Study 1, our Study 2 findings again showed that the nature of the preceding task affected the switch cost to a subsequent non-affective task. Central to our study's main aim and contrary to the predictions by the ACT, we again found no trait anxiety linked differences in overall or valence-specific switch costs, neither in the data from Study 2, nor after merging the data from both studies.

4. General Discussion

We used a task-switching paradigm to investigate whether elevated levels of trait anxiety impair (1) general attentional shifting, (2) affective-to-non-affective attentional shifting, or (3) only negative-to-non-affective shifting. We found no support for either of these

[3] The absence of trait-anxiety-linked differences in RT switch costs was not driven by our exclusion of RT outliers, nor was it influenced by gender distributions or age. Output of all RT analyses before the removal of outliers or including gender or age as a between-subjects factor or covariate is available on the study's OSF page.

possibilities. In Study 1, non-affective-to-non-affective switch costs were smaller than both positive-to-non-affective and negative-to-non-affective switch costs, and positive-to-non-affective switch costs were smaller than negative-to-non-affective switch costs. In Study 2, non-affective-to-non-affective switch costs and positive-to-non-affective switch costs were both smaller than negative-to-non-affective switch costs, but positive-to-non-affective and non-affective-to-non-affective switch costs did not differ. Crucially, in neither of the studies, nor in an analysis of the combined data of both studies, were any of the switch costs affected by trait anxiety.

One possible explanation for our null findings is limited statistical power. It is possible that trait anxiety linked differences in switch costs do exist, but that our samples were not large enough to detect such differences. To examine this possibility, we conducted a post-hoc sensitivity analysis with G*Power (Faul et al., 2007), with a conventional value of .80 for statistical power, a total sample size of 156 participants (= total N from merged dataset) divided over two groups, and three repeated measurements with a correlation between repeated measures of .72 (correlations between the three switch costs in the merged data file were .72, .77, and .78). This analysis showed that our sample was large enough to detect minimal effect sizes of f = .08, corresponding with very small effects. If HTA and LTA people do differ in their ability to switch between our different task sets, our study shows that such differences are likely very small.

In light of our null findings, it is important to consider the relatively limited level of specificity of the impaired attentional shifting hypothesis of the ACT. The theory posits only that anxiety impairs performance on tasks involving the shifting function, without specifying the potential influence of the affective nature of the tasks or stimuli. We consider it a strength of our study to have differentiated between three different types of switching (i.e., non-affective-to-non-affective switching, positive-to-non-affective switching, and negative-to-non-affective switching) that could have been differentially affected by trait anxiety. Previous studies have found relations between more efficient switching from affective to non-affective aspects of *negative* stimuli and increased reappraisal effectiveness (Malooly et al., 2013), decreased rumination (Genet et al., 2013), but also increased anxiety over time (Twivy et al., 2021). Inversely, more efficient switching from affective to non-affective aspects of *positive* stimuli has been associated with increased rumination (Genet et al., 2013). In absence of significant trait anxiety linked differences in our switch costs, future studies could address trait anxiety linked differences in other types of switching. For instance, given Johnson's (2009) finding of trait anxiety linked differences in non-affective-to-affective switching, future studies may further specify this effect by differentiating between non-affective-to-positive and non-affective-to-negative switching (Twivy et al., 2021), and negative-to-positive and positive-to-negative switching.

Previous studies reporting anxiety linked differences in non-affective switching almost exclusively found these differences when comparing participants differing in state anxiety rather than trait anxiety (Derakshan et al., 2009; Visu-Petra et al., 2013). This may suggest that state rather than trait anxiety impairs non-affective attentional shifting. Because we selected participants based on trait anxiety scores, our study was not designed to test this alternative. However, our groups did also differ significantly in state anxiety, and the correlation between trait and state anxiety in our study was very large. If differences in state rather than trait anxiety indeed impair non-affective switching, we should have replicated such effects. In addition, although Eysenck et al. (2007) mention the possibility that impairments in measures of attentional control are most evident when both trait and state anxiety are high, the ACT is concerned primarily with trait anxiety. Evidence unambiguously supporting the ACT should therefore follow from studies comparing participants with different levels of trait anxiety, with high trait anxious participants showing impaired switching relative to low trait anxious participants. Such evidence remains very scarce. The one study that did find a trait anxiety linked difference in non-affective switching (Gustavson et al., 2017) found this difference only when participants switched from a demanding task to a less demanding task, and not vice versa. As our study did not differentiate between levels of attentional demand of the two non-affective tasks, it indicates that there is no trait anxiety linked difference in non-affective switching, with the potential exception of switching from demanding to less demanding tasks.[4]

Notable strengths of our study include our systematic comparison of both non-affective-to-non-affective and affective-to-non-affective switch costs, using trial pairs to fully balance the numbers of trial types and thus the number of observations for each condition of interest. Limitations include the absence of non-affective-to-affective switch costs and the lack of differentiation between more and less effortful tasks, as previous findings suggest that both these factors may constitute boundary conditions for trait anxiety to affect task-switching (Gustavson et al., 2017; Johnson, 2009). In addition, we did not systematically address gender and age differences, both of which can affect cognitive processing in general and task switching in specific (e.g., Stoet et al., 2013; Wasylyshyn et al., 2011). Although the ACT does not make differential predictions for HTA and LTA groups based on gender or age, future studies may want to systematically address these potential moderators. While these limitations could in part account for our null results, our results from two independent studies show that high and low trait anxious participants do not necessarily differ in either affective-to-non-affective or non-affective-to-non-affective task-switching.

[4] Analyses of overall task difficulties are provided in the online supplementary materials.

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Declarations

Conflicts of interest

The authors report no conflict of interest.

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Availability of data and material

The raw data, outlier analysis description, transformed data, and the analysis output are available on the following OSF-page: https://osf.io/n2k9b

Table 1. Descriptive Statistics per Group for Measures of Anxiety and Attentional Shifting in Study 1.

	LTA		HTA	
	M	*SD*	*M*	*SD*
STAI-Trait	35.27	5.65	53.93	9.08
STAI-State	31.17	6.24	46.53	12.54
Non-affective repetition RT	1135.15	1171.48	1132.32	183.68
Positive-to-non-affective switch RT	1216.07	180.09	1221.85	220.99
Negative-to-non-affective switch RT	1223.66	188.99	1237.90	230.50
Non-affective-to-non-affective switch RT	1192.73	163.52	1212.96	210.29
Positive-to-non-affective SC RT	80.93	64.59	89.53	67.66
Negative-to-non-affective SC RT	88.51	67.86	105.58	77.55
Non-affective-to-non-affective SC RT	57.59	69.67	80.64	54.49
Non-affective repetition ERR	2.59	2.82	2.50	2.15
Positive-to-non-affective switch ERR	3.02	2.92	2.36	2.24
Negative-to-non-affective switch ERR	1.87	2.03	1.94	2.04
Non-affective-to-non-affective switch ERR	2.80	2.51	2.15	2.15
Positive-to-non-affective SC ERR	0.43	2.57	-0.14	2.50
Negative-to-non-affective SC ERR	-0.72	3.40	-0.56	2.56
Non-affective-to-non-affective SC ERR	0.22	2.38	-0.35	2.33

Note: LTA = Low Trait Anxious group, HTA = High Trait Anxious group, STAI = State-Trait Anxiety Inventory, RT = Reaction Time, SC = Switch Cost, ERR = Errors.

Table 2. Descriptive Statistics per Group for Measures of Anxiety and Attentional Shifting in Study 2

	LTA		HTA	
	M	*SD*	*M*	*SD*
STAI-Trait	27.48	5.06	60.22	9.57
STAI-State	23.36	3.95	48.94	12.76
Non-affective repetition RT	1023.55	155.57	1005.05	183.88
Positive-to-non-affective switch RT	1098.20	160.62	1073.52	184.72
Negative-to-non-affective switch RT	1107.11	163.31	1081.13	195.07
Non-affective-to-non-affective switch RT	1095.54	158.72	1072.27	200.82
Positive-to-non-affective SC RT	74.65	43.04	68.47	44.10
Negative-to-non-affective SC RT	83.56	45.35	76.08	46.44
Non-affective-to-non-affective SC RT	71.99	52.35	67.22	44.83
Non-affective repetition ERR	2.47	2.57	2.08	2.66
Positive-to-non-affective switch ERR	2.47	2.49	1.87	2.22
Negative-to-non-affective switch ERR	1.82	2.18	1.79	2.37
Non-affective-to-non-affective switch ERR	2.39	2.88	1.79	2.17
Positive-to-non-affective SC ERR	0.00	3.16	-0.21	2.98
Negative-to-non-affective SC ERR	-0.65	2.55	-0.30	2.44
Non-affective-to-non-affective SC ERR	0.09	3.30	0.30	2.66

Note: LTA = Low Trait Anxious group, HTA = High Trait Anxious group, STAI = State-Trait Anxiety Inventory, RT = Reaction Time, SC = Switch Cost, ERR = Errors.

Figure captions

Figure 1. Example Sequence in the Task-Switching Task.

Note: Images are stock photos, used for illustrating purposes only.

Figure 2. Positive-to-Non-Affective, Negative-to -Non-Affective, and Non-Affective-to-Non-Affective Switch Costs as a function of Trait Anxiety Group in Study 1.

Note: P/NA = Positive-to-Non-Affective; N/NA = Negative-to -Non-Affective; NA/NA = Non-Affective-to-Non-Affective

Figure 3. Positive-to-Non-Affective, Negative-to -Non-Affective, and Non-Affective-to-Non-Affective Switch Costs as a function of Trait Anxiety Group in Study 2.

Note: P/NA = Positive-to-Non-Affective; N/NA = Negative-to -Non-Affective; NA/NA = Non-Affective-to-Non-Affective

Figure 1.


"People"
"Outside"
"Positive"
"Outside"
Trial pair n: Non-affective to non-affective task-switch
Trial pair n+1: Positive to non-affective task-switch

Figure 2.

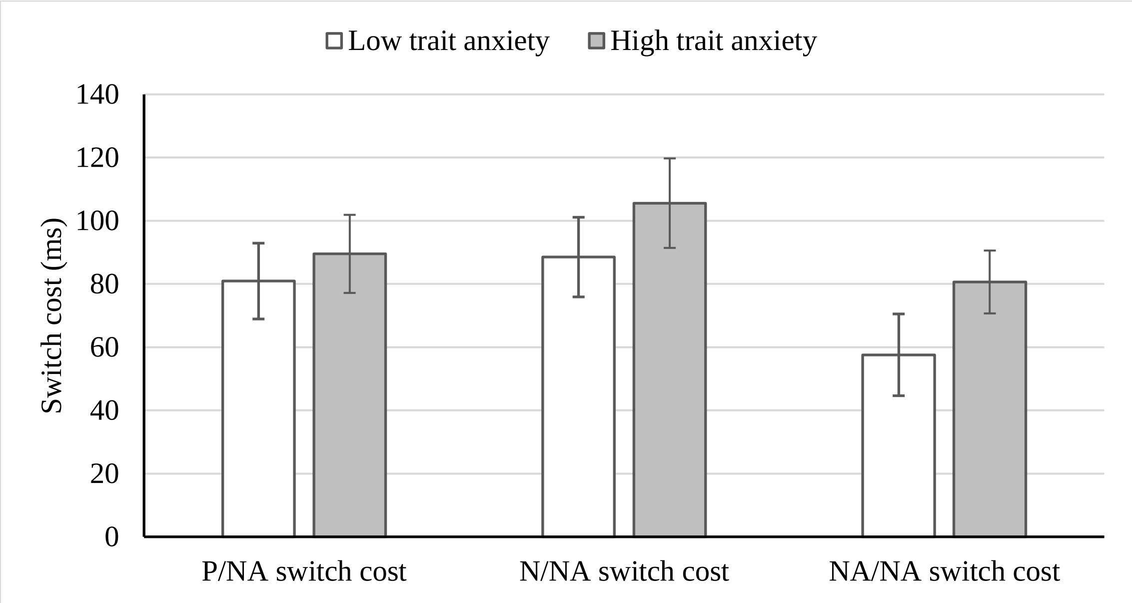
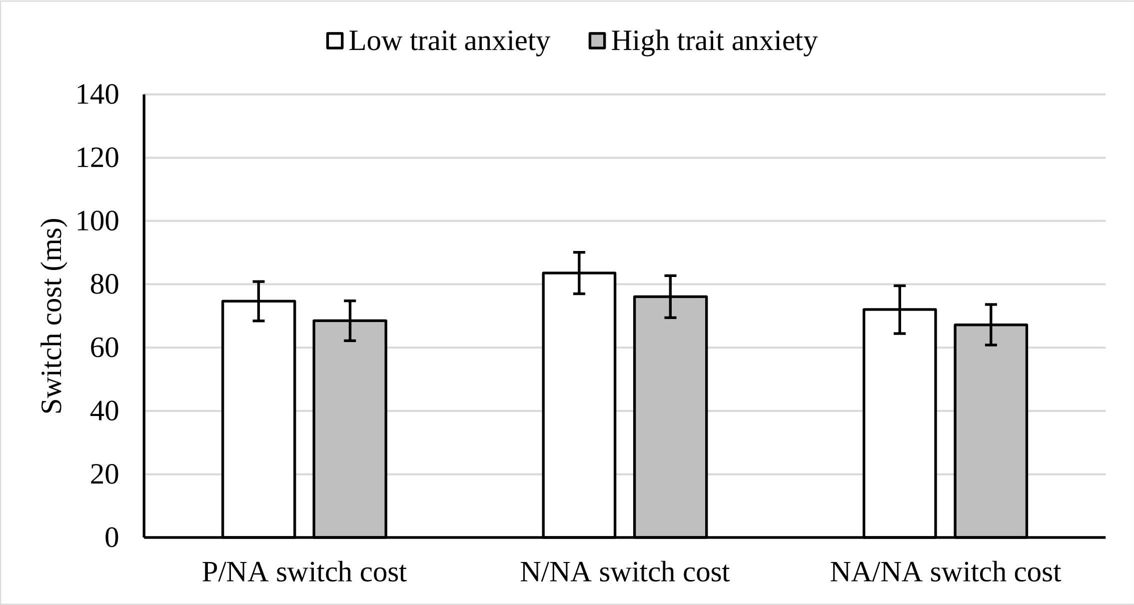

Low trait anxiety
High trait anxiety
Switch cost (ms)
140
120
100
80
60
40
20
0
P/NA switch cost
N/NA switch cost
NA/NA switch cost

Figure 3.


Low trait anxiety
High trait anxiety
140
120
100
80
60
40
20
0
Switch cost (ms)
P/NA switch cost
N/NA switch cost
NA/NA switch cost

Online Supplement for:

No Trait Anxiety Linked Differences in Affective and Non-Affective Task-Switching

1. Comparisons of task difficulties

Task difficulties were compared for each dataset separately, by first running a mixed measures ANOVA with Task (Negative, Outside, People, Positive) as a within-subjects factor and Anxiety Group as a between-subjects factor. Follow-up paired samples t-tests were used to test differences between tasks if the main effect of Task was significant. Full outputs of these analyses are available on the study's OSF page (https://osf.io/n2k9b)

In Study 1, mean RTs (Table S1) differed significantly between tasks, with faster RTs on the people task than all other tasks, faster RTs on the negative than the positive but not the outside task, and no difference between the outside and positive task. As for the errors (Table S2), people made less errors on the people task than on all other tasks, and they made less errors on the outside task than on both the positive and negative task. In Study 2, mean RTs (Table S3) again differed significantly between tasks, but RTs on the negative task were faster than all other tasks, RTs on the people task were faster than the positive and the outside task, and faster RTs on the positive task than the outside task. As for the errors (Table S4), people made less errors on the people task than on all other tasks, and they made less errors on the outside task than on both the positive and negative task. Finally, for the combined dataset, mean RTs (Table S5) differed significantly between tasks, with RTs on the negative task being faster than on the outside and positive tasks, and RTs on the people task being faster than the positive and the outside task. In the errors (Table S6), people made less errors on the people task than on all other tasks, and they made less errors on the outside task than on both the positive and negative task.

Table R1. Study 1 mean task reaction times and significance of differences between these means.

			P-value of difference		
	Mean	SD	M RT Outside	M RT People	M RT Positive
M RT Negative	1221.10	252.02	.173	.000	.000
M RT Outside	1240.91	216.59		.000	.066
M RT People	1149.60	169.55			.000
M RT Positive	1265.76	230.58			

Table R2. Study 1 mean task % correct and significance of differences between these means.

			P-value of difference		
	Mean	SD	Correct Outside	Correct People	Correct Positive
Correct Negative	93.80	4.47	.000	.000	.297
Correct Outside	97.05	2.47		.000	.003
Correct People	98.15	1.31			.000
Correct Positive	94.56	6.23			

Table R3. Study 2 mean task reaction times and significance of differences between these means.

			P-value of difference		
	Mean	SD	M RT Outside	M RT People	M RT Positive
M RT Negative	1001.76	212.33	.000	.000	.000
M RT Outside	1091.63	183.81		.000	.001
M RT People	1046.92	167.20			.000
M RT Positive	1072.59	173.73			

Table R4. Study 2 mean task % correct and significance of differences between these means.

			P-value of difference		
	Mean	SD	Correct Outside	Correct People	Correct Positive
Correct Negative	93.17	5.73	.000	.000	.147
Correct Outside	97.36	2.41		.000	.000
Correct People	98.48	1.52			.000
Correct Positive	93.96	6.56			

Table R5. Combined data mean task reaction times and significance of differences between these means.

			P-value of difference		
	Mean	SD	M RT Outside	M RT People	M RT Positive
M RT Negative	1084.72	251.15	.000	.915	.000
M RT Outside	1148.09	209.17		.000	.699
M RT People	1085.75	174.84			.000
M RT Positive	1145.65	217.76			

Table R6. Combined data mean task % correct and significance of differences between these means.

			P-value of difference		
	Mean	SD	Correct Outside	Correct People	Correct Positive
Correct Negative	93.41	5.28	.000	.000	.073
Correct Outside	97.24	2.43		.000	.000
Correct People	98.35	1.45			.000

Correct Positive	94.19	6.42