Published in final edited form as:
Emotion. 2017 February ; 17(1): 88–101. doi:10.1037/emo0000212.

Is Set Shifting Really Impaired in Trait Anxiety? Only When Switching Away from an Effortfully Established Task Set

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Abstract

The current study investigated whether trait anxiety was systematically related to task-set shifting performance, using a task-switching paradigm in which one task was more attentionally demanding than the other. Specifically, taking advantage of a well-established phenomenon known as asymmetric switch costs, we tested the hypothesis that the association between trait anxiety and task-set shifting is most clearly observed when individuals must switch away from a more attentionally demanding task for which it was necessary to effortfully establish an appropriate task set. Ninety-one young adults completed an asymmetric switching task and trait-level mood questionnaires. Results indicated that higher levels of trait anxiety were systematically associated with greater asymmetry in reaction-time (RT) switch costs. Specifically, the RT costs for switching from the more attentionally demanding task to the less demanding task were significantly greater with higher levels of trait anxiety, whereas the RT costs for switching in the opposite direction were not significantly associated with trait anxiety levels. Further analyses indicated that these associations were not attributable to comorbid dysphoria or worry. These results suggest that levels of trait anxiety may not be related to general set-shifting ability per se, but, rather, that anxiety-specific effects may primarily be restricted to when one must efficiently switch away from (or let go of) an effortfully established task set.

Keywords

trait anxiety; task switching; executive functions; Attentional Control Theory

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People vary in the extent to which they experience anxiety during everyday situations. These individual differences in trait anxiety, even at the subclinical level, have been suggested to be predictive of performance on various cognitive measures, including executive functions (EFs), defined here as a set of domain-general control processes that regulate one's thought and action (Miyake et al., 2000). The current study focuses on one of the frequently studied EFs, task-set shifting (or simply shifting), and examines how it is related to levels of trait anxiety (i.e., the tendency to be anxious in general but not necessarily anxious in the moment). Specifically, in light of some limited but suggestive existing evidence briefly reviewed below, the current study proposes and tests the hypothesis that, in emotionally

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neutral (nonthreatening) situations, trait anxiety is related to shifting performance only under certain circumstances, namely, when one must switch away from an effortfully established task set.

Trait Anxiety and Task-Set Shifting: Prior Research and A New Hypothesis

The starting point for the current study was a theoretical claim on task-set shifting made by Attentional Control Theory (ACT), a leading theory on the relationship between subclinical levels of anxiety and EFs (Eysenck, Derakshan, Santos, & Calvo, 2007). A major aim of ACT is to specify the relationship between anxiety and EF abilities, using Miyake et al.'s (2000) framework on EFs (Eysenck et al., 2007). This framework (for an update, see Friedman & Miyake, in press; Miyake & Friedman, 2012) focuses on three separable yet intercorrelated EFs: the updating of working memory representations (updating), the inhibition of prepotent or dominant responses (inhibition), and the efficient switching between multiple mental sets or tasks (shifting).[1] ACT claims that updating is generally spared in anxiety unless the situation is emotionally threatening, but that anxious individuals perform worse on the other two EFs — inhibition and shifting — whether the situation is threatening or neutral (Eysenck et al., 2007). Specifically, with respect to shifting ability, ACT proposes that "anxiety impairs processing efficiency (and often performance effectiveness) on tasks involving the shifting function" (Eysenck et al., 2007, p. 346). In other words, ACT hypothesizes that individuals with higher levels of anxiety will perform more slowly (i.e., reduced processing efficiency) than those with lower levels of anxiety on set-shifting tasks and that this negative impact of anxiety may sometimes manifest itself as higher error rates as well (i.e., reduced performance effectiveness). In the current study, we evaluated this claim.

Given that ACT assumes that trait anxiety and situational stress jointly influence an individual's performance on EF tasks (Eysenck et al., 2007), its claim on the anxiety–shifting relationship is based on research using both state and trait measures of anxiety. Moreover, ACT's scope encompasses not only emotionally neutral but also emotionally threatening situations. In this study, however, we restrict our scope by focusing on the associations between *trait* anxiety and shifting under situations involving only *emotionally neutral* stimuli. Despite this restricted scope, the current study is still highly relevant to the evaluation of ACT's claim on set shifting, because it assumes trait anxiety as an important source of influence on shifting performance and also because unlike its claim on updating, ACT's claim on the negative effect of anxiety on shifting performance does not exclude emotionally neutral situations (Eysenck et al., 2007).

Although ACT's theoretical claim on the effect of anxiety on shifting has remained essentially the same since its original conception (for more recent reviews, see Berggren & Derakshan, 2013; Eysenck & Derakshan, 2011), we see a strong need for further

[1]Throughout this article, we use the terms *shifting* and *switching* in different ways. We use the term *(task-set) shifting* to refer to a type of EF postulated in the theoretical framework proposed by Miyake et al. (2000) and later adopted by Eysenck et al. (2007). In contrast, we use the term *switching* (or *task switching*) in a narrower sense, referring to a class of experimental paradigms used in cognitive psychology, in which participants must switch back and forth between two (or more) tasks, often on the basis of external cues.

investigating the relationship between trait anxiety and shifting. This is primarily because the existing evidence for the negative impact of trait anxiety on shifting performance in emotionally neutral situations is highly limited and is mostly restricted to neuropsychological measures on set shifting.[2] In particular, even though more than 20 years have passed since the initial development of task-switching paradigms (Allport, Styles, & Hsieh, 1994; Rogers & Monsell, 1995), little research on the EF correlates of anxiety has taken advantage of this experimental paradigm popular in cognitive psychology (for comprehensive reviews on the task switching literature, see Kiesel et al., 2010; Vandierendonck, Liefooghe, & Verbruggen, 2010). Moreover, the limited amount of evidence currently available on the relationship between trait anxiety and set-shifting performance is at best mixed, as we briefly review below. Thus, it is not only timely but also important to revisit ACT's claim on shifting, especially using the task-switching paradigm.

Prior Evidence on the Relationship Between Trait Anxiety and Set Shifting

There is limited evidence that trait anxiety is associated with shifting in emotionally neutral situations. In fact, the only consistent evidence for the claim that higher trait anxiety is associated with impaired shifting performance comes from studies using the Wisconsin Cart Sorting Task (WCST). The WCST is a popular neuropsychological EF task, often associated with set shifting (e.g., Miyake et al., 2000), in which participants sort a deck of cards based on one of a few rules (e.g., number of objects on the card), but must avoid perseverating on old rules when, unbeknownst to them, these sorting rules are changed. Two studies have showed that individuals with higher levels of trait anxiety perform worse on measure of performance effectiveness, including total errors (Casselli, Reiman, Hentz, Osborne, & Alexander, 2004), perseverative errors (Caselli, et al., 2004), or the failure to maintain sets (Gershuny & Sher, 1995). More recently, another study (Edwards, Edwards, & Lyvers, 2015) examined performance on the WCST using a measure of processing efficiency (based on the reaction time [RT] on perseverative errors). Although their results suggested that the association between trait anxiety and WCST efficiency may be specific to certain situations (i.e., when mental effort was high, or when mental effort was low but levels of situational stress were high), performance was impaired in trait anxiety across most task conditions (the only situation that did not show an association with anxiety was when both mental effort and situational stress were low). Together, these WCST studies suggest that individuals with high levels of trait anxiety struggle more than their nonanxious counterparts in this set-shifting task, which necessitates overcoming a prepotent task representation that is abruptly changed (e.g., previously correct sorting rules).

In contrast, there is little evidence that anxiety is associated with shifting performance for another popular neuropsychological measure of set-shifting, the Trail Making Test (TMT). In the TMT, baseline trials in which participants sequentially trace only numbers (e.g., 1–25) or only alphabet letters (e.g., A-Z) are compared with key switching trials in which

[2]Although the original ACT article (Eysenck et al., 2007) cited the results from prospective memory studies as evidence for shifting impairments in anxiety (Cockburn & Smith, 1994; Harris & Cumming, 2003; Harris & Menzies, 1999), we will not review such studies in this article because the extent to which prospective memory tasks selectively implicate set-shifting ability is unclear. Similarly, we will also not discuss here two recent studies that examined the relationship between trait anxiety and shifting using a dual-task paradigm (Edwards, Moore, Champion, & Edwards, 2015; Johnson & Gronlund, 2009), because there is some evidence that dual-tasking ability might be separable from shifting ability (e.g., Alzahabi & Becker, 2013; Miyake et al., 2000).

participants must switch back and forth between two equally practiced tracing rules (e.g., switching between numbers and letters, as in 1-A-2-B-3-C...). Thus, this task requires switching between two categories of stimuli (numbers and letters), but, unlike WCST, it does not implicate any overcoming of a prepotent task representation. To the best of our knowledge, the only TMT study that included a direct measure of trait anxiety, the State-Trait Anxiety Inventory (STAI), failed to show any clear association between trait anxiety and performance on the alternating trials (Waldstein, Ryan, Jennings, Muldoon, & Manuck, 1997). Other work has suggested (Orem, Petrac, & Bedwell, 2008) that perceived stress is associated with performance on the key switching trials, but this study did not directly assess trait anxiety, and the association with stress was not significant when switch costs (i.e., the difference between baseline and alternating trials) were examined. Thus, the existing studies using the TMT fail to provide much evidence for a robust relationship between trait anxiety and shifting ability.

Moreover, there is little evidence that trait anxiety is associated with shifting ability when assessed with a typical task-switching paradigm. The only published task-switching study (Bunce, Handley, & Gaines, 2008) we know of that used only emotionally neutral stimuli (i.e., switching between color and shape judgments) did not find a significant correlation between trait anxiety and switching performance ($r = -.05$), even though they used a large sample ($N = 300$). Because the sample in this study included a wide age range of participants (18 to 85 years) and the main dependent measure was the switch-trial RTs (rather than RT switch costs), this null result must be interpreted with caution. Nevertheless, the results from the Bunce et al. (2008) study suggest that the evidence for shifting impairment in trait anxiety is weak when the task-switching paradigm uses only emotionally neutral stimuli and requires switching between two tasks that are equivalent in their attentional control demand.

A New Hypothesis

The prior evidence we just reviewed seems inconsistent with the hypothesis that trait anxiety is associated with across-the-board shifting impairments. We propose, however, that these prior results are consistent with an alternative hypothesis: The relationship between trait anxiety and shifting performance is most robust when there exists some asymmetry in prepotency or attentional control demand in the task setup, thus necessitating people to effortfully establish a mental set to avoid making errors on attentionally demanding trials. Once a new mental set is effortfully established to deal with attentional control demands, it might be more difficult for people to get out of that mental set to switch to a new mental set. Thus, when anxious individuals spend extra effort to establish task sets, such effort may ironically make it more difficult for them to switch away from those tasks (as in the WCST). When there is no such asymmetry in attentional control demands, however, the relationship between trait anxiety and shifting performance may be considerably weaker or even nonexistent (as in the TMT or symmetric task switching). The current study tested this alternative hypothesis about the relationship between trait anxiety and shifting by taking advantage of a phenomenon known as asymmetric switch costs.

Asymmetric Switching Paradigm

Asymmetric switch costs are a well-established phenomenon in the task switching literature (e.g., Allport et al., 1994; Bryck & Mayr, 2008; Meuter & Allport, 1999; Wylie & Allport, 2000, Yeung & Monsell, 2003). Asymmetric switch costs are observed when the tasks that one needs to switch between differ in their levels of prepotency or attentional control demands. What is interesting about asymmetric switch costs is that the directionality of the effect is counterintuitive: Switch costs are greater for the switch from the more effortful and less prepotent task to the less attentionally demanding and more prepotent task than for the switch in the opposite direction. For example, if one uses Stroop-type stimuli (e.g., *RED* printed in blue ink), switching to the easier, more prepotent task (word reading) yields greater switch costs than switching to the more attentionally demanding task (color naming).

To clarify this pattern of asymmetric switch costs, we provide a graphic illustration of some hypothetical yet typical results in Figure 1. As displayed in the graph, overall RTs are longer for the more difficult, attentionally demanding task than for the easier, more prepotent task. However, the switch cost itself (defined as switch-trial RTs minus repeat-trial RTs) is larger for the easier task (i.e., when switching away from the more attentionally demanding task) than for the more difficult task (i.e., when switching away from the easier task). Although the precise cognitive mechanism underlying such an asymmetry in switch costs is still debated (Bryck & Mayr, 2008; Schneider & Anderson, 2010; Yeung & Monsell, 2003), one prevalent explanation for this asymmetric switch cost is that it reflects people's difficulty getting out of (or letting go of) the more effortfully established task set (e.g., Wylie & Allport, 2000).

This explanation of the asymmetric switch costs provides a novel, theoretically motivated way to investigate the anxiety–shifting relationship especially in light of another major component of ACT, the processing efficiency hypothesis (Eysenck et al., 2007). This hypothesis states that anxiety primarily affects processing efficiency (e.g., RTs) rather than performance effectiveness (e.g., accuracy), and that "anxious individuals compensate for the adverse effects of anxiety on processing efficiency [...] *by increased effort and use of resources*" (Eysenck et al., 2007, p. 341, emphasis added). Thus, according to this hypothesis, anxious individuals must exert extra effort to establish the task set for the more attentionally demanding task to achieve high levels of accuracy. If so, then switching away from that attentionally demanding task should be particularly challenging from them, thus resulting in even larger switch costs than those observed for nonanxious individuals. In contrast, switching in the opposite direction might not reveal much impact of trait anxiety because performing the more prepotent task does not require effortful establishment of the task set, even for individuals with high trait anxiety.

The Current Study

In the current study, we used an asymmetric switching paradigm to test the hypothesis that trait anxiety would be associated with shifting performance primarily when switching away from an effortfully established task set. In this paradigm, displayed in Figure 2, participants switched between two tasks: (a) a less attentionally demanding task of identifying which

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side of the screen a simple arrow stimulus (<<<<<) is presented on, and (b) a more attentionally demanding task of identifying the direction that this stimulus points (left or right). Shortly (750 ms) before the presentation of the target stimulus, participants were instructed on which task to perform on that trial with an external cue (a plus sign “+” or an asterisk “*”). Consistent with the previous experimental results, we expected to find larger switch costs when participants switched from the more attentionally demanding direction task to the more prepotent location task.

To further examine the effect of effort and attentional demand on switch costs, we introduced a secondary manipulation to this paradigm: After performing four blocks of the switching task using a particular cue-task mapping rule (+ for the location task and * for the direction task), participants were asked to reverse the mapping rule in the remaining two blocks (* for the location task and + for the direction task). Because this cue reversal requires participants to abandon the previously learned and practiced mapping rule, we hypothesized that this manipulation would exaggerate the magnitudes of the asymmetric switch costs.

We made the following two predictions in this study. First, we predicted that larger switch costs (especially RT switch costs) for switching from the more effortful task (the direction task) to the less effortful task (the location task) would be exaggerated among individuals with higher levels of trait anxiety, whereas the switch costs for switching in the opposite direction would not be systematically related to trait-anxiety levels. Second, we also predicted that such an asymmetry in the switch costs exhibited by individuals with higher levels of trait anxiety would become even more exaggerated after the cue-mapping reversal.

We also addressed some additional questions in this study. First, levels of dysphoria (more generally, depression) are substantially correlated not only with levels of anxiety (Ehring & Watkins, 2008; Mineka, Watson, & Clark, 1998) but also with broad impairments in EFs (Snyder, 2013; Snyder, Miyake, & Hankin, 2015). Thus, we included a measure of dysphoria in an effort to distinguish the associations between trait anxiety and asymmetric switch costs from those between trait dysphoria and asymmetric switch costs (for examples of recent research using this type of analysis, see Edwards et al., 2015a, 2015b; Gustavson & Miyake, 2016). Second, anxiety is not a unitary construct, and one of its subcomponents often discussed in the literature is worry (Eysenck et al., 2007). Because some research has shown that it is the worry component of anxiety that is associated with variation in some EF abilities such as working memory updating (e.g., Gustavson & Miyake, 2016), we also tested the extent to which worry could explain the predicted association between trait anxiety and asymmetric switch costs.

Method

Participants

Ninety-one undergraduate students (36 men and 55 women) completed this study for partial course credit. An additional 14 participants completed this study, but their data were excluded from the analyses because they performed at or below chance level on one of the initial pure blocks (performing just the location or direction task without any switching requirement), suggesting that they might have misunderstood the task instructions.[3]

Materials and Procedure

Participants first performed a computerized measure of asymmetric task-switching, programmed in PsyScope 1.2.5 (Cohen, MacWhinney, Flatt, & Provost, 1993). RTs were recorded with a ms-accurate button box (ioLab Systems). After this computerized task, participants completed several mood-related questionnaires.[4] We administered the questionnaires after task switching to avoid potential induction of anxiety and dysphoria due to their responses to a series of emotionally charged questions.

Task-switching paradigm—Figure 2 displays some example trials of the asymmetric task-switching paradigm used in this study. On each trial, a cue (+ or *) appeared in the middle of the screen for 750 ms, indicating the dimension (location or direction) of the arrow stimulus (>>>>> or <<<<<) to which participants should attend. The + cue meant to respond with the location of the arrow, and the * cue meant to respond with the arrow's direction. This cue-to-stimulus interval of 750 ms was chosen because prior research has established that it typically takes over 500–600 ms to process the cue and prepare for the forthcoming stimulus as much as possible (e.g., Rogers & Monsell, 1995). Immediately after the cue was removed, arrow stimuli were presented on either the left or right side of the screen. After each response, the next cue was presented on the screen with no delay. To minimize the number of trials in which participants could respond correctly regardless of whether they were performing the correct task, the locations and directions of arrows were incongruent on 75% of trials (e.g., if the stimulus was presented on the right side of the screen, it pointed left 75% of the time).

Initially, participants performed the location task alone, and then the direction task alone (72 trials each). These pure blocks were introduced before the mixed blocks to make sure that participants had a complete understanding and mastery of the task requirement and stimulus-response mapping rules. Next, four mixed blocks containing both tasks were performed (112 trials per block, excluding 4 warm-up trials at the beginning of each block that we did not analyze). Mixed block trials were pseudorandomly ordered so that after switching tasks, participants would repeat the same task for 0–3 trials. For each task within these mixed blocks, participants switched after completing either 0-repeat trials (12 times per block), 1-repeat trial (8 times per block), 2-repeat trials (4 times per block), or 3-repeat trials (4 times

[3]A close examination of the actual responses made during the initial pure block indicated that, despite the explicit instructions, almost all of these participants performed the wrong task (the direction task) in the first pure block (all participants were supposed to perform the location task in the first pure block, as noted in the procedure section). Given that performing simple judgments during the initial pure blocks is fairly easy, it is not clear why a substantial number of participants made such an error, though we speculate that it may have to do with the ambiguous (bivalent) nature of the arrow stimuli. Because we cannot ensure that these participants fully understood the task requirements or paid close attention to the initial instructions, we excluded their data from analyses.

[4]To fully disclose all the individual differences measures administered in the current study, we note here that, besides the measures described in the Method section, all participants completed two additional tasks (a White Bear thought suppression task and a goal-neglect Stroop task) and four other questionnaires (the Habit Index of Negative Thinking, the Five Factor Mindfulness Questionnaire, the Ruminative Responses Scale, and the Inventory of Depression and Anxiety Symptoms). These additional measures were administered as part of a separate study on the relationship between shifting and trait tendencies to experience repetitive negative thoughts.

per block). Therefore, in sum, each block contained 28 switch trials, 16 1-repeat, 8 2-repeat, and 4 3-repeat trials per task (56 for the location task and 56 for the direction task).

Finally, participants performed two more mixed blocks (112 trials per block, again excluding 4 initial warm-up trials) with the reverse cue-to-task mapping, so that + cued the direction task and * cued the location task. After the completion of Block 4, participants were told about this cue-mapping reversal and asked to complete the next two blocks (Blocks 5–6) with this new rule. Although participants completed 6 mixed blocks in total (4 before the cue reversal and 2 afterward), analyses were performed collapsing across pairs of blocks (Blocks 1–2 vs. 3–4 vs. 5–6) so that we could analyze practice effects on trials before the cue reversal (Blocks 1–2 vs. 3–4) and the direct effect of the reversal itself (Blocks 3–4 vs. 5–6).

Questionnaires—Levels of trait anxiety and dysphoria were measured with the Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988) and the Beck Depression Inventory (BDI; Beck & Steer, 1987), respectively. Both questionnaires had 21-items and were scored with a 4-point rating scale per question. Although the most frequent measure of trait anxiety in this literature is the STAI (Ansari, Derakshan, & Richards, 2008; Derakshan, Smyth, & Eysenck, 2009), we chose the BAI instead because there is evidence that the BAI may be more effective than the STAI at differentiating anxiety from depressive symptoms (Bieling, Antony, & Swinson, 1998; Caci, Bayle, Dossios, Robert, & Boyer, 2003; Creamer, Foran & Bell, 1995). Finally, worry was measured with the 16-item Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzer, & Borkovec, 1990).

Data Trimming and Analyses

RT analyses were based on correct trials with RTs greater than 150 ms. In addition to removing error trials, trials immediately following those error trials were also excluded from analyses, as is typically done in task-switching studies (e.g., Meiran, 1996; Meiran, Chorev, & Sapir, 2000; Rogers & Monsell, 1995). Excluding trials following errors is important because, after an error is made, it is difficult to tell whether the current trial is a switch or repeat trial.

RTs were trimmed using methods recommended by Wilcox and Keselman (2003), as our research group has typically done with RT-based measures of EF (e.g., Friedman et al., 2008; Ito et al., 2015), to reduce undue influences from outliers and improve reliability. Specifically, participant RT means excluded RTs outside of 3.32 times the median absolute deviation from each participant's median by trial type (removing 10.3% of trials). In addition, to minimize undue influences from participants with extreme mean RTs and error rates, we set limits at 3 standard deviations from the group mean for each measure, and outlier participants' values were replaced with the nearest limit.

Error rate analyses were performed on raw error rates. We also conducted the analysis using arcsine-transformed scores because the error rates were generally low, showing some tendency for the ceiling effect. However, because this transformation did not change the statistical results, the raw data are reported here.

Results

Clinical Measures

Trait anxiety (*M* = 12.0, *SD* = 7.8) and dysphoria levels (*M* = 10.6, *SD* = 8.3) were relatively low in this nonclinical sample, but were moderately correlated with each other, $r(89) = .51$, $p < .001$. Although this finding is not surprising, it nonetheless highlights the importance of statistically controlling for dysphoria when assessing the specific association between trait anxiety and task switching performance. Both measures had high reliability (Cronbach's alpha = .86 for BAI and .89 for BDI). Levels of worry, measured with PSWQ (*M* = 49.7, *SD* = 14.2, Cronbach's alpha = .73), were also correlated substantially with both trait anxiety, $r(89) = .38$, $p < .001$, and dysphoria, $r(89) = .52$, $p < .001$.

Although this was a nonclinical sample, the questionnaire responses indicated that some individuals had "severe" levels of anxiety or dysphoria, according to the conventional cutoff values used for the BAI (>25, $n = 9$) and BDI (>28, $n = 4$). Because excluding these participants from analysis did not change the overall pattern of results, we report below the analyses based on all 91 participants.

Preliminary Analyses: Basic Experimental Effects

Before presenting the results of the associations between trait anxiety and task switching performance, we first report the basic experimental effects to document the asymmetric effect of switch costs at the overall group level (see Table 1). All ANOVAs we conducted included the within-subjects factors of Task (location vs. direction) and Switch (switch vs. repeat trials). Depending on the analyses, we also included Block as another within-subjects factor. We report partial eta-squared (η^2_p) as our measure of effect sizes.[5]

Because those experimental effects per se were not the main focus of our study and because the patterns were consistent with previous research on asymmetric switch costs, our presentation of the experimental effects in this section focuses only on the asymmetric switch cost effect, as indicated by the Task×Switch interaction (or the Task×Switch×Block interaction). For completeness, however, a summary of the ANOVA results for the experimental effects are presented in the Appendix for both the RT and error data.

Before cue reversal (Blocks 1–4)—We replicated the expected asymmetric switch cost effect for both RTs and error rates. Specifically, the Task×Switch interaction was significant for both the RT data, $F(1,90) = 18.74$, $\eta^2_p = .17$, $p < .001$, and the error data, $F(1, 90) = 49.26$, $\eta^2_p = .35$, $p < .001$, indicating that the switch cost was larger for the less attentionally demanding location task than for the more demanding direction task (see Table 1). Although there were some practice effects across Blocks 1–4, the magnitudes of the switch-cost asymmetry remained relatively stable across the blocks, as indicated by the lack of a significant Task×Switch×Block interaction (the effect, however, was marginally significant for the RT data).

[5]A recent tutorial review of effect sizes (Richardson, 2011) provides some rough guidelines as to how to interpret the magnitudes of effect sizes expressed as η^2_p on the basis of an initial proposal from Cohen (1969): .01 as a small effect, .06 as a medium effect, and .14 as a large effect (Richardson, 2011, p. 142).

After cue reversal (Blocks 5–6)—When focusing on blocks after the reversal, the Task×Switch interaction was also significant in both the RT data, $F(1, 90) = 19.85$, $\eta^2_p = .18$, $p < .001$, and the error data, $F(1, 90) = 27.91$, $\eta^2_p = .24$, $p < .001$.

Effects of cue reversal (Blocks 3–4 vs. 5–6)—To examine whether asymmetric switch costs increased after the cue reversal, we compared RTs and error rates for the two blocks immediately preceding the reversal (Blocks 3–4) to those after the reversal (Blocks 5–6). As shown in Table 2 and the Appendix, overall switch costs were larger after the reversal (Switch×Block interaction) for both the RT and error data. However, as Table 1 indicates, even though the degree of asymmetry in switch costs seemed greater during the trials following the reversal (Blocks 5–6) compared to those before the reversal (Blocks 3–4), this effect (Task×Switch×Block) was not significant in either the RT or error rate data.

Summary—These results demonstrated the robust effects of asymmetric switch costs across all 6 mixed blocks. As expected, the switch costs were larger for the less attentionally demanding location task (i.e., when switching away from the more demanding direction task) than for the more demanding direction task (i.e., when switching away from the less demanding task), even though the direction task was associated with much longer RTs and higher error rates overall. However, although overall switch costs were significantly greater after the cue reversal (Blocks 5–6) than before the reversal (Blocks 3–4), this cue reversal did not significantly magnify the degree of asymmetry in the switch costs between the location and direction tasks.

Primary Analyses: Association Between Trait Anxiety and Asymmetric Switch Costs

After establishing the asymmetric switch cost effect for both RT and error data, we examined whether the magnitudes of such switch cost asymmetry was systematically related to individual differences in trait anxiety, both before and after the cue reversal. To do so, we conducted a series of regression analyses (Judd, McClelland, & Ryan, 2008) in which levels of trait anxiety were allowed to interact with the within-subjects factors of the ANOVAs described above: Task, Switch, and, in some analyses, Block. The regression models also included higher-order interactions between trait anxiety and within-subjects factors (e.g., Task×Switch×Anxiety). In all analyses reported here, the levels of dysphoria were statistically controlled for, following the procedure recommended by Yzerbyt, Muller, and Judd (2004). We treated all of the individual differences measures in this study (e.g., trait anxiety, dysphoria) as continuous variables to avoid well-known statistical problems associated with the still-prevalent practice of creating dichotomous variables with arbitrary cut-off values such as the median score (Irwin & McClelland, 2003; MacCallum, Zhang, Preacher, & Rucker, 2002).

The complete results of these analyses involving trait anxiety are summarized in Table 2, for both the RT and error data. As shown in Table 2, however, because levels of trait anxiety were primarily related to RT results, but not to error results, only the analyses with RT data will be discussed in this section. The finding that the correlations with trait anxiety were consistently observed only for RT data (even though the experimental effects of asymmetric switch costs were robustly observed for both RT and error data) is consistent with ACT's processing efficiency hypothesis, which states that the effects of anxiety are often observed for measures of processing efficiency (RTs) than for performance effectiveness (error rates).

Before cue reversal (Blocks 1–4)—The primary hypothesis concerned the moderating role of trait anxiety in the degree of asymmetry in switch costs for the location and direction tasks. As predicted, for trials before the cue reversal, the degree of asymmetry in switch costs for the two tasks were larger for individuals higher in trait anxiety (Task×Switch×Anxiety), $F(1, 88) = 4.97$, $\eta^2_p = .05$, $p = .028$ (see Table 2a). In other words, although trait anxiety was associated with larger overall switch costs (Switch×Anxiety), $F(1, 88) = 4.31$, $\eta^2_p = .05$, $p = .041$, the association with trait anxiety was greater for the less effortful location task than for the more effortful direction task. Figure 3 illustrates this pattern as regression lines of trait anxiety level versus RT by trial type, for Blocks 1–2 (Figure 3a) and Blocks 3–4 (Figure 3b). In these figures, switch costs can be seen by the difference between the solid and dotted lines for each task (i.e., switch vs. repeat trials), and this difference is considerably larger for the location task lines than for the direction task lines (i.e., the asymmetric switch costs). Importantly, at high levels of anxiety, this asymmetry in switch costs was much more pronounced than at low levels of anxiety.

To confirm that these results were driven by location-task trials (i.e., when switching away from the more attentionally demanding direction task), we analyzed the location-task and direction-task trials separately. On location-task trials only, higher trait anxiety was associated with significantly larger switch costs, collapsed across Blocks 1–4, $F(1, 88) = 4.41$, $\eta^2_p = .05$, $p = .039$. In contrast, levels of anxiety were not associated with switch costs for the direction-task trials, again collapsed across Blocks 1–4, $F(1, 88) = .41$, $\eta^2_p = .01$, $p = .524$. Therefore, the RT switch costs for the location task primarily accounted for the increased asymmetry in switch costs among individuals with higher levels of trait anxiety. Not surprisingly given these results, the overall association between trait anxiety and RTs was significant, $F(1, 88) = 7.89$, $\eta^2_p = .08$, $p = .006$, and the association with anxiety was larger for the location task than for the direction task (Task×Anxiety), $F(1, 88) = 6.77$, $\eta^2_p = .07$, $p = .011$. Finally, there was no evidence that the associations with trait anxiety changed over time (i.e., no interactions involving both Anxiety and Block were significant, all Fs$(1, 88) < .86$, $\eta^2_p < .01$, ps $> .355$).

After cue reversal (Blocks 5–6)—Next, we examined the results for trait anxiety on only those blocks following the reversal (Blocks 5–6). As shown in Figure 3c and Table 2b, the asymmetric switch cost associated with anxiety remained statistically significant after the cue reversal (Task×Switch×Anxiety), $F(1, 88) = 6.91$, $\eta^2_p = .07$, $p = .010$. Levels of trait anxiety were again related to larger switch costs (Switch×Anxiety), $F(1, 88) = 10.38$, $\eta^2_p = .07$, $p = .002$, and worse performance on the location task compared to the direction task (Task×Switch), $F(1, 88) = 5.47$, $\eta^2_p = .06$, $p = .022$.

Effects of cue reversal (Blocks 3–4 vs. 5–6)—Finally, we compared the associations with trait anxiety before the reversal (Blocks 3–4) to those after the reversal (Blocks 5–6) to examine whether the cue reversal magnified these asymmetric effects associated with anxiety (Table 2c). There was no evidence that the associations between trait anxiety and asymmetric switch costs were larger after the reversal (Task×Switch×Block×Anxiety), F(1,

88) = 1.03, $\eta^2_p = .01$, $p = .314$. There was also no strong evidence that the association between trait anxiety and overall switch cost was larger after the reversal, although this difference was marginally significant (Switch×Block×Anxiety), $F(1, 88) = 3.48$, $\eta^2_p = .04$, $p = .066$. These findings suggest that, although the cue reversal manipulation demonstrated the experimental effect of increased switch costs, it did not robustly moderate the associations observed for trait anxiety.

Summary—As predicted, individuals with higher trait anxiety tended to have greater levels of asymmetry in switch costs. More specifically, participants generally experienced greater difficulty switching to the location task than to the direction task, but this tendency was exaggerated for people with higher levels of trait anxiety. Furthermore, although there was some suggestion that the associations between trait anxiety and RT switch costs were larger after the cue reversal, this difference was not statistically significant.

These results from the primary analyses suggest that trait anxiety is not universally related to switching performance, but, rather, that the relationship between trait anxiety and switching may be observed only under some circumstances (i.e., when there is a clear asymmetry in effort expended between the two tasks). Moreover, these results are consistent with the proposal that anxious individuals exerted more effort in establishing the more attentionally demanding task set for the direction task, hence later experiencing greater difficulty when they need to switch away from that task to perform an easier, more automatic location task.

Secondary Analyses: Associations Between Dysphoria/Worry and Asymmetric Switch Costs

In all regression models reported for our primary analyses, we statistically controlled for the level of dysphoria by allowing dysphoria levels to interact with the within-subjects factors in the same way as trait anxiety (Yzerbyt et al., 2004). In this section, we first report the results for the main and interaction effects involving the dysphoria variable in the above models, controlling for levels of trait anxiety. We then describe the results of additional analyses conducted to examine the extent to which the results that we reported above for trait anxiety could be accounted for by the worry component of anxiety.

Dysphoria—Dysphoria was not systematically related to switching performance for the RT data. Specifically, unlike levels of trait anxiety, levels of dysphoria did not interact with any of the within-subjects experimental variables, before, after, or across the reversal, all Fs(1, 88) < 2.62, $\eta^2_p < .03$, ps > .108. Levels of dysphoria were not associated with overall RTs in any of these models, either (i.e., no main effects of dysphoria), all Fs(1, 88) < .06, $\eta^2_p < .01$, ps > .814.

The error data showed the same pattern of results, with one exception: a significant Task×Dysphoria interaction was obtained on some blocks, indicating that participants with higher dysphoria made more errors on the more effortful direction task than on the less effortful location task, $F(1, 88) = 7.61$, $\eta^2_p = .08$, $p = .007$, for Blocks 5–6 only, $F(1, 88) = 8.79$, $\eta^2_p = .09$, $p = .004$, for Blocks 3–4 vs. 5–6 (Task×Dysphoria×Block). These results suggest that the associations observed for dysphoria may be more pronounced for performance effectiveness for attentionally demanding tasks, rather than the efficiency of task switching per se. Importantly, these results also suggest that the key associations reported for our primary analyses (significant Task×Switch×Anxiety interactions) are specific to trait anxiety and cannot be attributed to a substantial amount of variance shared between anxiety and dysphoria.

Worry—We also examined the potential role of worry by adding levels of worry to the regression models (with anxiety and dysphoria above) as another continuous predictor that could interact with the experimental factors. As was the case with the analyses with dysphoria, worry was essentially unrelated to performance on the asymmetric switching task. For both RT and error data, worry did not generally interact with any experimental factors, all *F*s(1, 87) < 2.57, $\eta^2_p < .03$, *p*s > .111, for RT data, all *F*s(1, 87) < 2.67, $\eta^2_p < .03$, *p*s > .105, for error data. Although there were two exceptions (both observed for the RT data),[6] these results depended on the inclusion of the trait anxiety variable in the model. In other words, neither of these associations remained significant if anxiety was removed from the model. Thus, it is not clear whether these results reflect real associations with worry or are possibly spurious findings (e.g., due to the large number of statistical tests performed). Important to note, in these analyses involving worry, all of the significant results for trait anxiety reported for our primary analyses above remained statistically significant, and no associations that were not statistically significant before became significant after the addition of worry in the model. Thus, the systematic relationship reported above for trait anxiety cannot be accounted for by the worry component of trait anxiety.

Discussion

The purpose of this study was to test the hypothesis that trait anxiety is related to shifting performance in emotionally neutral contexts primarily when individuals must switch away from an effortfully established task set. To test this new hypothesis, we used an asymmetric task switching paradigm in which participants switched between two tasks differing in their attentional demands. Replicating the basic asymmetric switching effect, we demonstrated that both RT and error switch costs were larger for the less attentionally demanding location task than for the more demanding direction task. More important, in line with our hypothesis, we found that individuals with higher trait anxiety exhibited a greater asymmetry in their RT switch costs (but not error switch costs) than those with lower trait anxiety. These results support the proposal that individuals with higher trait anxiety have difficulty switching away from more effortfully established task sets, but do not necessarily have general difficulty with switching per se. Furthermore, we also found that these results were specific to trait anxiety and unrelated to variance shared between anxiety and dysphoria or a subcomponent of trait anxiety, worry.

Although our primary hypothesis was confirmed, we did not observe strong evidence for our secondary hypothesis that the relationship between trait anxiety and the degree of asymmetry in switch costs would become even stronger after the cue-mapping reversal.

[6]First, in blocks before the reversal only (Blocks 1–2 & 3–4), worry was associated with smaller overall switch costs (Switch x Worry), *F*(1, 87) = 4.04, $\eta^2_p = .04$, $p = .048$. Second, in the same model comparing Blocks 1–2 and 3–4, there was some suggestion that levels of worry were associated with greater RT reduction for the direction task than for the location task (Task x Block x Worry), *F*(1, 88) = 7.16, $\eta^2_p = .08$, $p = .009$.

There was some indication that the associations between trait anxiety and RT switch costs were larger after the cue reversal, but the cue-mapping reversal neither significantly amplified the asymmetric switching effect at the experimental level nor moderated the strength of the association between anxiety and switch costs in the regression analyses. In hindsight, this finding makes sense, considering that reversing the cue-mapping rules was a one-time change introduced between Blocks 4 and 5 and did not involve constant changes in task rules. This cue-mapping reversal was likely challenging to participants right after its introduction (i.e., at the beginning of Block 5), but, once this rule change was mentally established shortly thereafter, no such further reversal was required. Thus, these results suggest that the effects of trait anxiety on shifting may be strongest immediately or shortly after when individuals must switch away from effortfully established task sets, but that such effects may not persist across many trials in the absence of constant shifting requirements.

In the rest of this section, we discuss how these results (a) reconcile the existing evidence on trait anxiety and shifting, (b) inform other work on anxiety and shifting more broadly, and (c) can be used to refine ACT and extend it in new directions.

Specifying the Relationship Between Trait Anxiety and Shifting

On the basis of the limited prior evidence regarding the relationship between trait anxiety and shifting in emotionally neutral situations, we proposed a new hypothesis that the negative effect of trait anxiety on shifting performance may be observed primarily when individuals must switch away from an effortfully established task set. As noted in the introduction, this hypothesis provides a coherent explanation of the seemingly mixed previous evidence on trait anxiety and shifting performance. Specifically, existing evidence suggests that an association between trait anxiety and shifting can be observed for the WCST, a task that requires participants to effortfully build a task representation and then quickly override it, but not for the TMT and symmetric switching, which require constant switching between two task representations relatively equivalent in attentional demands (e.g., counting 1–9 vs. A-Z in the TMT, making color vs. shape judgments in symmetric task switching). These prior results are consistent with the alternative hypothesis on the anxiety–shifting relationship tested and supported in the current study.

It is important to acknowledge, however, that two existing studies that examined switch costs in a task-switching paradigm may potentially challenge our hypothesis (Ansari et al., 2008; Ansari & Derakshan, 2011). Specifically, in these studies, participants switched, on the basis of a visual cue, between trials in which they needed to quickly attend to a stimulus on the same side of the screen (prosaccade) or on the opposite side of the screen (antisaccade). In both studies, RT switch costs were larger for the high-anxiety group (STAI scores > 44 or 45) compared to the low-anxiety group (STAI scores < 34 or 38), but only for the more attentionally demanding antisaccade task. In other words, the effect of trait anxiety was observed not when participants were switching away from the more attentionally demanding task but, rather, when they were switching back to that attentionally demanding task.

Upon close examination, however, it is unclear whether the results from these two studies directly contradict our hypothesis (Ansari et al., 2008; Ansari & Derakshan, 2011). This is primarily because the patterns of switch costs in these studies deviate, in some important ways, from typical findings based on the asymmetric switching paradigm (i.e., their data did not show the widely replication pattern illustrated in Figure 1). First, in the mixed prosaccade/antisaccade blocks, there was actually a switching RT benefit, rather than a cost, when switching to the more attentionally demanding task. Second, high error rates for the antisaccade task (as high as 25–30% on switch trials in the mixed blocks) indicate that participants in the Ansari and Derakshan (2011) study likely failed to consistently establish the more attentionally demanding task set before switching,[7] which we consider vital to our suggestion that the anxiety–shifting relationship is most robust when one is switching away from the more demanding task.Together, these considerations suggest that, even though Ansari and colleagues used an asymmetric switching paradigm, these two prior studies might have primarily tapped participants' inhibition performance, rather than shifting performance, especially given that the antisaccade task is a commonly used measure of response inhibition (e.g., Miyake et al., 2000).

Extending the results to other aspects of shifting—Although we investigated the relationship between trait anxiety and shifting performance using the asymmetric switching paradigm, asymmetric switch costs are only one of the well-established phenomena in the task-switching literature. In fact, various other task-switching phenomena demonstrated in the literature (for reviews, see Kiesel et al., 2010; Vandierendonck et al., 2010) can be used to examine which aspects or components of switching may be affected in trait anxiety.

It is possible, for example, to examine whether the associations with trait anxiety may extend to repeat trials in the mixed blocks as well by looking at another commonly used dependent measure in task-switching studies known as the mixing cost. Unlike switch costs, the mixing costs compare performance on repeat trials in baseline (or pure) blocks consisting of only repeat trials to performance on repeat trials in mixed blocks (i.e., when participants are also switching). If levels of trait anxiety are systematically related to the magnitudes of mixing costs, such an association would suggest that trait anxiety may be related to one's ability to minimize the negative influence from the other task set that should not be currently active. Indeed, follow-up analyses in our own RT data suggested that, like the effects for switch costs, trait anxiety was associated with larger mixing costs for location-task trials, and not for direction-task trials.[8] Future research could also capitalize on manipulating preparation time (cue-stimulus intervals), given that the time participants have to prepare for a given switch may affect the efficiency of disengaging from a previous task set and establishing a new one.

Shifting Impairments in Different Aspects of Anxiety

A secondary goal of this study was to examine which aspects of trait anxiety were primarily associated with shifting in the context of this asymmetric switching paradigm. As has been

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[7]Further consistent with this interpretation, the Ansari and Derakshan (2011) study found that these effects were specific to situations with short cue-stimulus intervals, namely, when participants did not have enough time to interpret the cue and effortfully engage in advance task-set configuration. In contrast, we used a cue-stimulus interval of 750 ms in this study to allow for active establishment of task sets.

[8]These analyses were based on mixing cost RTs, operationalized as the difference between repeat-trial RTs in mixed blocks and repeat-trial RTs in the baseline pure block, computed separately for blocks 1–2, 3–4, and 5–6. Significantly larger mixing costs in high anxiety were observed for the location task across all blocks, all Fs(1, 88) > 4.46, $\eta^2_p > .04$, ps < .039, but not for the direction task, all Fs(1, 88) < 1.62, $\eta^2_p < .02$, ps > .206 (all analyses statistically controlled for levels of dysphoria).

suggested by recent studies that focused on working memory updating (Gustavson & Miyake, 2016; Stout, Shackman, Johnson, & Larson, 2015), the association between anxiety and shifting observed in the current study could primarily reflected the worry subcomponent of trait anxiety. In fact, ACT has suggested that worry is responsible for the association between anxiety and processing efficiency (and sometimes also performance effectiveness), at least with regard to state worry (Eysenck, et al., 2007). The results of the current study, however, do not reveal any systematic relations between trait levels of worry and asymmetric switch costs, suggesting that the worry component of anxiety could not account for the association between anxiety and shifting described here. These results, in turn, suggest that other components of trait anxiety assessed with the BAI (e.g., anxious arousal, fear) may be able to better predict shifting performance, although this speculative influence must be tested more directly in future studies.

Although the current study focused on trait anxiety, there is some evidence suggesting that our hypothesis may extend to the relationship between state anxiety and shifting as well. Specifically, Derakshan et al. (2009) observed an association between state anxiety and RT switch costs when switching between multiplication and division tasks, but not when switching between addition and subtraction tasks. Derakshan et al. (2009) explain these findings as an effect of task complexity (i.e., multiplication and division require complex mental operations than additional and subtraction), but an alternative interpretation is that these results were driven by the large asymmetry in the difficulty between the multiplication and division tasks (RT switch costs were not reported separately, but the multiplication-task RTs were about 5,000 ms larger than the division-task RTs in baseline blocks, whereas addition and subtraction RTs were comparable, ~3,000 ms each). Thus, although task complexity may have also contributed, these results are also consistent with the idea that RT switch costs in anxiety are most pronounced when there is a clear asymmetry in task demands.

Theoretical Implications for ACT

The results of the current study have some important theoretical implications for ACT, even though the scope of this study was restricted to the association between trait anxiety and task switching in neutral contexts. First, our results were only partially consistent with ACT's original claim on the anxiety-shifting relationship (Eysenck et al., 2007). Specifically, our results were consistent with ACT's claim that the effects of anxiety are most salient in terms of processing efficiency, rather than performance effectiveness. In particular, at the overall group level, both the RT and error data demonstrated the predicted asymmetry in switch costs, but only the RT data revealed a significant relationship between levels of trait anxiety and the degree of asymmetry in switch costs between the location and direction tasks. These results, in turn, are consistent with our explanation that, to achieve the same degree of performance effectiveness (i.e., accuracy), individuals with high trait anxiety must exert stronger attentional control (i.e., more effort) to perform well on the more attentionally demanding task. As a result, rather ironically, individuals with high levels of trait anxiety find it more difficult to get out of (or let go of) that task set, hence demonstrating a greater asymmetry in RT switch costs than those with low levels of trait anxiety.

Our results, however, are not consistent with ACT's claim that shifting performance is generally impaired in anxiety, even in emotionally neutral contexts. Instead, our results suggest that the association between anxiety (or at least trait anxiety) and shifting performance may be restricted primarily to the process of switching away from effortfully established task sets. Thus, the results from the current study invite closer reexaminations of the anxiety–shifting relationship. Our alternative hypothesis is more specific and more precise than ACT's original hypothesis on shifting, is clearly testable, and could potentially be generalized to the effect of state anxiety. Thus, we believe that our alternative hypothesis help guide future theoretically motivated investigations on the anxiety–shifting relationship.

More generally, it may also be time for the other EF-related hypotheses of ACT to be reexamined and, if necessary, revised. Since its initial conception (Eysenck et al., 2007), ACT has provided simple, clearly stated hypotheses regarding anxiety and different EF components (i.e., shifting and inhibition abilities are impaired in anxiety, but updating ability is not, unless tested under threatening situations). In light of newer evidence, however, it is important to evaluate and potentially refine these general theoretical claims. First, given that inhibition is a multifaceted construct (Nigg, 2000; Friedman & Miyake, 2004), it is possible that some aspects of inhibitory control abilities may be more or less strongly associated with anxiety than others. Second, although ACT has claimed that updating ability is generally spared in anxiety, a recent meta-analysis involving 177 studies (total $N = 22{,}061$) found a significant association between anxiety and working memory capacity (Moran, 2016). Moreover, recent research has also found that levels of trait anxiety may be systematically related to the processing efficiency of updating performance when RT measures were used (Gustavson & Miyake, 2016). Finally, although different facets of EFs (e.g., inhibition, updating, and shifting) have been known to be substantially correlated (e.g., Miyake et al., 2000), ACT has so far emphasized the separability of EFs. Given that a recent review of the clinical evidence (Snyder et al., 2015) points to a potentially important role in psychopathology of general EF ability (i.e., what is common to different EF components; Friedman & Miyake, in press; Miyake & Friedman, 2012), it will be useful to examine how anxiety is related to general EF ability. As these possible future directions indicate, refining and rigorously testing the current ACT hypotheses will help substantially advance our understanding of the anxiety–EF relationship.

Acknowledgments

This research was supported by Grant MH016880 from the National Institutes of Health.

We thank Vicky Grunberg, Bess Reynolds, Janelle Kramer, Auburn Meisner, and Anna Zelinskaya for data collection.

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Appendix

Basic Experimental Effects on the Asymmetric Switching Task

	Reaction Times			Error Rate		
	F	η^2_p	p	F	η^2_p	p
A. Before Reversal Only (blocks 1–4)						
Task (Location vs. Direction)	266.73	.75	< **.001**	3.10	.03	.082
Switch (Switch vs. Repeat)	60.04	.40	< **.001**	108.14	.55	< **.001**
Block (1–2 vs. 3–4)	33.58	.27	< **.001**	22.56	.20	< **.001**
Task × Switch	18.74	.17	< **.001**	49.26	.35	< **.001**
Task × Block	4.89	.05	**.030**	1.51	.02	.223
Switch × Block	5.54	.06	**.021**	55.48	.38	< **.001**
Task × Switch × Block	3.89	.04	.052	2.43	.03	.123
B. After Reversal Only (blocks 5–6)						
Task	237.80	.73	< **.001**	1.14	.01	.289
Switch	42.54	.32	< **.001**	95.86	.52	< **.001**
Task × Switch	19.85	.18	< **.001**	27.91	.24	< **.001**
C. Effect of Reversal (blocks 3–4 vs. 5–6)						
Task (Location vs. Direction)	315.03	.78	< **.001**	4.25	.05	**.042**
Switch (Switch vs. Repeat)	51.54	.36	< **.001**	91.77	.51	< **.001**
Block (1–2 vs. 3–4 vs. 5–6)	.79	.01	.376	.08	.00	.777
Task × Switch	20.19	.18	< **.001**	56.19	.38	< **.001**
Task × Block	6.66	.07	**.011**	2.74	.03	.102

	Reaction Times			Error Rate		
	F	η^2_p	p	F	η^2_p	p
Switch × Block	7.57	.08	**.007**	7.87	.08	**.006**
Task × Switch × Block	2.45	.03	.121	1.21	.01	.274
D. All Blocks (blocks 1–2 vs. 3–4 vs. 5–6)						
Task (Location vs. Direction)	310.76	.78	**< .001**	3.04	.03	.085
Switch (Switch vs. Repeat)	63.42	.41	**< .001**	147.76	.62	**< .001**
Block (1–2 vs. 3–4 vs. 5–6)[a]	25.13	.22	**< .001**	14.56	.14	**< .001**
Task × Switch	27.04	.23	**< .001**	62.84	.41	**< .001**
Task × Block [a]	9.91	.10	**< .001**	1.19	.01	.308
Switch × Block [a]	3.92	.04	**.022**	26.85	.23	**< .001**
Task × Switch × Block	2.17	.02	.117	1.35	.02	.263

Note: Degrees of freedom for all comparisons were $F(1, 90)$ except when noted ([a]), where degrees of freedom were $F(2, 90)$.

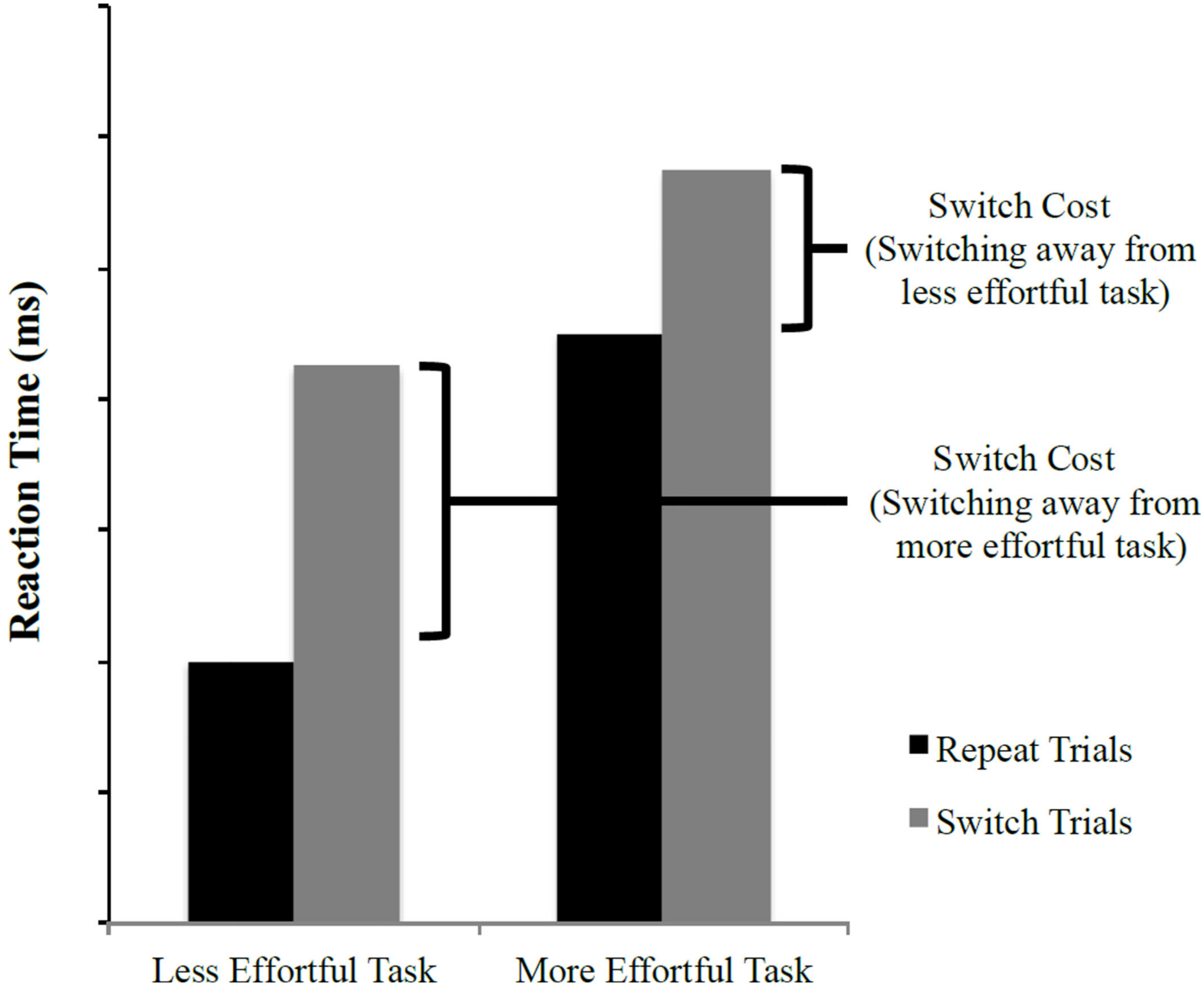

Figure 1.

A visual illustration of a typical pattern of asymmetric switch costs. Even though RTs are generally slower on the more effortful task, switch cost RTs (i.e., Switch trial RT – repeat trial RT) are larger for the less effortful task.

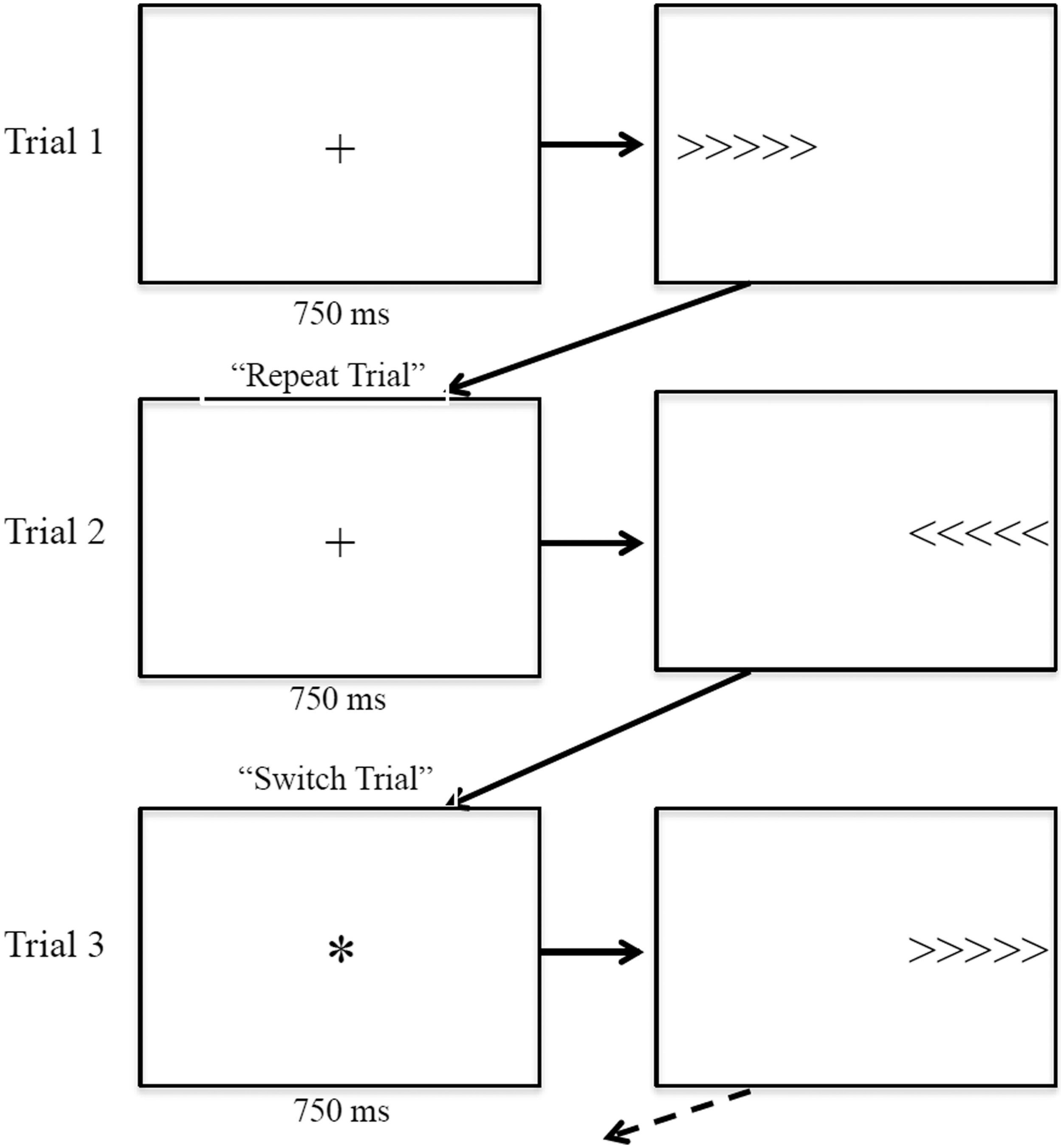

Figure 2.
Example trials of the switching task in the mixed blocks. Trial 2 represents a repeat trial because the same task was cued on Trial 1 (i.e., location judgment), and Trial 3 represents a switch trial because it cued a switch to the direction judgment. These 'Repeat Trial' and 'Switch Trial' labels were not actually presented on the screen.

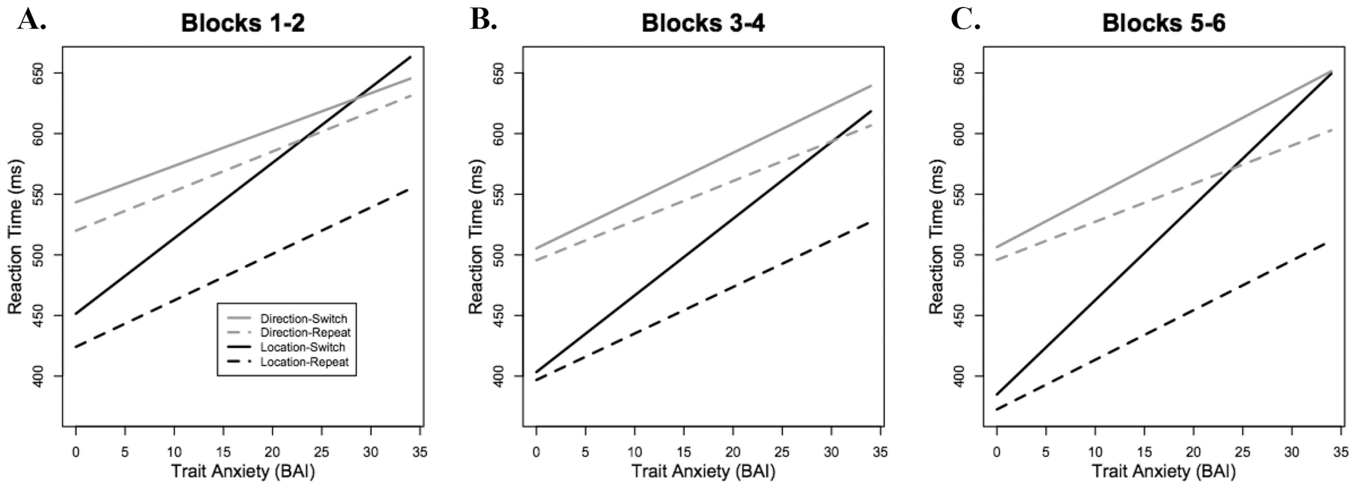

Figure 3.

Anxiety effects with RTs by task and by switch, both before (A and B) and after (C) the cue-to-task mapping reversal. Levels of trait anxiety were associated with larger asymmetric switch costs. Namely, location task lines diverge substantially (i.e., exhibiting larger switch costs) for those with high anxiety, but diverge at a much smaller degree for the direction task, even for those high in trait anxiety. Dysphoria (as measured by the BDI) was controlled for in all linear models.

Table 1

Experimental Effects of the Asymmetric Switching Task

	Blocks 1–2			Blocks 3–4			Blocks 5–6		
	Mean	**SD**	**Switch Cost**	**Mean**	**SD**	**Switch Cost**	**Mean**	**SD**	**Switch Cost**
Reaction Time (ms)									
Location – switch	526	147	56	479	115	36	478	141	56
Location – repeat	470	111		443	94		422	100	
Direction – switch	579	119	20	553	111	18	558	128	25
Direction – repeat	559	107		535	99		533	98	
Error Rate (% Incorrect)									
Location – switch	14.8	9.7	7.9	11.6	8.8	4.8	11.5	8.5	5.7
Location – repeat	6.9	5.8		6.8	6.4		5.8	6.8	
Direction – switch	12.3	10.4	4.6	7.6	8.5	0	9.1	8.6	1.9
Direction – repeat	7.7	8.1		7.6	7.8		7.2	8.7	

Note: Reaction times, error rates, and switch costs for trials by task (location or direction), switch (switch or repeat), and before and after the cue-to-task mapping reversal.

Table 2

Summary of the Regression Results Involving Trait Anxiety

	Reaction Times			Error Rate		
	F	η^2_p	p	F	η^2_p	p
A. Before Reversal Only (blocks 1–4)						
Task (Location vs. Direction) × Anxiety	6.77	.07	**.011**	4.33	.05	**.040**
Switch (Switch vs. Repeat) × Anxiety	4.31	.05	**.041**	2.26	.03	.137
Block (1–2 vs. 3–4) × Anxiety	.13	.00	.718	3.06	.03	.084
Task × Switch × Anxiety	4.97	.05	**.028**	.17	.00	.682
Task × Block × Anxiety	.09	.00	.772	.14	.00	.707
Switch × Block × Anxiety	.43	.01	.517	.96	.01	.329
Task × Switch × Block × Anxiety	.86	.01	.356	.43	.01	.515
B. After Reversal Only (blocks 5–6)						
Task × Anxiety	5.47	.06	**.022**	1.60	.02	.209
Switch × Anxiety	10.38	.11	**.002**	2.03	.02	.158
Task × Switch × Anxiety	6.91	.07	**.010**	.25	.00	.619
C. Effect of Reversal (blocks 3–4 vs. 5–6)						
Task × Anxiety	6.72	.07	**.011**	4.71	.05	**.033**
Switch × Anxiety	10.54	.11	**.002**	2.05	.02	.156
Block (3–4 vs. 5–6) × Anxiety	.08	.00	.782	.45	.01	.506
Task × Switch × Anxiety	6.51	.07	**.012**	.66	.01	.420
Task × Block × Anxiety	.37	.00	.545	1.96	.02	.165
Switch × Block × Anxiety	3.48	.04	.066	.14	.00	.709
Task × Switch × Block × Anxiety	1.03	.01	.314	.05	.00	.817
D. All Blocks (blocks 1–2 vs. 3–4 vs. 5–6)						
Task × Anxiety	7.72	.08	**.007**	4.28	.05	**.041**
Switch × Anxiety	8.03	.08	**.006**	3.14	.03	.080
Block (1–2 vs. 3–4 vs. 5–6) × Anxiety[a]	.19	.00	.824	1.43	.02	.243
Task × Switch × Anxiety	8.15	.09	**.005**	.31	.00	.579
Task × Block × Anxiety[a]	.15	.00	.861	.82	.01	.440

	Reaction Times			Error Rate		
	F	η^2_p	p	F	η^2_p	p
Switch × Block × Anxiety[a]	3.05	.03	**.050**	.46	.01	.631
Task × Switch × Block × Anxiety	.63	.01	.532	.24	.00	.785

Note: The interactions between levels of anxiety and the within-subjects ANOVA factors. In all models, levels of dysphoria were also included as continuous predictors. Degrees of freedom for all comparisons were $F(1, 88)$ except when noted ([a]), where degrees of freedom were $F(2, 88)$.