Accepted Manuscript
(25th April, 2016)
doi:10.1016/j.concog.2016.04.011
Consciousness and Cognition
Volume 42
May 2016
Pages 358-365

The effect of task-relevant and irrelevant anxiety-provoking stimuli on response inhibition

Kyle M. Wilson[a]*, Neil R. de Joux[b], Kristin M. Finkbeiner[a], Paul N. Russell[a], and William S. Helton[a]

[a]*Department of Psychology, University of Canterbury, Christchurch, New Zealand*
[b]*Human Factors Research Group, Faculty of Engineering, University of Nottingham, Nottingham, UK*

Institution affiliation and address (all authors):
Department of Psychology, University of Canterbury, Private Bag 4800, Christchurch, New Zealand. Fax +64 3 3642181.
Author email addresses:
Kyle Wilson: k.wilson@hud.ac.uk
Neil de Joux: neil.dejoux@nottingham.ac.uk
Kristin Finkbeiner: kristin.finkbeiner@pg.canterbury.ac.nz
Paul Russell: paul.russell@canterbury.ac.nz
Deak Helton: deak.helton@canterbury.ac.nz

*Corresponding author. Address: Department of Behavioural and Social Sciences, University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, United Kingdom. Phone 01484 472770.
Email address: k.wilson@hud.ac.uk (K.M. Wilson)

 doi:10.1016/j.concog.2016.04.011 Consciousness and Cognition
Volume 42
May 2016
Pages 358-365

Abstract

The impact of anxiety-provoking stimuli on the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), and response inhibition more generally, is currently unclear. Participants completed four SARTs embedded with picture stimuli of two levels of emotion (negative or neutral) and two levels of task-relevance (predictive or non-predictive of imminent No-Go stimuli). Negative pictures had a small but detectable adverse effect on performance regardless of their task-relevance. Overall, response times and rates of commission errors were more dependent upon the predictive value (relevance) of the pictures than their attention-capturing nature (i.e., negative valence). The findings raise doubt over whether anxiety improves response inhibition, and also lend support to a response strategy perspective of SART performance, as opposed to a mindlessness or mind-wandering explanation.

Keywords: Anxiety; Attention; Emotion; Sustained attention; Response inhibition; SART; Speed–accuracy trade-off; Inhibitory control; Vigilance; Picture processing

1. Introduction

The Sustained Attention to Response Task (SART) is a Go/No-Go response task requiring motor inhibition (Robertson et al., 1997). In the SART subjects make repetitive responses to Go stimuli on approximately 90% of trials, but have to withhold responses to rarer No-Go stimuli. The speeded repetitive responding in the SART results in the development of a feed-forward ballistic motor program (Head & Helton, 2013; Robertson et al., 1997). Indeed, commission errors are more likely in the SART when responses to Go stimuli are faster suggesting a trade-off between the speed of response to Go stimuli and the ability to withhold responding to No-Go stimuli (Helton, 2009). The SART provides a measure of the ability to inhibit pre-potent motor responses.

Robinson and colleagues (2013) in a prior study using the SART demonstrated that the administration of task-irrelevant electric shocks to participants during the SART reduced commission errors without affecting response times to Go stimuli (Robinson, Krimsky, & Grillon, 2013). A number of factors influence SART performance by shifting the participants' emphasis on speed at the cost of accuracy or vice versa (Head & Helton, 2013; Head & Helton, 2014; Seli, Cheyne, & Smilek, 2012; Seli, Jonker, Solman, Cheyne, & Smilek, 2013), but in this case the administration of shocks improved response inhibition with no evidence of a response strategy shift. To further examine this finding, Wilson and colleagues (2015) developed a SART in which pictures of spiders and neutral stimuli served as the Go or No-Go stimuli (both combinations were used). They compared this modified spider picture SART with the original SART in which the Go and No-Go stimuli are the numbers 1–9. Since spiders are anxiety provoking stimuli (Gerdes, Uhl, & Alpers, 2009), Wilson and colleagues predicted in line with Robinson et al. (2013) that the spider SART in comparison to the number SART would result in fewer commission errors but at no cost to response time. This prediction was correct. However, the authors also proposed that spider stimuli may simply be more salient and consequently identified more quickly. Researchers have suggested people may have the ability to recognise spiders extremely quickly (Flykt, 2005; LoBue, 2010). Smallwood (2013) found that making the No-Go number stimuli red versus the Go number stimuli black improved accuracy at no cost to response time in the number SART.

The impact of affect provoking stimuli on the SART, or response inhibition more generally, is unclear. In terms of tasks involving fine motor control, exposure to negative picture stimuli has been shown to increase error after short exposure and increase speed following long exposure (Coombes, Janelle, & Duley, 2005). In cognitive tasks, negative emotional stimuli have been found to impair task performance by competing with attentional resources (Helton & Russell, 2011; Ossowski, Malinen, & Helton, 2011). Helton and Russell (2011) observed that negative picture stimuli led to significantly more misses (the equivalent to omission errors in a SART) compared to neutral picture stimuli and a no-picture control in a vigilance task. In a task where participants made multiple shoot or no-shoot decisions, similar to the way SART participants make responses to Go and No-Go stimuli, stress induced through the use of a shock belt led to more commission errors (Patton, 2014). Unlike the shocks in Robinson and colleagues' (2013) study, shocks in Patton's study resulted in impaired ability to inhibit responses. However, in this case the shocks were not task-irrelevant but tied to the task-stimuli themselves; the shocks were task-relevant.

The role of affect provoking stimuli on response inhibition clearly warrants further exploration. In the current experiment we used picture stimuli embedded into SARTs in a factorial design combining two levels of emotion (negative vs. neutral pictures) and two levels of task-relevance (predictive—task-relevant vs. non-predictive—task-irrelevant). In our SARTs, the pictures either did predict or did not predict the imminent onset of No-Go stimuli. In one condition, all pictures reliably predicted the occurrence of No-Go stimuli whereas in another condition they occurred randomly, before Go or No-Go stimuli. In addition, the pictures were either rated high for negative valence and arousal or rated neutral for valence and arousal.

 doi:10.1016/j.concog.2016.04.011 Consciousness and Cognition
Volume 42
May 2016
Pages 358-365

Participants performed four SARTs: predictive–negative, predictive–neutral, non-predictive–negative, and non-predictive–neutral.

The experimental design allows us to determine whether the effect of stimulus valence is moderated by the task relevance (predictive vs. not predictive). While we expected that negative picture stimuli would lead would lead to fewer commission errors, it was not clear whether valence would influence the impact that task-relevance might have, or the direction that any such effect might be. If stimulus valence affects rates of commission errors regardless of the task relevance of the picture stimuli, a statistically reliable emotion main effect will be found. If the effect of stimulus valence is moderated by task relevance an emotion x relevance interaction effect will be evident. There is less uncertainty about the effects of task relevance on commission errors. In previous studies, predictive warning stimuli improved SART performance (Finkbeiner, Wilson, Russell, & Helton, 2014; Helton, Head, & Russell, 2011; Helton, Head, & Kemp, 2011) through reducing commission errors as well as shortening response times. The same findings are expected here. That is, there is expected to be main effects of task-relevance, whereby task-relevant stimuli will reduce commission errors and shorten response times.

Self-report measures were included to verify that that the negative picture SARTs effectively elicited negative emotional reactions in participants relative to neutral picture SARTs. In addition, the inclusion of the self-report measures was to address an ongoing debate in the SART literature. While there is agreement that speed–accuracy trade-offs are prevalent in the SART, there is an ongoing debate around what causes the trade-off. One explanation for errors in the SART is that participants become bored and their attention to the task wanes, leading to a state of mindlessness (Manly, Robertson, Galloway, & Hawkins, 1999; Robertson et al., 1997) or mind-wandering (Smallwood & Schooler, 2006). From the inattention perspective, self-reported decreases in task-related and task-unrelated thoughts (mindlessness) or increases in task-unrelated thoughts (mind-wandering) are often taken as evidence of perceptual decoupling.

Alternatively, it is possible to explain the trade-off between the risk of responding to No-Go stimuli and speed of response to Go stimuli without invoking attention, mindlessness, mind-wandering or perceptual decoupling at all (e.g. Helton, Kern, & Walker, 2009; Peebles & Bothell, 2004). When 89% of trials are Go trials requiring a speeded response and only 11% are No-Go trials, participants decide that the benefits of speed on 89% of trials outweigh the costs of reducing speed on all (100%) trials, which is necessary to avoid making the occasional commission error to a No-Go stimulus. Indeed Peebles and Bothell (2004) presented a model based on the Adaptive Control of Thought-Rational architecture (ACT-R; Anderson & Lebiere, 1998), which incorporates two competing response strategies. One strategy favours speed at the expense of accuracy (encode and ‘click’) while the other strategy is slower but more accurate (encode and ‘check’). The strategy choice is dynamic, and participants balance the utility of each strategy from trial to trial within the SART. For example, after a fast correct Go response, the utility of “click” is reinforced, while a commission error will see the utility of “check” enhanced. The model proposed by Peebles and Bothell successfully predicts the speed–accuracy trade-off and other response time data in the SART (Helton, 2009; Helton, Weil, Middlemiss, & Sawers, 2010).

Concerning the self-report stress scale, two items that are of particular interest to this debate are the measures of task-related thoughts and task-unrelated thoughts, as these measures are central to the two main competing theories. From an inattention perspective, increased task-unrelated thoughts and/or decreased task-related thoughts should be seen in the condition where SART commission errors are highest, because mind-wandering and mindlessness are thought to cause commission errors (Robertson et al., 1997). On the other hand, those advocating a simple response strategy perspective do not necessarily expect high task-unrelated thoughts/low task-related thoughts in the SART with the highest commission errors, because this view does not attribute errors to failures of conscious attention per se. From a response strategy perspective if subjects are sensitive to stimulus contingencies and relative probabilities of Go and No-Go stimuli then

 doi:10.1016/j.concog.2016.04.011 Consciousness and Cognition
Volume 42
May 2016
Pages 358-365

task performance should depend much more on the predictive value of warning cues than on the attention-capturing potential of the stimuli or reports of conscious focus.

2. Methods

2.1 Participants

Forty-two (16 male, 26 female) undergraduate students from the University of Canterbury in Christchurch, New Zealand, participated as part of a course laboratory class requirement. They ranged in age between 17 and 53 years (*M* = 21.5, *SD* = 12.3). All participants had normal or corrected-to-normal vision.

2.2 Materials and procedure

Participants were tested in individual workstation cubicles. They were given an information sheet and a consent form which they signed. Wrist watches were removed and mobile phones were switched off. Participants were seated approximately 50 cm in front of Phillips 225B2 LCD computer screens (1680 x 1050 pixels, 60 Hz refresh rate) that were mounted at eye level. Participants' head movements were not restrained. Stimuli presentation, response accuracy, and timing were achieved using E-prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2002).

The tasks were modified versions of the SART (Robertson et al., 1997). They required participants to monitor the screen for digit stimuli, responding by pressing the spacebar to frequently-occurring Go stimuli (the digits 1–9, excluding 3) and withholding responses to infrequent No-Go stimuli (the digit 3). Go stimuli occurred with a probability of 0.89 and No-Go stimuli occurred with a probability of 0.11. Participants were told to emphasise speed and accuracy equally. Digits varied in size, were randomly selected from point sizes 48, 72, 94, 100, and 120, and were all of Arial font. Each SART consisted of 225 trials. In addition to the digit stimuli, which occurred on every trial, picture stimuli were also incorporated into the SARTs. These were displayed on 11% of trials (the same amount as No-Go trials) and their presentation always came immediately before digit stimuli. On non-picture trials (89% of trials) a mask consisting of a ring with a diagonal line through it firstly appeared on screen for 450 ms. On picture trials (11% of trials) a picture appeared for 250 ms, followed by the mask for 200 ms. Following this for both trial types, a digit stimulus appeared for 250 ms. Finally, the mask was displayed on screen for 750 ms (see Fig. 1). Responses were recorded up to 1000 ms following stimulus onset. The onset-to-onset interval was 1450 ms and each SART was approximately 5.4 mins in duration. The picture stimuli were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2001). The IAPS contains picture stimuli rated for both arousal and valence on a 9-point scale. Two sets of picture stimuli (*N* = 25 for each) were used: a neutral set and a negative set. Pictures selected for the neutral set were rated as being neutral in valence (*M* = 5.02, *SD* = .13) and low in arousal (*M* = 3.04, *SD* = .59), while pictures selected for the negative set were rated as being negative in valence (*M* = 1.79, *SD* = .33) and high in arousal (*M* = 6.64, *SD* = .53). Two of the SARTs contained neutral pictures (e.g., a towel and a satellite) while the other two SARTs contained negative pictures (e.g., a mortally injured person and a gun pointing at the participant). Pictures spanned the width and height of the screen. A second manipulation was the predictive nature of the picture stimuli. In two of the SARTs ("predictive"—task-relevant), pictures always came before No-Go stimuli, effectively serving as predictors of No-Go stimuli on 100% (25/25) of the No-Go trials. In the other two SARTs ("non-predictive"—task-irrelevant) the pictures had equal likelihood of occurring before any of the digit stimuli, 1-9. Before the experimental tasks began, participants completed a practice session to familiarise themselves with the task. This provided verbal feedback on accuracy, contained 18 trials and was approximately 40 sec

Accepted Manuscript
(25th April, 2016) doi:10.1016/j.concog.2016.04.011 Consciousness and Cognition
Volume 42
May 2016
Pages 358-365

in duration. No picture stimuli were included here and it was essentially identical to a typical digit SART. Participants completed all four SARTs (predictive–negative; predictive–neutral; non-predictive–negative; non-predictive–neutral) in a repeated measures design. Half of participants began with a SART containing negative pictures and the other half began with a SART containing neutral pictures, and similarly half of participants' first SART contained task-relevant (predictive) stimuli while the other half of participants' first SART had task-irrelevant (non-predictive) stimuli. Counterbalancing was used and participants were randomly assigned to pre-determined task orders. In order to prevent potential confusion for participants by requiring them to switch back and forth between the two different levels of task-relevance, participants always completed either both predictive SARTs or both non-predictive SARTs first. Alternating between the two different emotional valences instead of the two different prediction levels was done to minimise the chances of participants becoming confused as to what the pictures indicated (i.e., whether a No-Go stimulus was certain to follow or not). Participants were informed of the predictive nature (either predictive or non-predictive) of each forthcoming SART immediately before they began that SART. They were not told whether it would contain negative or neutral pictures—they were however told at the beginning of the experiment that each task contained either negative or neutral pictures.

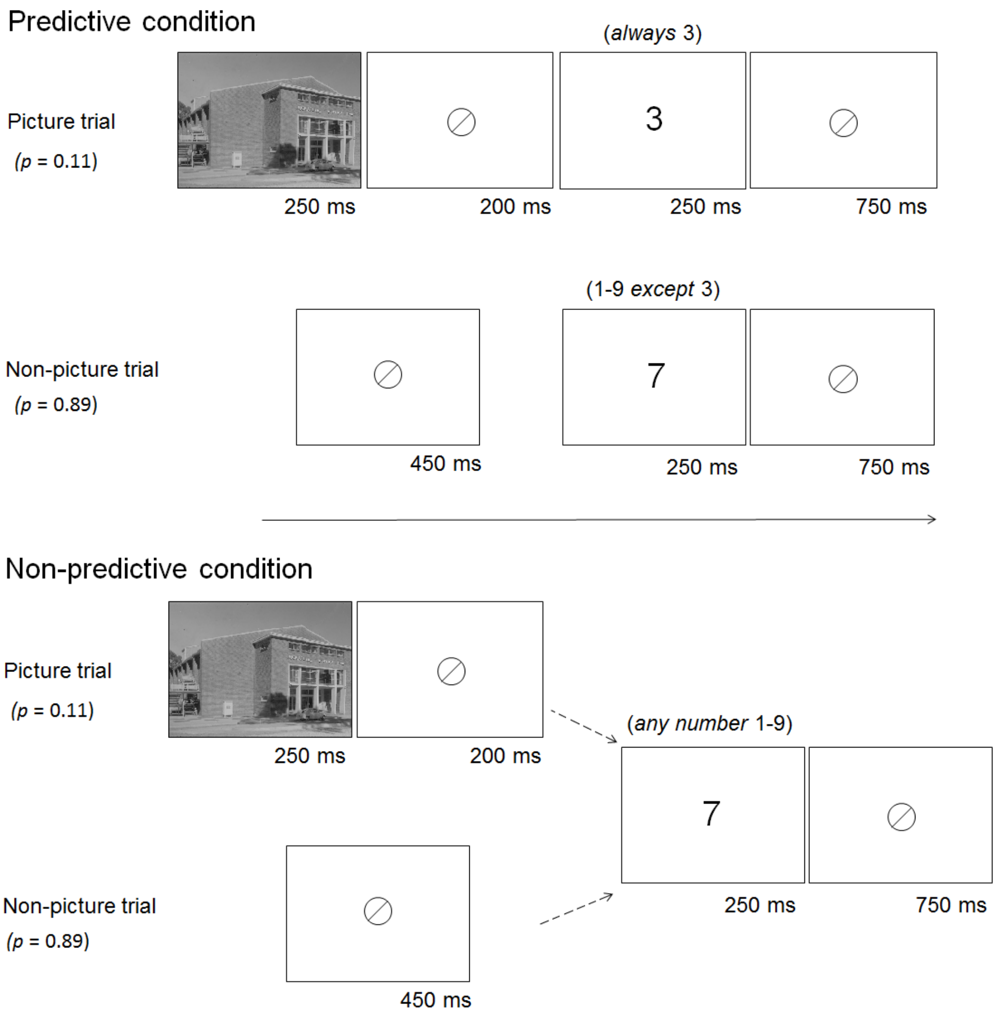

Fig. 1 Schematics depicting examples of trials for the predictive (top) and non-predictive condition (bottom).

Self-report measures were also used to assess participants' stress and emotional response to each task. A Stress Scale questionnaire (Blakely, 2014; Sellers, Helton, Näswall, Funke, & Knott, 2014) was completed by participants immediately following each task (four times in all). This consisted of 11 Likert-scale items with a scale of 0 ("very low") to 100 ("very high"). These individual items were each based on factors from the Dundee Stress State Questionnaire (DSSQ; Matthews, Joyner, Gilliland, Huggins, & Falconer, 1999). The whole experiment took approximately 30 mins to complete.

3. Results

Results from 2 participants were excluded as they made excessive commission and omission errors throughout each of the tasks, indicating that they had failed to follow task instructions.

3.1 Anxiety induced by picture stimuli

To check that the negative stimuli were indeed anxiety provoking for participants, the subjective ratings of Tense and Unhappy were examined. Ratings of Tense were significantly higher for the negative condition (M = 52.86, SD = 23.64) than the neutral condition (M = 33.43, SD = 22.66), $F(1, 39) = 37.21$, $p < .01$, $\eta_p^2 = .49$. Ratings of Unhappiness were also significantly higher for the negative condition (M = 55.49, SD = 24.61) than the neutral condition (M = 30.25, SD = 21.53), $F(1, 39) = 45.18$, $p < .01$, $\eta_p^2 = .54$. These findings were expected and supported the idea that the negative stimuli induced anxiety in participants, consistent with the IAPS (Lang et al., 2001).

3.2 SART performance

For each subject in each condition, the proportion of commission errors (proportion of No-Go trials where the stimulus was selected; Fig. 2), omission errors (proportion of Go trials where the stimulus was not selected; Fig. 3), and the mean correct response times to Go stimuli (Fig. 4) were calculated.

Separate 2 (emotional valence: negative vs. neutral) x 2 (task-relevance: predictive vs. non-predictive) repeated measures ANOVAs were performed on each of the three performance measures. These were then followed up with paired sample *t*-tests when appropriate.

For errors of commission, there was a significant main effect of task-relevance, $F(1, 39) = 125.23$, $p < .01$, $\eta_p^2 = .76$, with significantly more errors made for the non-predictive condition (M = .51, SD = .21) than the predictive condition (M = .14, SD = .11). There was also a significant valence main effect, $F(1, 39) = 4.02$, $p = .05$, $\eta_p^2 = .09$, with more commission errors occurring in the negative (M = .35, SD = .16) than the neutral condition (M = .31, SD = .13). There was no interaction effect, $p > .05$.

For errors of omission, there was a significant main effect of valence, $F(1, 39) = 7.42$, $p = .01$, $\eta_p^2 = .16$, with more omission errors made in the negative condition (M = .01, SD = .02) than the neutral condition (M = .01, SD = .01). There was no main effect for task-relevance, $p > .05$, however there was a significant interaction effect between valence and task-relevance, $F(1, 39) = 7.93$, $p = .01$, $\eta_p^2 = .17$. A paired *t*-test revealed that there were significantly more omission errors made in the negative valence (M = .02, SD = .02) than the neutral valence (M = .01, SD = .01) when pictures were non-predictive, $t(39) = 3.27$, $p < .01$, $d = .52$. To determine if this effect was limited to picture trials or non-picture trials within the non-predictive condition, a further paired *t*-test was conducted. This revealed that the effect of increased omission errors was limited to picture trials within the non-predictive condition; there were significantly more errors of omission made following the presentation of negative pictures (M = .03, SD = .03) than the presentation of neutral pictures (M = .01, SD = .02), $t(39) = 3.56$, $p < .01$, $d = .56$.

Accepted Manuscript
(25th April, 2016) doi:10.1016/j.concog.2016.04.011 Consciousness and Cognition
Volume 42
May 2016
Pages 358-365

For response time, there was a significant main effect of prediction, $F(1, 39) = 146.80$, $p < .01$, $\eta_p^2 = .79$, with response times to Go stimuli faster in the predictive condition (M = 264.12 ms, SD = 58.11) than the non-predictive condition (M = 370.16 ms, SD = 60.63). There was no main effect of valence and no interaction effect, $p > .05$.

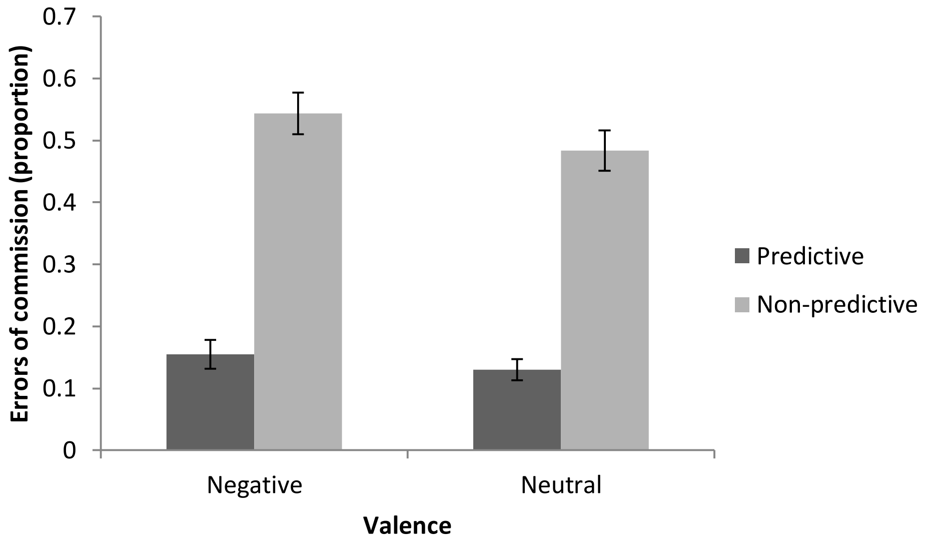

Fig. 2 Mean proportion of errors of commission (proportion of No-Go trials where the stimulus was selected) for each of the four SARTs. *Error bars* are standard errors of the mean.

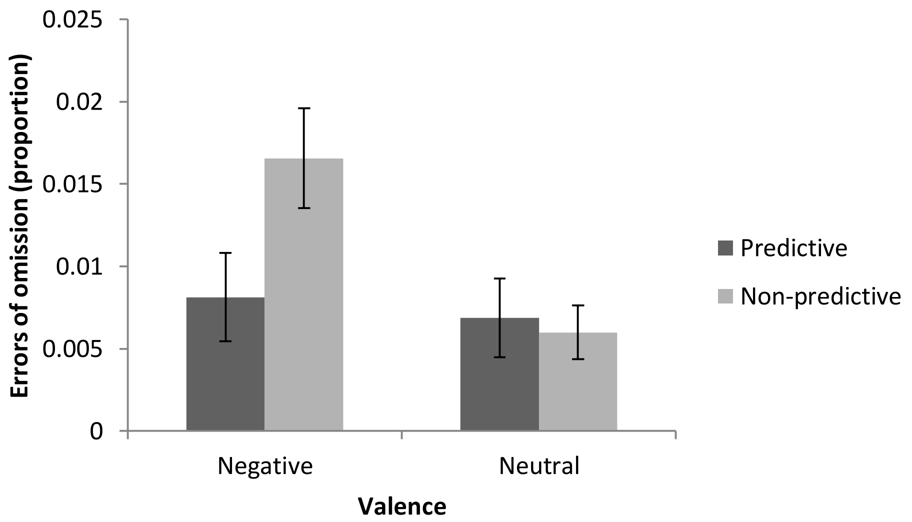

Fig. 3 Mean proportion of errors of omission (proportion of Go trials where the stimulus was not selected) for each of the four SARTs. *Error bars* are standard errors of the mean.

Accepted Manuscript
(25th April, 2016) doi:10.1016/j.concog.2016.04.011 Consciousness and Cognition
Volume 42
May 2016
Pages 358-365

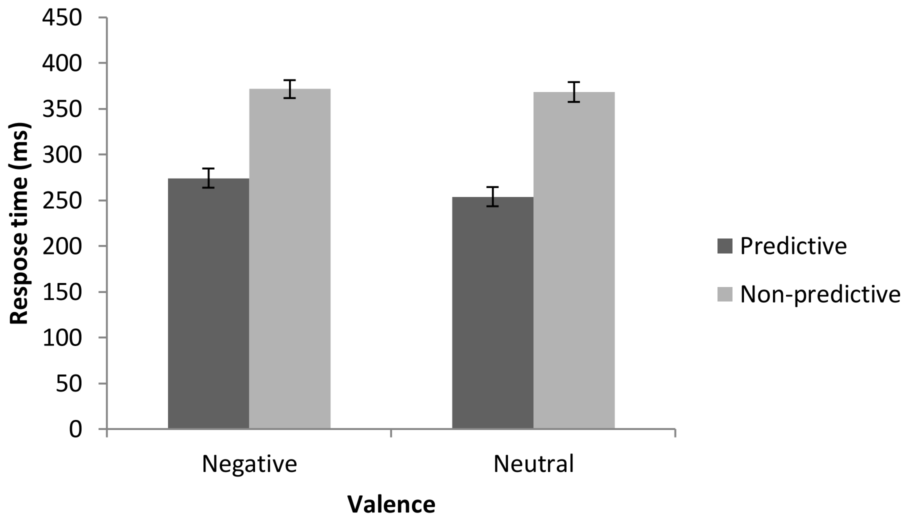

Fig. 4 Mean response time for Go trials (ms) for each of the four SARTs. *Error bars* are standard errors of the mean.

3.3 Correlations between response time and commission errors

Correlations between response time and errors of commission for each of the four SARTs were investigated using simple Pearson product correlation coefficients (N = 40 in all cases). There was a significant negative correlation between response time and commission errors for the non-predictive–negative SART, r = -.72, p < .01, as well as the non-predictive–neutral SART, r = -.58, p < .01. Conversely, for the predictive–negative SART, r = -.04, p > .05, and the predictive–neutral SART, r = -.10, p > .05, there was no evidence of speed–accuracy trade-off.

3.4 Subjective state

For each subject in each valence x prediction condition, we calculated the average scores on each of the 11 Stress Scale items (Table 1). As with the behavioural results, separate 2 (emotional valence: negative vs. neutral) x 2 (task-relevance: predictive vs. non-predictive) repeated measures ANOVAs were performed on each of the 11 scale items. These were then followed up with paired sample t-tests when appropriate.

For both task-related thoughts and task-unrelated thoughts there were no significant effects, p > .05. There was a significant main effect of valence for self-related thoughts, with self-related thoughts significantly higher for the neutral condition than the negative condition, $F(1, 39) = 6.22$, $p = .02$, $\eta_p^2 = .14$. As noted in section 3.1 above, there were also significant main effects of valence for both tense and unhappiness, with both of these items rated significantly higher for the negative condition than the neutral condition. There was a significant main effect of task-relevance for confidence, with confidence significantly higher for the predictive condition than the non-predictive condition, $F(1, 39) = 30.67$, $p < .01$, $\eta_p^2 = .44$. There were no significant main effects for the remaining items of physical fatigue, mental fatigue, motivation, task interest, concentration, nor any significant interactions for any of the 11 items, p > .05.

Table 1 Stress Scale items' means and standard deviations

	Predictive–Negative	Predictive–Neutral	Non-predictive–Negative	Non-predictive–Neutral
Task-related thoughts	67.15 (21.81)	60.00 (18.03)	62.38 (27.62)	62.64 (22.81)
Task-unrelated thoughts	37.13 (25.74)	43.62 (21.36)	39.25 (27.54)	43.02 (28.35)
Self-related thoughts[v]	30.92 (24.01)	39.88 (24.87)	36.13 (27.49)	41.08 (27.45)
Physical fatigue	43.25 (26.01)	45.50 (24.57)	42.75 (28.33)	41.78 (23.64)
Mental fatigue	61.25 (23.45)	61.68 (25.16)	60.50 (29.50)	53.95 (25.91)
Tense[v]	51.13 (25.13)	30.38 (24.71)	54.60 (27.00)	36.48 (25.69)
Unhappy[v]	55.95 (26.80)	29.25 (25.00)	55.03 (27.54)	31.25 (23.91)
Motivation	51.13 (24.61)	57.45 (26.38)	53.63 (29.00)	53.40 (27.99)
Task interest	39.75 (25.14)	36.38 (25.19)	42.73 (25.70)	35.75 (27.45)
Concentration	63.72 (24.35)	60.00 (25.12)	63.20 (24.21)	58.50 (26.17)
Confidence[p]	61.07 (24.61)	65.37 (21.30)	46.43 (22.92)	50.68 (24.03)

Note. [v] denotes a significant valence main effect, [p] denotes a significant prediction main effect, $p < .05$.

4. Discussion

The purpose of this experiment was to examine the impact of task-relevant (predictive) and task-irrelevant (non-predictive) negative and neutral picture stimuli on SART performance. If negative stimuli inherently and regardless of task relevance improve response accuracy with no cost to response speed, then a main effect for emotional valence (negative vs. neutral pictures) would be found for errors of commission, but with no increase in response time. Alternatively if the effect of stimulus valence on commission errors is contingent on task-relevance, a significant interaction would be found between emotion and task-relevance in which negative valence results in increased commission errors with task relevant stimuli and reduces errors when task-irrelevant. In the present experiment, the effect was different to the possibilities we had primarily proposed. The inclusion of negative picture stimuli actually resulted in more commission errors, not fewer. There was moreover no evidence of an interaction. Although the effect itself was small ($\eta_p^2 = .09$), its direction may mean Wilson et al.'s (2015) alternative explanation that the spider stimuli improved commission errors because spiders are highly salient and detected quickly, not because they were negatively arousing (tension–anxiety inducing), is more plausible. The current findings are consistent with Patton's (2014) finding that stress, in that case through task-relevant shocks, caused firearm operators to make more friendly fire errors (i.e., errors of commission) in a shoot/don't shoot simulation. Robinson et al.'s (2013) finding that the threat of task-irrelevant shocks improves commission errors is harder to reconcile with the present findings. It could be that it is not the negative arousing nature of the stimuli, but the actual perceived threat (possible pain) of the stimuli that improves response inhibition. It is possible that the differences in the method which anxiety was induced between the current study and the previous studies discussed here may also account for some of the discrepancies. The present pictures based on self-report resulted in more unhappiness and more tension, but perhaps they were not perceived as personal threats. Nevertheless this requires further research.

The negative pictures in the non-predictive task significantly increased errors of omission (failures to respond to the Go stimuli), relative to the other three tasks. This finding is similar to previous studies using low Go, high No-Go stimuli detection tasks (vigilance tasks), where errors of omission also increase when task-irrelevant negative picture stimuli are inserted into the task (Helton & Russell, 2011; Ossowski, et al., 2011; although see Flood, Näswall, & Helton, 2014). This could be because the task-irrelevant negative pictures directly capture attention. Negative picture stimuli may also trigger further distracting thoughts (Ossowski et al., 2011; Smallwood, Fitzgerald, Miles, & Phillips, 2009). There was, however, no evidence from the self-report measures of the negative picture stimuli triggering more conscious thoughts (either task-related or task-unrelated thoughts). Indeed, negative pictures actually resulted in significantly fewer self-related thoughts. Perhaps the impact of the negative picture stimuli on omission errors is not because they

Accepted Manuscript
(25th April, 2016) doi:10.1016/j.concog.2016.04.011 Consciousness and Cognition
Volume 42
May 2016
Pages 358-365

trigger further thoughts about them, but instead because these pictures induce suppression of further thoughts about them (especially thoughts about them in the context of the individual). Suppression of these thoughts may demand executive control which competes with the ongoing task demands for attention (McVay & Kane, 2010). Another possibility is that suppression of these thoughts involves the same kinds of resources as suppressing a prepotent motor response, given that negative pictures also led to more commission errors. Further investigation of this is required.

In regards to task-relevance we predicted a main effect, in which task-relevant picture stimuli would reduce commission errors. This was indeed the case. The effect of predictive stimuli on the SART is well known and lends general support for a strategic perspective of the SART (Finkbeiner, et al., 2014; Helton et al., 2011a; 2011b). Participants take active advantage of any cues which are helpful in withholding responses to the No-Go stimuli. In regards to the role of conscious thoughts on commission errors in the SART, there were no significant differences between the predictive, where commission errors were relatively rare, and the non-predictive conditions, where commission errors were much more prevalent. This lends some support to the perspective that the causative impact of either the lack of conscious thoughts (mindlessness) or high reports of task-unrelated thoughts (mind-wandering) on actual SART performance is highly overestimated by many researchers (Smallwood, McSpadden & Schooler, 2007; Smallwood & Schooler, 2006). SART performance may be better explained by mechanisms like Peebles' and Bothell's (2004) dynamic response strategy model, which does not need to account for either conscious states or the contents of consciousness. SART commission errors are the result of two task demands, to go as fast as possible in response to Go stimuli yet to be accurate in withholding to No-Go stimuli, that are essentially impossible to simultaneously satisfy without forewarning. If the nature of the stimuli is cued accurately, the participant has more time to respond overall and there is, therefore, no penalty to perform encode and check, instead of simply encode and click. Researchers have found simple response delays also markedly reduce commission errors (Head & Helton, 2013; Seli et al., 2012).

Comparing the respective impacts of task-relevance and valence on SART performance shows that task-relevance had a more substantial effect. This was evidenced by significant main effects of task-relevance on both commission errors and response time (versus a significant main effect of valence on commission errors only) and greater effect sizes for the task-relevance effects. Essentially, task-relevance accounted for much more of the variance than valence in both the commission error and the response time results.

The present experiment casts some doubts regarding the likelihood that tense arousal (tension) or anxiety itself improves response inhibition. It may be that the mechanism needs to be more specific, such as the presence of actual personal threat, but this requires further research. Regardless the present results do provide more evidence in support of a response strategy perspective of the SART.

References

Anderson, J. R., & Lebiere, C. (1998). *The atomic components of thought.* Hillsdale, NJ: Erlbaum Associates.

Blakely, M. J. (2014). *Born to Run-Dual Task Cognitive Effects of Ecological Unconstrained Running* (Master's thesis, University of Canterbury, Christchurch, New Zealand). Retrieved from http://ir.canterbury.ac.nz/bitstream/10092/9226/1/thesis_fulltext.pdf

Coombes, S. A., Janelle, C. M., & Duley, A. R. (2005). Emotion and motor control: Movement attributes following affective picture processing. *Journal of motor behavior, 37,* 425–436.

Finkbeiner, K. M., Wilson, K. M., Russell, P. N., & Helton, W. S. (2015). The effects of warning cues and attention-capturing stimuli on the sustained attention to response task. *Experimental Brain Research, 233*(4), 1061–1068.

Flood, G., Näswall, K., & Helton, W. S. (2014). The effects of emotional stimuli on visuo-spatial vigilance. *Psychological research*, 1–11.

Flykt, A. (2005). Visual search with biological threat stimuli: accuracy, reaction times, and heart rate changes. *Emotion, 5*, 349.

Gerdes, A. B., Uhl, G., & Alpers, G. W. (2009). Spiders are special: fear and disgust evoked by pictures of arthropods. *Evolution and Human Behavior, 30*, 66–73.

Head, J., & Helton, W. S. (2013). Perceptual decoupling or motor decoupling? *Consciousness and Cognition*, *22*, 913–919.

Head, J., & Helton, W. S. (2014). Practice does not make perfect in a modified sustained attention to response task. *Experimental Brain Research*, *232*, 565–573.

Helton, W.S. (2009) Impulsive responding and the sustained attention to response task. *Journal of Clinical and Experimental Neuropsychology, 31*, 39–47.

Helton, W. S., Head, J., & Kemp, S. (2011a). Natural disaster induced cognitive disruption: Impacts on action slips. *Consciousness and cognition, 20*(4), 1732–1737.

Helton, W. S., Head, J., & Russell, P. N. (2011b). Reliable- and unreliable-warning cues in the Sustained Attention to Response Task. *Experimental brain research, 209*(3), 401–407.

Helton, W. S., Kern, R. P., & Walker, D. R. (2009). Conscious thought and the sustained attention to response task. *Consciousness & Cognition*, *18*, 600–607.

Helton, W. S., & Russell, P. N. (2011). The effects of arousing negative and neutral picture stimuli on target detection in a vigilance task. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *53*(2), 132-141.

Helton, W. S., Weil, L., Middlemiss, A., & Sawers, A. (2010). Global interference and spatial uncertainty in the Sustained Attention to Response Task (SART). *Consciousness and Cognition, 19*, 77–85.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2001). *International Affective Picture System: Instruction manual and affective ratings* (Tech. Rep. No. A-5). Gainesville: University of Florida, Center for Research in Psychophysiology.

LoBue, V. (2010). And along came a spider: An attentional bias for the detection of spiders in young children and adults. *Journal of experimental child psychology*, *107*, 59–66.

Manly, T., Robertson, I.H., Galloway, M., & Hawkins, K. (1999). The absent mind: Further investigations of sustained attention to response. *Neuropsychologia*, *37*, 661–670.

Matthews, G., Joyner, L., Gilliland, K., Huggins, J., & Falconer, S. (1999). Validation of a comprehensive stress state questionnaire: Towards a state big three? In I. Merville, I. J. Deary, F. DeFruyt, & F. Ostendorf (Eds.). *Personality psychology in Europe* (Vol. 7, pp. 335–350). Tilburg: Tilburg University Press.

 doi:10.1016/j.concog.2016.04.011 Consciousness and Cognition
Volume 42
May 2016
Pages 358-365

McVay, J. C., & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006) and Watkins (2008). *Psychological Bulletin, 136*, 188–197.

Ossowski, U., Malinen, S., & Helton, W. S. (2011). The effects of emotional stimuli on target detection: indirect and direct resource costs. *Consciousness and cognition*, *20*(4), 1649–1658.

Patton, D. J. (2014). How Real Is Good Enough? Assessing Realism of Presence in Simulations and Its Effects on Decision Making. In *Foundations of Augmented Cognition. Advancing Human Performance and Decision-Making through Adaptive Systems* (pp. 245–256). Springer International Publishing.

Peebles, D., & Bothell, D. (2004). Modelling performance in the sustained attention to response task. In *Proceedings of the Sixth International Conference on Cognitive Modelling* (pp. 231–236). Pittsburgh, PA: Carnegie Mellon University/University of Pittsburgh.

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). 'Oops!': performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*, 747–758.

Robinson, O. J., Krimsky, M., & Grillon, C. (2013). The impact of anxiety on response inhibition. *Frontiers of Human Neuroscience, 7*, 1–5.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-prime user's guide*. Pittsburgh: Psychology Software Tools Inc..

Seli, P., Cheyne, A., & Smilek, D. (2012). Attention failures versus misplaced diligence: Separating attention lapses from speed–accuracy trade-offs. Consciousness and Cognition, 21(1), 277–291.

Seli, P., Jonker, T. R., Solman, G. J. F., Cheyne, J. A., & Smilek, D. (2013). A methodological note on evaluating performance in a sustained attention to response task. *Behavioural Research Methods, 45*,355–363.

Sellers, J., Helton, W. S., Näswall, K., Funke, G. J., & Knott, B. A. (2014, September). Development of the Team Workload Questionnaire (TWLQ). In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 58, No. 1, pp. 989-993). SAGE Publications.

Smallwood, J. (2013). Penetrating the fog of the decoupled mind: the effects of visual salience in the sustained attention to response task. Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale, 67, 32–40.

Smallwood, J., Fitzgerald, A., Miles, L. K., & Phillips, L. H. (2009). Shifting moods, wandering minds: negative moods lead the mind to wander. *Emotion*, *9*, 271.

Smallwood, J., McSpadden, M., & Schooler, J. W. (2007). The lights are on but no one's home: Meta-awareness and the decoupling of attention when the mind wanders. *Psychonomic Bulletin & Review, 14*, 527–533.

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*, 949–958.

Wilson, K. M., Russell, P. N., & Helton, W. S. (2015). Spider stimuli improve response inhibition. *Consciousness and Cognition, 33*, 406–413.