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

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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.

1. Introduction

The Sustained Attention to Response Task (SART) is a Go/No-Go response task requiring motor inhibition (Robertson, Manly, Andrade, Baddeley, & Yiend, 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, Krimsky, and Grillon (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 et al., 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, 2014; Seli, Cheyne, & Smilek, 2012; Seli, Jonker, Solman, Cheyne, & Smilek, 2013), but in this case the administration of shocks improved response inhibition with no

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evidence of a response strategy shift. To further examine this finding, Wilson, Russell, and Helton (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 et al. 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 et al.'s (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. 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 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 × 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, 2015; Helton, Head, & Kemp, 2011; Helton, Head, & Russell, 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 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