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Spider Stimuli Improve Response Inhibition

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ABSTRACT

Anxiety can have positive effects on some aspects of cognition and negative effects on others. The current study investigated whether task-relevant anxiety could improve people's ability to withhold responses in a response inhibition task. Sixty-seven university students completed a modified and an unmodified version of the Sustained Attention to Response Task (SART; Robertson et al., 1997) and provided subjective measures of arousal and thoughts. Anxiety appeared to improve participants' ability to withhold responses. Further, participants' performance was consistent with a motor response inhibition perspective rather than a mind-wandering perspective of SART commission error performance. Errors of commission were associated with response times (speed-accuracy trade-off) as opposed to task-unrelated thoughts. Task-related thoughts were associated with the speed-accuracy trade-off. Conversely task-unrelated thoughts showed an association with errors of omission, suggesting this SART metric could be an indicator of sustained attention. Further investigation of the role of thoughts in the SART is warranted.

Keywords: Anxiety***;*** Motor control***;*** Motor decoupling***;*** Response inhibition***;*** SART***;*** Speed-accuracy trade-off***;*** Subjective state***;*** Sustained attention***;*** Task-related thought***;*** Task-unrelated thought

1. Introduction

Unravelling the relationship between subjective states, especially those which are consciously reportable, and performance may help resolve the role consciousness plays in human behavior. Matthews et al. write (2002, p. 316), “a subjective state may be defined as a relatively transient mental quality permeating conscious awareness whose representation is distributed across a variety of mental processes or structures, and which has the potential to generalize across activities and contexts.” Matthews (2001) proposes a state-mediation model in which environmental conditions and tasks impact internal states which then influence information-processing. Research has explored the performance correlates of conscious states.

For example, anxiety and arousal states affect cognitive performance. Often anxiety has negative consequences, such as being detrimental to working memory (Matthews & Campbell, 1998) and test anxiety has been found to be detrimental to retrieval from long term memory (Kanfer & Ackerman, 1996; Kanfer & Stevenson, 1985). Energetic arousal, however, correlates with perceptual sensitivity on high-event target detection tasks and visual search tasks (Funke, Matthews, Warm, & Emo, 2007; Helton, Shaw, Warm, Matthews, & Hancock, 2008; Helton & Warm, 2008; Matthews & Davies, 1998a; Matthews & Davies, 1998b; Matthews, Davies, & Lees, 1990). Humphreys and Revelle (1984) suggested arousal increases the availability of resources for sustained information-processing. There are situations where experiencing anxiety may also have positive effects on a person’s cognition. In a recent study, Robinson, Krimsky, and Grillon (2013) showed that the threat of a painful electric shock increased participants’ ability to withhold responses in a response inhibition task. In their experiment anxiety was induced externally to the task itself by the threat of electric shock. Whether or not task-*relevant* anxiety can similarly produce advantageous effects remains to be seen.

In the current study, participants completed a Go/No-Go response task as used by Robinson and colleagues (2013). This time however, the stimuli intended to induce anxiety was incorporated into the task itself, and thus task-relevant anxiety rather than task-irrelevant anxiety was examined. The Go/No-Go response task used was the Sustained Attention to Response Task (SART; Roberston Manly, Andrade, Baddeley, & Yiend, 1997). This is an experimental paradigm where participants respond to frequent Go stimuli and withhold responses to rare No-Go stimuli. Normally number stimuli 1-9 are used in the SART, but researchers have employed picture stimuli as well (Head & Helton, 2013). In the current experiment, we used pictures of spiders judged to be negative and arousing in nature, thus incorporating the anxiety-inducing stimuli into the task itself. The SART has been used extensively in research in a variety of contexts and populations. The primary metrics of interest are errors of commission, errors of omission, and response times to Go stimuli. A commission error describes a failure to withhold to a rare No-Go target stimulus, while an omission error is a failure to respond to a Go stimulus. Errors of commission are characteristically high in the SART; an error rate upwards of thirty to fifty percent is not uncommon (Carter, Russell, & Helton, 2013; Wilson, Head, & Helton, 2013).

The SART is characterized by a speed-accuracy trade-off, where faster response times are associated with more errors of commission (Helton, 2009; Helton, Head, & Russell, 2011; Helton, Kern, & Walker, 2009; Peebles & Bothell, 2004). While recognized as requiring response inhibition, there has been a debate regarding what the SART actually measures. One perspective is that errors of commission are primarily the result of absentmindedness caused by mind wandering (Smallwood et al., 2004). In tasks such as the SART, there is little exogenous support of attention in the time between critical targets. Smallwood and colleagues argue that this causes participants to become bored with the monotonous nature of the SART and thus their attention drifts from the task, which is manifested as an increase in task-unrelated thoughts. From this perspective SART commission errors are indicators of perceptual decoupling. Another perspective is that failures to withhold to the rarely occurring targets are actually motor response inhibition errors rather than perceptual errors per se. The repetitive nature of responding in the SART leads to the development of a prepotent ballistic motor program, which is difficult to inhibit when necessary (i.e. occurrence of a target) (Helton, Weil, Middlemiss, & Sawers, 2010; Head & Helton, 2014). Even when the participant is fully perceptually coupled, errors of commission can occur due to motor decoupling resulting from a strategic shift towards speed of response, not perceptual decoupling per se (Head & Helton, 2013). Therefore an additional research goal was to examine how the inclusion of spider picture stimuli impacted reports of task-related and task-unrelated thoughts during the SART. Thus, along with performance on the SART, we measured participants’ subjective arousal levels, both energetic and tense, and both task-related and task-unrelated thoughts with four subscales from the Dundee Stress State Questionnaire (DSSQ; Matthews, Joyner, Gilliland, Huggins, & Falconer, 1999; Matthews et al., 2002).

It was expected that participants’ performance would be enhanced when exposed to spider pictures in the SART, and that they would also report higher levels of anxiety, showing that task-relevant anxiety improves response inhibition. Specifically, participants would be said to show 'better' performance if their speed or accuracy was superior in a SART incorporating pictures of spiders in comparison to performance on the neutral number stimuli SART. According to the mind-wandering perspective of the SART, increased commission errors should occur when task-unrelated thoughts are more prevalent, revealed by a positive association between these metrics. From the motor perspective however, commission errors will be more frequent when response times are shorter, reflecting a speed-accuracy trade-off, rather than a relationship with task-unrelated thoughts. Indeed, from the motor perspective, self-reported task-related thoughts elicited after the SART likely reflect awareness of task performance and may even be influenced by performance itself (performance appraisal), e.g., a sportsperson following a match, stewing over a game in which they made many mistakes. McAvinue, O'Keefe, McMackin, & Robertson (2005) observed that people were aware of their SART commission errors 99.1% of the time. People are fully aware of their performance on the task. It was predicted that a speed-accuracy trade-off will be apparent, i.e. participants who overall respond faster should make more errors of commission, and vice versa.

2. Method

2.1 Participants

Sixty-seven (39 females, 28 males) undergraduate students from the University of Canterbury in Christchurch, New Zealand, participated in this study. They ranged in age between 17 and 42 years (M = 21.7 years, SD = 5.0). All participants had normal or corrected-to-normal vision.

2.2 Materials and Procedure

Participants were tested in individual cubicles. They were given an information sheet and a consent form which they signed. Participants were seated approximately 50 cm in front of a computer screen (377 mm x 303 mm, 75 Hz refresh rate) that was mounted at eye level. Their head movements were not restrained. Wrist watches were removed and mobile phones were switched off. Stimuli presentation and response accuracy and timing were achieved using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Two SARTs were used, the original number SART and the new picture SART. Both required participants to respond by pressing the spacebar to frequently-occurring Go stimuli and withhold responses to rarely occurring No-Go targets. Go stimuli occurred with a probability of 0.89 and No-Go targets occurred with a probability of 0.11. The tasks were each 4.3 min long and consisted of 225 trials. Stimuli were presented centrally in the screen for approximately 250 ms, followed immediately by a 900 ms mask comprising of a circle with a diagonal line through it. From the onset of the stimuli participants had a 1100 ms window to register a response. The number SART was an exact replica of that used by Robertson et al. (1997). It required participants to monitor the screen for number stimuli, withholding responses to the number 3 (No-Go target) and responding to all other numbers 1-9 (Go stimuli). Digits varied in size and were randomly selected from sizes 48, 72, 94, 100 and 120, and were all of Arial font. There were two versions of the picture SART, both comprising of a mixture of pictures of spiders and pictures of neutral objects or scenes. Both picture sets were taken from the Geneva Affective Picture Database (GAPED; Dan-Glauser & Scherer, 2011). Examples of the picture stimuli can be seen in Fig 1. Picture stimuli were sized so that they stretched to fit the entire screen, thus their dimensions were the same as the computer screen (377 mm x 303 mm). The mean arousal ratings for the spider pictures was M = 64.6 (SD = 6.8), while the mean arousal ratings for the neutral pictures was M = 24.9 (SD = 7.8). The mean valence ratings for the spider pictures was M = 27.6 (SD = 8.0), while the mean valence ratings for the neutral pictures was M = 55.8 (SD = 6.1). In one version the spider pictures were used as No-Go targets and the neutral pictures were used as Go stimuli. In the other version the neutral pictures were used as No-Go targets and the spider pictures were used as Go stimuli. Four subscales from the DSSQ (Matthews et al., 1999) were used to gauge energetic arousal, tense arousal, task-related thoughts, and task-unrelated thoughts. Two additional questions were also asked, the first being "Are you afraid of spiders?" and the second being "How much do you dislike spiders?" Participants answered this using a 5-pt Likert scale. All participants completed the number SART and one of the two picture SARTs. Through random assignment, half completed the picture SART which utilised spider pictures as No-Go targets and neutral pictures as Go stimuli, while the other half completed the picture SART which utilised neutral pictures as No-Go targets and spider pictures as Go stimuli. The order in which the number SART and picture SARTs were completed was counterbalanced across participants. A practice SART was completed before both the number SART and the picture SART. Participants completed the four DSSQ subscales and the two additional spider questions on four occasions, before and after each task.

Fig 1. Examples of neutral (above) and spider (below) picture stimuli. The picture stimuli can be found at http://www.affective-sciences.org/researchmaterial

3. Results

3.1 SART performance

For each individual for each task, picture and number, we calculated the proportion of commission errors, proportion of omission errors, and the mean correct Go-response reaction times. These data are present in Table 1. Because the participant had only 1100 ms in which to respond, the reaction times are essentially trimmed. For each performance metric we performed a 2 (SART Task: Picture vs. Number) by 2 (Spider Go, Spider No-Go) mixed analysis of variance. Participants made significantly fewer errors of commission in the picture SART than in the number SART, $F(1, 67) = 15.41$, $p < .001$, $\eta^2_p = 0.19$. No other results were significant, $p > .05$.

Table 1
SART performance between conditions: means and standard deviations. Values enclosed represent standard deviations.

	Number	Picture
Errors of commission	0.46 (.22)	0.37 (.18)
Errors of omission	0.01 (.02)	0.01 (.01)
Response time (ms)	333.14 (73.8)	321.44 (45.7)

3.2 Subjective state

For each participant we calculated their pre-task, post-number SART, and post-picture SART mean response for each DSSQ scale: Energetic Arousal, Tense Arousal, Task-Related Thoughts, and Task-Unrelated Thoughts. These data are present in Table 2. For each DSSQ scale we performed a 3 (time: pre-task, post-number SART, and post-picture SART) by 2 (Spider Go, Spider No-Go) mixed analysis of variance. Participants whose go stimuli were spiders reported higher tense arousal ($M = 2.58$, $SD = .46$) than participants whose go stimuli were not spiders ($M = 2.43$, $SD = .35$), $F(1, 65) = 4.65$, $p = .035$, $\eta_p^2 = .07$. In addition there was a significant main effect of time for tense arousal, $F(2, 130) = 4.50$, $p = .013$, $\eta_p^2 = .07$. This main effect was followed up with paired t-tests. The only significant difference was between pre-task tense arousal and post-number SART tense arousal, $t(67) = 2.75$, $p = .008$. The interaction between time and tense arousal was statistically insignificant, $p > .05$. For energetic arousal there were no significant findings, $p > .05$. For task-related thoughts there was a significant main effect for time, $F(2, 130) = 24.16$, $p < .001$, $\eta_p^2 = .27$. This main effect was followed up with paired t-tests, and both post-number SART, $t(66) = 5.59$, $p < .001$, and post-picture SART, $t(66) = 5.09$, $p < .001$, participants reported more task-related thoughts than at pre-task baseline. The two post-SART tasks did not differ statistically, $p > .05$. For task-unrelated thoughts there was a significant main effect for time, $F(2, 130) = 23.82$, $p < .001$, $\eta_p^2 = .27$. This main effect was followed up with paired t-tests, and both post-number SART, $t(66) = 6.03$, $p < .001$, and post-picture SART, $t(66) = 4.60$, $p < .001$, participants reported less task-unrelated thoughts than at pre-task baseline. The two post-SART tasks did not differ statistically, $p > .05$. Paired samples *t*-tests were used to detect any differences between measures of both fear and dislike for spiders after the number SART versus the picture SART. Ratings of fear for spiders were significantly higher after participants completed the picture task ($M = 2.45$, $SD = 1.23$), than after the number task ($M = 2.30$, $SD = 1.26$), $t(66) = 3.06$, $p = .003$. Ratings of dislike for spiders did not differ statistically between the two post-SART tasks, $p > .05$.

Table 2

DSSQ means and standard deviations. Values enclosed represent standard deviations.

	Pre-task	Post-Number Task	Post-Picture Task
Energetic arousal	2.55 (.30)	2.54 (.41)	2.56 (.35)
Tense arousal	2.57 (.36)	2.42 (.42)	2.51 (.41)
Task-related thoughts	2.29 (.80)	2.93 (.99)	2.82 (.91)
Task-unrelated thoughts	1.91 (.67)	1.43 (.53)	1.49 (.53)

3.3 Relationships between subjective measures and performance.

For both the number SART and the picture SART we examined the relationships between the DSSQ self-report measures at pre-task baseline and post-task with performance. The simple correlation coefficients are presented in Table 3 with the results for the number SART above the main diagonal and the results for the picture SART below the main diagonal.

Table 3

Correlations between performance metrics and self-reported measures (picture SART below the main diagonal; number SART above)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Response time		-.656**	.097	.403**	.022	-.034	.014	-.021	.099	-.263*	.302*	-.194	-.073	-.229	-.052
2	Commission errors	-.672**		.130	-.230	.147	.038	.023	-.141	.055	.301*	-.069	.067	.035	.092	.104
3	Omission errors	-.067	.125		.186	.337**	.118	.272*	.049	.245*	-.002	.258*	.054	.000	-.100	-.022
4	Energetic arousal - Pre	.226	-.081	.283*		.181	-.016	.167	.191	.240	-.089	.338**	-.141	.088	-.100	.099
5	Tense arousal - Pre	-.020	-.081	.151	.181		.185	.296*	.120	.352**	.195	.313**	.042	.158	-.004	.028
6	Task-related thoughts - Pre	-.028	-.035	.140	-.016	.185		.391**	.104	.203	.464**	.258*	.180	.223	.272*	.200
7	Task-unrelated thoughts - Pre	.190	-.124	.277*	.167	.296*	.391**		.186	.202	.076	.443**	.037	.009	.073	-.058
8	Energetic arousal - Post	-.082	-.046	.192	.409**	.311*	.093	.322**		.416**	.292*	.205	.118	.104	.116	.182
9	Tense arousal - Post	-.057	-.040	.202	.337**	.513**	.250*	.344**	.481**		.260*	.195	-.049	.060	.079	.118
10	Task-related thoughts - Post	-.252*	.249*	.121	-.049	.110	.504**	.222	.184	.299*		.172	.163	.230	.269*	.179
11	Task-unrelated thoughts - Post	.119	.079	.095	.249*	.106	.248*	.242*	.080	.288*	.208		.152	.117	.021	.069
12	Spider fear - Pre	-.200	.005	.026	-.141	.042	.180	.037	.009	.113	.147	.137		.731**	.832**	.636**
13	Spider dislike - Pre	-.110	-.053	.024	.088	.158	.223	.009	.105	.168	.152	.037	.731**		.720**	.876**
14	Spider fear - Post	-.231	-.004	.024	-.019	-.006	.256*	.068	.014	.164	.183	.092	.824**	.756**		.692**
15	Spider dislike - Post	-.179	.016	-.029	.076	.090	.178	-.064	.078	.216	.190	.030	.636**	.886**	.758**	

* $p < .05$

** $p < .01$

Of particular interest is the relationship task-related thoughts appears to share with errors of commission and response time. For both the picture and the number SART, post-task related thoughts correlated negatively with errors of commission and positively with response time. Thus participants that reported more post-task related thoughts made more commission errors and were faster to respond. To investigate this possible mediating role of response time with task-related thoughts and errors of commission we used linear regression analyses as outlined by Baron and Kenny (1986).

For the number SART, firstly a model was tested to determine whether post-task related thoughts predicted response time. This model was significant, $F(1, 65) = 4.84$, $p = .031$, $R^2 = .07$, $\beta = -.26$, $t = -2.20$. Following this a model was tested to see whether post-task related thoughts predicted errors of commission. The model was significant, $F(1, 65) = 6.49$, $p = .013$, $R^2 = .09$, $\beta = .30$, $t = 2.55$. The mediation test was then performed by entering response time and post-task related thoughts into the predictive model, to test whether post-task related thoughts was still a significant predictor of commission errors when response time was included in the model. The total model was significant, $F(2, 64) = 25.98$, $p = <.001$, $R^2 = .45$. Response time was significant, $\beta = -.62$, $t = -6.44$, $p < .001$, however post-task related thoughts was not, $\beta = .14$, $t = 1.43$, $p = .156$.

For the picture SART, firstly a model was tested to determine whether post-task related thoughts predicted response time. This model was significant, $F(1, 65) = 4.41$, $p = .040$, $R^2 = .06$, $\beta = -.25$, $t = -2.10$. Following this a model was tested to see whether post-task related thoughts predicted errors of commission. The model was significant, $F(1, 65) = 4.29$, $p = .042$, $R^2 = .06$, $\beta = .25$, $t = 2.07$. The mediation test was then performed by entering response time and post-task related thoughts into the predictive model, to test whether post-task related thoughts was still a significant predictor of commission errors when response time was included in the model. The total model was significant, $F(2, 64) = 27.04$, $p = <.001$, $R^2 = .46$. Response time was significant, $\beta = -.65$, $t = -6.84$, $p < .001$, however post-task related thoughts was not, $\beta = .09$, $t = .89$, $p = .375$.

These results suggest that response speed was the main contributor to commission errors in the SARTs, rather than task-related thoughts per se. Response speed appeared to mediate the relationship between task-related thoughts and errors of commission. Essentially, task-related thoughts were associated with the speed-accuracy trade-off.

4. Discussion

Participants performed better in the picture SART than the number SART, evidenced by significantly fewer errors of commission in the picture SART than the number SART. There were no significant differences in response times between the two SARTS. In terms of anxiety, while subjective reports of tense arousal were higher after the picture SART than the number SART this difference was not significant. However reported fear for spiders following the picture SART was significantly higher than after the number SART. Also, participants who had spiders as Go stimuli in the picture SART reported higher levels of tense arousal than those who had spiders as No-Go stimuli. Reports of task-related thoughts were significantly higher post-task than at baseline. Reports of task-unrelated thoughts and tense arousal were both significantly lower post-task than at baseline. Correlation analyses revealed a strong significant relationship between response times and errors of commission for both types of SART, as expected. Post-task related thoughts appeared to be associated with both response times and errors of commission for both types of SART. Subsequent stepwise regression analyses showed there was a mediating relationship occurring, with response time appearing to mediate the effect of task-related thoughts on commission errors. Pre-task unrelated thoughts seemed to be more closely linked to errors of omission for both types of SART.

The finding that participants were more accurate in the picture SART than the number SART supports the hypothesis that task-relevant anxiety can improve response inhibition. While greater spider-related anxiety was not clearly evident in the questionnaire results, participants were more fearful of spiders after the picture SART, suggesting this task may have exacerbated any pre-existing spider related fear. Also, in the picture SART tense arousal was higher in the condition that contained the greater proportion of spider pictures (spider-Go), even though there were no apparent performance differences between the spider-Go and the spider-No-Go group. If participants indeed found the picture SARTs to be more arousing than the number SARTs, this could explain why they made fewer errors of commission, at no cost to reaction time. This is in line with Robinson and colleagues whose findings suggest that the threat of shock improved people's ability to withhold habitual prepotent responses on the SART. One alternative explanation however relates to visual salience, i.e., participants found it easier to discriminate between spiders and the neutral pictures, than between the number 3 and the remaining numbers 1-9. If spiders were indeed more visually salient this could have been simply due to the characteristic and consistent spider profile, i.e., long thin legs extending out from a central body, enabling quicker picture recognition. Increasing the visual salience of stimuli has been shown to decrease errors of commission (Smallwood, 2013). Another alternative is that a greater visual salience could be due to an inbuilt predator detection mechanism, such as that proposed by Rakinson & Derringer (2008) who found evidence suggesting young infants had an evolutionary-evolved perceptual template of spiders. Presumably it is advantageous for humans to be quick to recognise a potential threat such as a spider. A further possibility is that ecological stimuli, regardless of any relation to threat, can enhance performance in detection tasks. Parasuraman et al. (2009) suggest that perceptually relevant stimuli can attenuate the decrement in vigilance, after it was seen that biological motion had this effect in their study. If these alternative ideas, all in some way relating to visual salience, were better explanations we might expect to see *general* SART performance improvement, i.e., quicker response times alongside the improved accuracy rates, which would suggest spider detection was superior to number detection overall. However this was not the case, with the improvements being restricted to accuracy rates only (although there was a slight decrease in response time in the picture task, it was not statistically significant).

While we failed to find any performance differences dependent upon whether spiders were targets (No-Go stimuli) or Go stimuli in the picture SART, participants who had spiders as Go stimuli reported significantly higher tense arousal than participants who had spiders as No-Go stimuli. Perhaps forcing participants to physically respond to spiders induced anxiety, just as repetitively touching spiders could induce anxiety. The sheer volume of spiders in the Spider-Go condition could also have contributed to this (89% spiders in Spider-Go versus 11% spiders in Spider-No-Go). Given these apparent differences, it was unexpected that this did not lead to performance differences between these two groups. However, the effect of spider stimuli as No-go stimuli versus Go stimuli may be somewhat complex: even though there are a higher proportion of spider images in the spider-Go condition, the spiders are not the targets that the participant is searching for here, they are frequent stimuli amongst rare neutral picture targets. In the spider-No-Go condition, while there are far less spider images relative to neutral images, by being targets the spiders are the images that should be receiving most of the attention by the participants – during all the neutral stimuli occurrences the participant still probably still has ‘spiders’ on his/her mind. It is in this way that the spider-No-Go condition could conceivably induce levels of anxiety that parallel those induced in the spider-Go condition. Indeed, both these conditions led to higher reports of tense arousal than in the number SART, however this difference was not significant. Furthermore, while tense arousal reduced from pre-task to post-task for the number SART, this did not occur in the picture SART. Additionally, the heightened fear for spiders after the picture SART but not the number SART further supports the idea that more anxiety was induced in the picture SART condition.

Task-related thoughts increased from pre-task to post-task for both the picture and number SART, while task-unrelated thoughts showed the opposite, decreasing from pre-task to post-task for both SARTs. Task-related thoughts were closely associated with errors of commission and reaction time, the two metrics central to the SART’s speed-accuracy trade-off. As expected, there was a marked speed-accuracy trade-off between response time and errors of commission for both SARTs. Post-task related thoughts significantly correlated with both of these measures. Participants who had faster response times reported more post-task related thoughts, and similarly those who made more commission errors reported more post-task related thoughts. Nested regression analyses revealed a mediating relationship between these variables, where the effect of task-related thoughts on commission errors was dependent upon response time or vice versa. Two explanations could be offered regarding these findings. First, perhaps participants who experienced an increase in task-related thoughts during the task sped up their response times, leading to a subsequent increase in errors of commission. Alternatively, participants adopting a faster response strategy where they in-turn made more commission errors may have then experienced an increase in task-related thoughts.

Task-unrelated thoughts on the other hand shared a relationship with errors of omission. Greater task-unrelated thoughts before the task were associated with more omission errors during the task. For the number SART, post-task unrelated thoughts were also associated with omission errors in this manner. While the use of the commission error metric for addressing sustained attention is probably not appropriate, as it likely reflects failures of response inhibition, not perceptual awareness per se, perhaps the SART omission error metric can be used as an indicator of sustained attention. Task-unrelated thoughts are associated with total omission errors on low-Go vigilance tasks as well (Helton & Warm, 2008). In addition, errors of omission on the SART were previously found to be elevated after exposure to a natural disaster than prior to the disaster, perhaps indicative of the sensitivity of errors of omission to disaster induced cognitive disruption (Head & Helton, 2012).

Future research should determine the extent to which the improvements in commission errors noted in this experiment were actually due to increased anxiety versus simply improved perceptual salience. In addition, research resolving the causal direction between self-reports of task-related and task-unrelated thoughts and performance in the SART is warranted. Claims that SART errors of commission are indicators of mind-wandering in particular warrant further examination. In this experiment errors of commission and global reports of task-unrelated thoughts were not associated. This has also been the case in other studies using global assessments of task-unrelated thoughts (Head & Helton, 2014). Researchers using more immediate thought probes have found an association between commission errors and reports of off-task thoughts (Smallwood et al., 2004), however, as McAvinue et al. (2005) observed people are aware of their SART commission errors 99.1% of the time. If participants are probed immediately after a commission error in regards to whether they were task-focused or thinking about something else, their performance itself may influence their thought report (e.g., if a person makes an error and then is asked immediately what they were thinking about, they may conclude that because they made an error they must have been thinking about something other than the task). Researchers need to integrate additional measures of conscious awareness in order to assess these different possibilities.

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