Slow and Steady Improves Accuracy in Attention Tasks: Implications for Evaluating Attention Training

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

There have been increased efforts to develop methods for improving attention across a range of tasks including those assessing sustained attention. Using a variety of techniques, researchers have reported modest reductions in errors on sustained attention tasks. However, published reports often have not documented changes in response times (RTs) that might accompany error reductions, which is problematic given that the error reductions could be mediated by a slowing strategy (i.e., speed-accuracy trade-off). In three studies, I explored the effects of speed-accuracy trade-offs in a sustained attention task (The Sustained Attention to Response Task; SART). In Study 1, I examined the effects of changing SART instructions from the double-edged "be fast and accurate" to the more conceptually accurate goal of maintaining high accuracy by responding slowly and carefully, and found that instructions to respond slowly and accurately resulted in both significantly longer RTs and fewer SART errors. In Studies 2 and 3, I developed a modified version of the SART that allowed me to experimentally manipulate RTs and found that errors were a systematic function of manipulated differences in RT independent of individual differences in response strategies. The results of these experiments indicate that it is possible that any technique that alters RT might indirectly alter error rates independently of improvements in sustained attention. I therefore conclude that investigators need to carefully attend to, control for, and report any changes in RT that accompany improvements in accuracy of performance, or alternatively employ tasks controlling for RT.

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Human attentional abilities are known to be unreliable (e.g., Rensink, O'Regan, & Clark, 1997; Shapiro & Raymond, 1997) and inherently unstable (e.g., Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; Cheyne, Solman, Carriere, & Smilek, 2009). Failures of attention have been associated with more traffic fatalities and injuries than alcohol, drugs, speed, or fatigue (Knowles & Tay, 2002). Given the frailty of attention and the potential severity of its failures, there has been a growing effort to develop methods of improving attention across a broad range of tasks. Recent claims have been made that (1) mindfulness and meditation training improve performance on the Attention Network Test (ANT; e.g., Jha, Krompinger, & Baime, 2007; see Tang & Posner, 2009, for a review) , (2) training attentional control and attention switching improves performance on attention switching tasks (see Gopher, 1992; Tang & Posner, 2009 for reviews), (3) playing action video games improves performance on tasks assessing visual and spatial attention (e.g., Green & Bavelier, 2003, 2007, 2009; Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994), (4) adding a moderate attention-demanding task improves performance on temporal and spatial attention tasks (e.g., Gil-Gomez de Liano, Botella, & Pascual-Ezama, 2011a; Olivers & Nieuwenhuis, 2005, 2006; Smilek, Enns, Eastwood, & Merikle, 2006), (5) taking a walk in natural settings improves directed-attention abilities (e.g., Berman, Jonides, & Kaplan, 2008), (6) instructing people to adopt a more passive rather than an active attention strategy increases efficiency of attention shifts during search (Smilek et al., 2006; Watson, Brennan, Kingstone, & Enns, 2010), and (7) manipulating participants' mood with a standard induction procedure improves temporal attention (e.g., Jefferies, Smilek, Eich, & Enns, 2008).

Recently, there has been a particular focus on improving performance on *sustained attention* tasks in which individuals must maintain a relatively narrow focus of attention for protracted periods (e.g., Manly, Heutink, Davison, Gaynord, Greenfield et al., 2004; Mrazek, Smallwood, & Schooler, 2012; Valentine & Sweet, 1999). Much of this work has been done in the context of continuous performance GO-NOGO tasks in which NOGO stimuli are infrequent and errors of commission to NOGO stimuli are common. One such popular task is the Sustained Attention to Response Task (SART; Robertson et al., 1997; see also Smilek, Carriere, & Cheyne, 2010), in which failures to withhold button pressing to the NOGO stimulus are scored as errors of commission and are used to index sustained attention abilities, with more errors indicating poorer sustained attention ability. Using such tasks to index sustained attention, researchers have attempted to assess potential improvements in sustained attention performance by (1) having participants engage in "mindful breathing" (Mrazek et al., 2012), (2) inducing a positive compared to a negative mood (Smallwood, Fitzgerald, Miles, & Phillips, 2009), (3) providing self-alertness training strategy (O'Connell, Bellgrove, Dockree, Lau, Fitzgerald et al., 2008) and (4) presenting periodic auditory alerts to bring attention back on task (Manly et al., 2004).

Most attempts to improve sustained attention have yielded modest reductions in error rates, as measured by performance on the SART. However, it is sometimes unclear from these studies whether even these modest reductions in errors are truly attentional effects per se, rather than the result of strategic changes in responding (cf. Helton, 2009; Helton, Kern, & Walker, 2009). This lack of clarity arises because the majority of these studies (e.g., Mrazek et al., 2012; O'Connell et al., 2008; Smallwood et al., 2009) do not include mean response time (RT) data to accompany the mean error data, making it impossible to assess possible speed-accuracy trade-offs, where participants slow down to increase their accuracy. That the foregoing concern is justified is suggested by those cases in which, when mean RTs have been reported, the observed reductions in errors in sustained attention performance were in fact accompanied by slower RTs (see Manly et al., 2004), indicative of a speed-accuracy trade-off.

Further highlighting the need to consider speed-accuracy trade-offs in sustained attention tasks, it was recently reported that participants made fewer errors on an auditory as compared to a visual version of the SART, but this error reduction was entirely explained by the slower RTs under the auditory condition (Seli, Barton, Cheyne, & Smilek, 2012). Also relevant is the finding that sustained attention performance in the SART, as measured by reduction in errors, improves with age, but this error reduction also is entirely accounted for by robust response slowing with increasing age (Carriere, Cheyne, Solman, & Smilek, 2010). Such changes in sustained attention performance appear to reflect adjustments in response strategies to deal with attention-demanding tasks rather than modification of attentional ability per se.

That speed-accuracy trade-offs occur in psychological research and are worthy of consideration is by no means a novel claim. Indeed, speed-accuracy trade-offs are among the oldest and most well-documented findings in experimental psychology (Woodworth, 1899; see Pachella, 1974). And, as is the case in most experimental psychology literatures, the sustained attention literature has seen its fair share of debates over the extent to which performance on sustained attention tasks is reflective of differences in choices regarding where to respond along the speed-accuracy trade-off curve (see Helton, 2009; Helton et al., 2009; Peebles & Bothell, 2004). However, despite this longstanding issue, it appears that researchers concerned with sustained attention and, in particular, sustained attention training, have not typically considered the potential impact of speed-accuracy trade-offs on their results.

Manipulating Speed-Accuracy Trade-offs

To my knowledge, no one examining sustained attention performance has yet directly manipulated RTs to evaluate speed-accuracy trade-offs.[1] Rather, speed-accuracy trade-offs have been detected by correlational analyses. That is, it has been observed that when participants speed up they make more errors and when they slow down they make fewer errors (e.g., Helton et al., 2009; Peebles & Bothell, 2004; Seli et al., 2012). Although these data certainly suggest that speed-accuracy trade-offs exist, given the correlational nature of the data, there may be a number of other variables contributing to this outcome. For example, any manipulation that encourages caution or an emphasis on accuracy over speed might potentially lead to both improvements in performance and more measured responding (e.g., Seli et al., 2012a). Thus, to gain a better understanding of the role of speed-accuracy trade-offs in the SART, experimental manipulations are required to break this interdependence.

The Present Studies

In the present studies, I systematically explored the effects of speed-accuracy trade-offs in the SART by using manipulations intended to alter RTs. In Study 1, I examined the effects of changing SART instructions from the double-edged "be fast and accurate" to the more conceptually accurate goal of maintaining high accuracy by responding slowly and carefully. I then evaluated whether slowing, if it occurs, results in fewer commission errors on NOGO trials. In Study 2, I further explored the effects of speed-accuracy trade-offs in the SART by directly

[1] Notably, Manly et al. (2000) attempted a similar manipulation to the one presented here, however this manipulation only tested a single tempo – not substantially different from typical SART responding – and crucially, this manipulation did not successfully modulate RTs as desired.

controlling response rates by specifying, more precisely, the RT tempo that I wanted participants to adopt.

Study 1

Method

Participants. Participants were 60 University of Waterloo psychology undergraduate students (39 females) with self-reported normal or corrected-to-normal visual acuity who participated in a session lasting approximately 25 minutes. Participation was voluntary and participants received course credit. Thirty participants were assigned to each instructional condition.

Materials. Stimulus presentation was controlled by a Dell Latitude D800 laptop. Displays were presented on a Viewsonic G225F 21" CRT. Responses were collected on a Dell RT7D50 keyboard. All programs were constructed with E-prime software (Psychology Software Tools Inc., Pittsburgh, PA).

Measures. The dependent variables of interest were (1) the proportion of commission errors on NOGO trials and (2) mean RTs on GO trials. GO trials in which no response was made (i.e., omissions) were not included when calculating mean RTs on GO trials.

The Sustained Attention to Response Task (SART). In each SART trial, a single digit (1-9) was presented in the centre of a computer monitor for 250 ms, followed by an encircled "x" mask for 900 ms. The digits appeared in 48, 72, 94, 100, and 120 point size Symbol font (randomly selected), in white, on a black background. Digits were randomly distributed across all 630 trials with equal frequency of each. Participants viewed displays at a distance of approximately 50 cm. Following 18 practice trials, which included the presentation of 2 NOGO targets, there were 630 uninterrupted experimental trials, which included the presentation of 70 NOGO targets (i.e., $1/9^{th}$ of all trials were NOGO trials).

Procedure. Participants were randomly assigned to one of two instruction conditions: (1) standard instruction condition, or (2) go-slow instruction condition. Each set of instructions was visually presented on the monitor and was read aloud by the experimenter. Participants assigned to the standard instruction condition were instructed to give equal importance to speed and accuracy when completing the task. Participants assigned to the go-slow instruction condition were instructed to take their time and respond slowly so as to reduce the number of errors they made (See Appendix A for the full instructions). All participants were instructed to respond to GO stimuli (i.e., digits 1-2 and 4-9) by pressing the spacebar on the keyboard and to withhold such responses when they saw the NOGO digit (i.e., the digit 3). If participants in either condition had any questions about the instructions, the researcher provided clarification.

Results and Discussion: Study 1

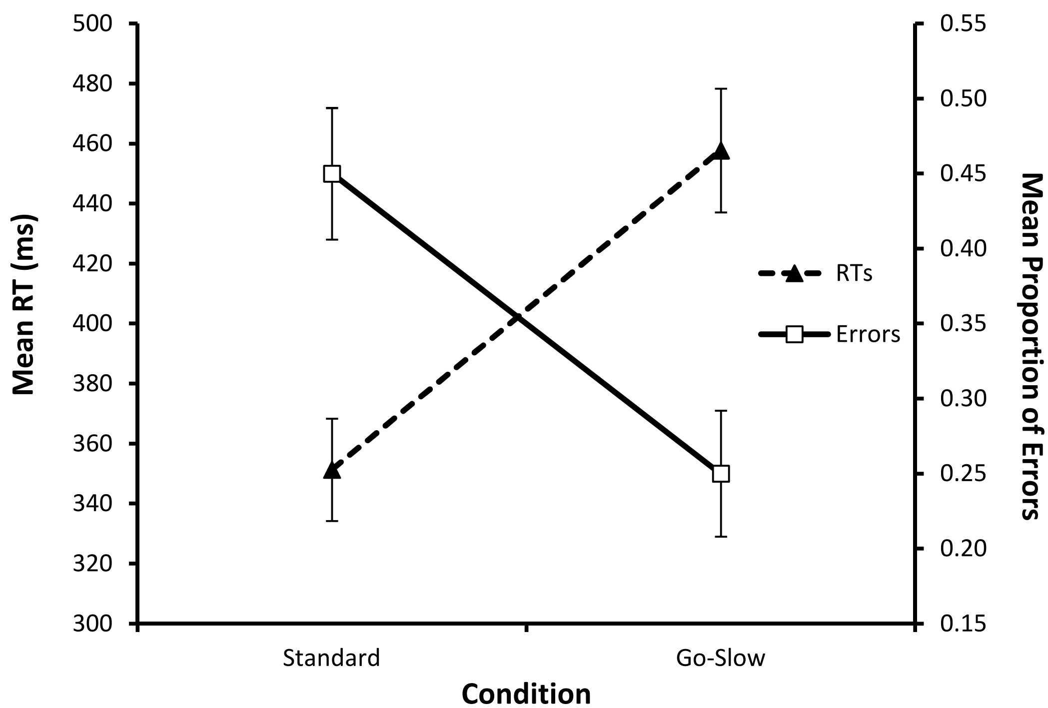
NOGO Errors and GO RT. Mean proportion of NOGO errors and mean GO trial RTs are presented in Figure 1. The proportions of NOGO commission errors across the standard and go-slow SART conditions were analyzed with an independent *t*-test. The analysis indicated a significant difference across the two conditions, $t(58) = 3.06$, $SE = 0.06$, $p < .05$, with fewer errors accompanying go-slow instructions.

Parallel analysis with RT as the dependent variable also yielded a significant difference across the two conditions, $t(58) = 4.23$, $SE = 26.75$, $p < .01$, with response significantly slower RTs under the go-slow instruction condition.

Results of Study 1 showed that instructing participants to respond slowly cut commission errors roughly in half, from a mean of 0.45 for standard instructions to a mean of 0.25 for slowing instructions. The decrease in errors across conditions was accompanied by longer RTs

Figure 1

Figure 1. Mean GO trial RTs and mean proportion of NOGO Errors for standard and go-slow instructions. Error bars are standard errors.



on GO trials, increasing from a mean of roughly 350 ms with standard instructions to a mean of roughly 460 ms with slowing instructions.

As noted in the Introduction, published reports examining the efficacy of attention training techniques often have not documented changes in RTs that might accompany error reductions. Given the results of Study 1, this is clearly problematic because these results suggest that the error reductions could very well be mediated by a slowing strategy (i.e., speed-accuracy trade-off). However, although results from Study 1 provide insight into the effects of slowing on sustained attention performance, one limitation of this study is that our instructional manipulation did not allow us to control for individual differences in the interpretation of the instructions. For example, a given participant may take instructions to "respond slowly" to mean "respond approximately 400 ms after the onset of the digit," whereas another participant may take this to mean "respond approximately 600 ms after the onset of the digit."

In Study 2, I therefore systematically manipulated responses along the speed-accuracy trade-off curve by linking responses to a precisely timed metronome. To do this, I had participants complete either the standard SART or a modified version of the SART in which they were instructed to lock their responses to one of three tempos. Participants in the standard SART condition were instructed to respond to each GO digit as quickly as possible and to withhold responses to each NOGO digit. Participants were further instructed to attempt to maintain high accuracy. In the other three Sustained Metronome-Modulated Attention to Response Task (SMMART) conditions, participants were instructed to coordinate their responding to GO trials with metronome tones presented 400, 600, or 800 ms after the onset of each digit. I chose these different delays to create equally spaced intervals across a wide range of the inter-stimulus interval (ISI). Participants were further instructed to withhold responding to the NOGO digit. By encouraging responses across a wider range of the speed-accuracy trade-off curve, the SMMART allows assessment of the effects of different response tempos on sustained attention performance.

Study 2

Method

Participants. Participants were 200 University of Waterloo psychology undergraduate students (58 males) with self-reported normal or corrected-to-normal visual acuity participating in a session lasting approximately 30 minutes. Participation was voluntary and participants received course credit.

Materials. Stimulus presentation was controlled by either a Dell Latitude D800 laptop or a Lenovo ThinkPad T420 laptop. Displays were presented on a Viewsonic G225F 21" CRT. All programs used in Study 2 were constructed with E-prime software (Psychology Software Tools Inc., Pittsburgh, PA).

Measures. Mean RTs were calculated for all responses made during GO trials. Responses to the NOGO stimulus ("3") were coded as errors. Failures to respond during GO trials were coded as omissions.

The Sustained Attention to Response Task (SART). On each SART trial, a single digit (1-9) was presented in the centre of a computer monitor for 250 ms, followed by an encircled "x" mask for 1350 ms, for a total trial duration of 1600 ms. Typically in the SART, each digit is presented for 250 ms followed by a mask presented for 900 ms (for a total trial duration of 1150 ms). However, in piloting with the standard 1150 ms trial duration, I noticed that some responses made by participants in the 800 ms SMMART condition appeared to carry over to the next trial (resulting in an omission on the current trial and a very fast response on the subsequent trial), presumably because the trials terminated too quickly after the onset of the metronome. To eliminate this problem, I extended the trial duration across all conditions to 1600 ms to allow sufficient time to make responses within the boundaries of each trial.

Each of the digits was presented equally often across a total of 630 trials. On each trial, the digit was chosen randomly from the set and presented in white against a black background. The size of the digits was also varied randomly across trials, with the fonts being equally sampled from five possible sizes (120 points (largest), 100 points, 94 points, 72 points and 48 points (smallest)). Participants were instructed to respond as quickly as possible to GO digits and to withhold responses to the NOGO digit. They were further instructed to place equal emphasis on responding both quickly and accurately. Displays were viewed at a distance of approximately 50 cm. Following 18 practice trials, which included the presentation of 2 NOGO digits, there were 630 continuous experimental trials, which included the presentation of 70 NOGO digits.

The Sustained Metronome-Modulated Attention to Response Task (SMMART). All details of the SMMART were identical to those mentioned in the description of the SART, with one important exception. Namely, in the SMMART, a metronome tone was presented at 400, 600, or 800 ms after the onset of each digit and participants were instructed to respond synchronously with the onset of the metronome tone in each GO trial (and to withhold their responses in each NOGO trial). Participants were further instructed to place equal emphasis on responding synchronously with the metronome and responding accurately.

Prior to beginning the tasks, participants in both the SART and SMMART conditions were provided with brief demonstrations on how to properly complete the tasks. Specifically, the experimenter completed 18 SART or SMMART trials while the participant watched. This demonstration was included because in piloting the SMMART the mean RTs produced by some participants indicated that they may not have understood the task instructions (e.g., one participant in the 800 ms SMMART condition produced a mean RT of 321 ms). Hence, the demonstration was added to ensure participants' understanding of the tasks.

Procedure. Participants were randomly assigned to one of four conditions: (1) standard SART condition, (2) 400 ms SMMART condition, (3) 600 ms SMMART condition, or (4) 800 ms SMMART condition. Each set of instructions was visually presented on the monitor and was read aloud by the experimenter. All participants were instructed to respond to GO stimuli by pressing the spacebar on the keyboard.

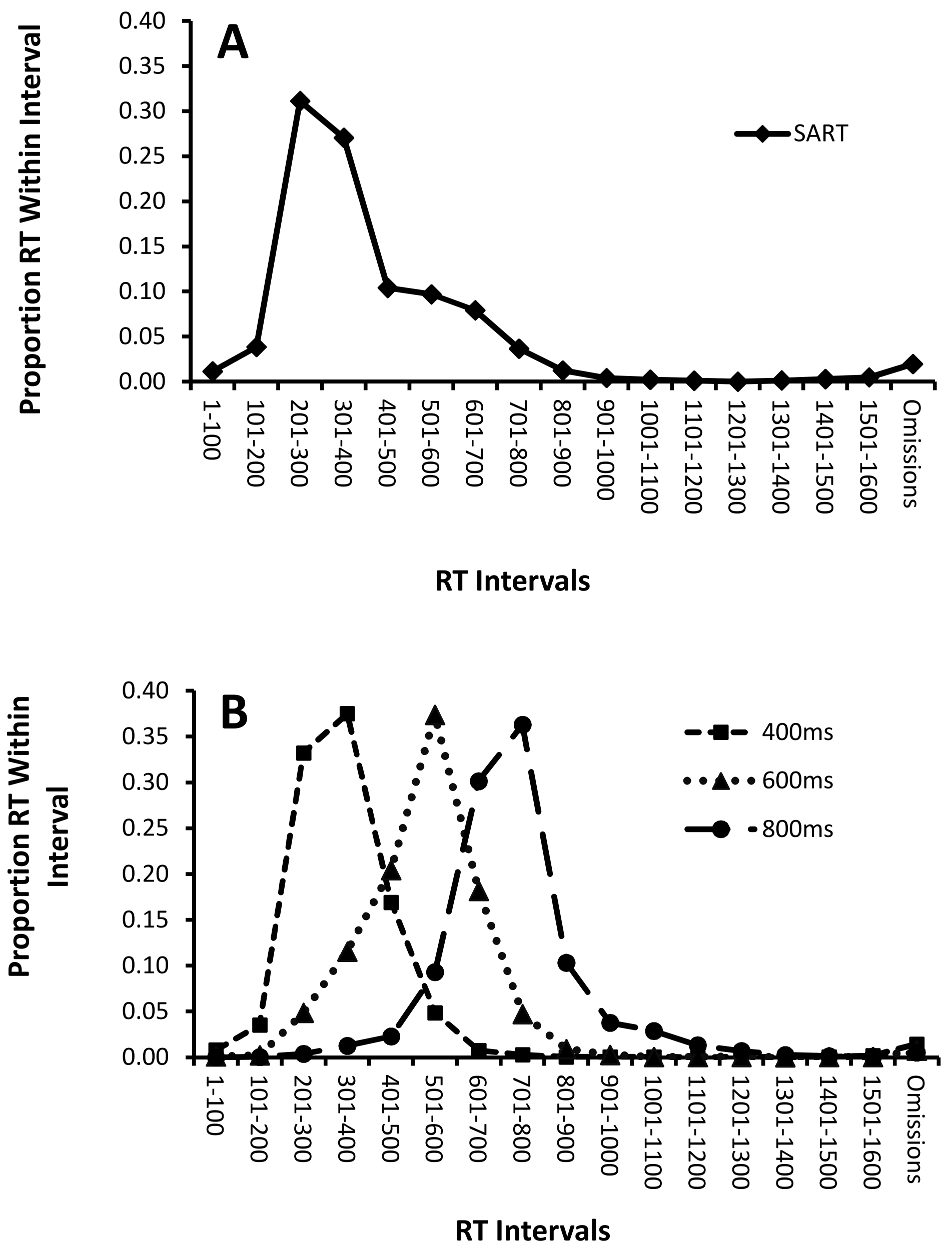
Results and Discussion: Study 2

Parsing the RT distribution: Proportion of RTs within 100 ms intervals. As a manipulation check, I parsed the 1-1600 ms response interval into 16, 100 ms bins, for each condition. I then measured the proportion of GO trials the fell into each bin. As can be seen in Figures 2a and 2b, the proportions of RTs falling in the 201-300 ms interval under standard SART and 400 ms SMMART conditions were far greater than under 600 ms and 800 ms SMMART conditions. Additionally, the proportions of RTs under the 600 ms SMMART condition peaked in the 501-600 ms interval, whereas in the 800 ms SMMART condition, they peaked in the 701-800 ms interval. This observation confirmed that on the whole, each group of participants was indeed following their SMMART instructions.

GO RT and NOGO Errors. Mean GO trial RTs and mean proportion of NOGO errors are presented in Figure 3. Mean RTs were analyzed with a one-way ANOVA with four levels of the between-subjects factor of condition (standard SART, 400, 600, and 800 ms SMMART). The analysis revealed a significant effect of condition, $F(3, 189) = 175.37$, $MSE = 8122.81$, $p < .001$. All *post hoc* analyses were conducted using Fisher's LSD tests. Response times were significantly different across all conditions (all *ps* $< .02$) with the fastest RTs produced in the 400

Figure 2

Figure 2. **(A)** Proportion of GO RTs for standard SART condition falling within each of 16 100 ms intervals plus omissions. **(B)** Proportion of GO RTs for 400 ms, 600 ms, and 800 ms SMMART conditions falling within each of 16 100 ms intervals, plus omissions.



ms SMMART condition, followed by the standard SART, the 600 ms SMMART, and the 800 ms SMMART conditions.

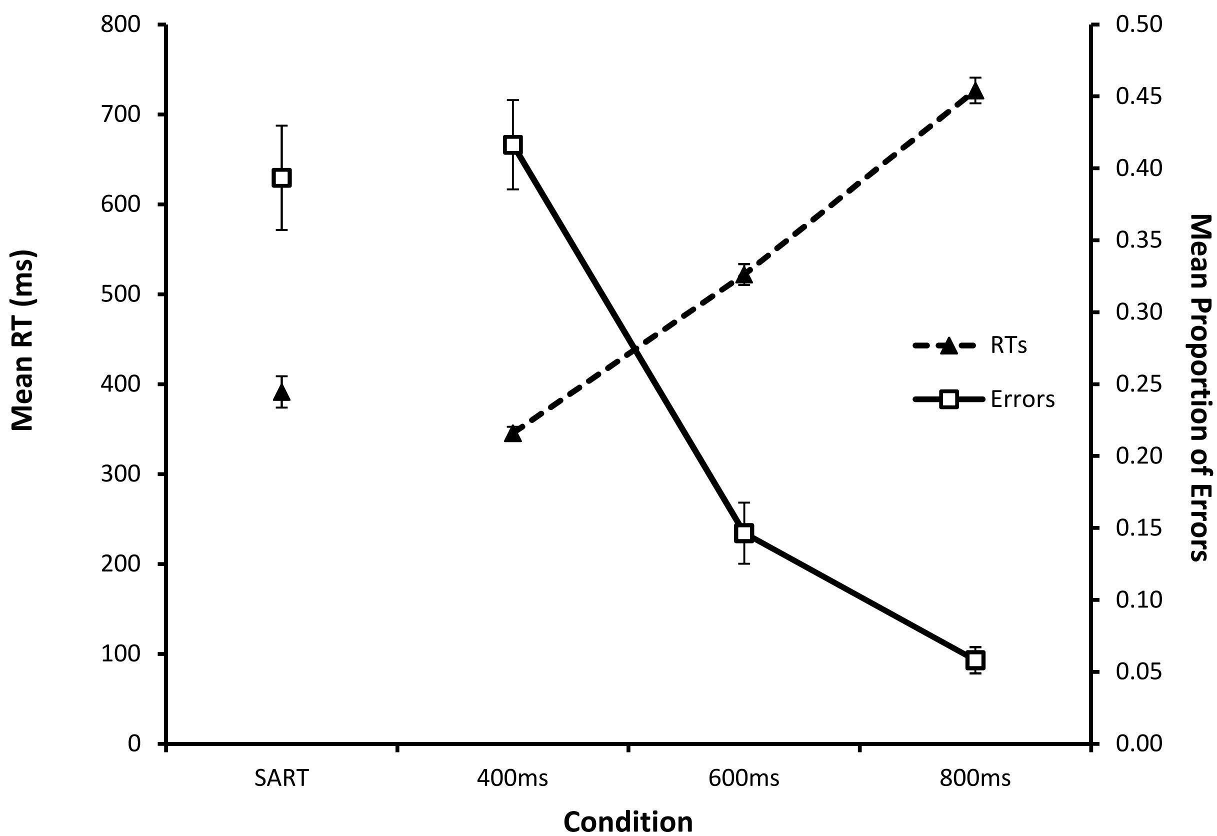
A parallel analysis with mean proportion of NOGO errors as the dependent variable revealed a significant effect of condition, $F(3, 189) = 46.64$, $MSE = .033$, $p < .001$. There were significantly fewer errors in the 600 ms SMMART condition relative to the standard SART condition, $p < .001$, and the 400 ms SMMART condition, $p < .001$. Additionally, participants in the 800 ms SMMART condition made significantly fewer errors than participants in all other conditions (all *ps* < .001). There was no significant difference in error rates across the standard SART and 400 ms SMMART conditions ($p > .05$).

Examination of the mean NOGO errors rates and GO trial RTs showed that as mean RTs increased across conditions (with the fastest mean RT produced in the 400 ms condition, followed by the SART, 600 ms, and 800 ms conditions), error rates decreased. Although RTs across the standard SART and 400 ms SMMART conditions were significantly different, the error rates across these conditions were not significantly different. However, the error rates were in the direction predicted by a speed-accuracy trade-off, with nominally more errors produced in the faster, 400 ms SMMART condition. Given the relatively small difference in RTs across these conditions, this result is not surprising and is consistent with the general finding of decreased errors with increased RT. Perhaps the most noteworthy result yielded by these error and RT analyses was that sustained attention performance was substantially improved (i.e., error rates were decreased to a mere 6%) by slowing responses to an RT range of roughly 800 ms.

Given the rather striking difference in error rates between the standard SART task and the 800-ms SMMART condition, I sought to evaluate the replicability of this effect. In particular, it was of interest to assess whether the error rate in the 800-ms condition was reliably near 6%, an

Figure 3

***Figure 3*.** Mean GO trial RTs and mean proportion of NOGO Errors for standard SART, 400 ms, 600 ms, and 800 ms SMMART conditions. Error bars are standard errors.



impressively low error rate. To this end, in Study 3 participants again completed either the standard SART or the 800ms SMMART.

Study 3

Method

Participants. Participants were 92 University of Waterloo psychology undergraduate students (34 males) with self-reported normal or corrected-to-normal visual acuity participating in a session lasting approximately 30 minutes. Participation was voluntary and participants received course credit.

Materials and Measures. All materials and measures were identical to those described in Study 2. The only difference between the two studies is that, in Study 2, participants were assigned to one of four conditions (i.e., the standard SART as well as the 400, 600, and 800 ms SMMART conditions), whereas in Study 3, they were assigned one of two conditions: (1) the standard SART or (2) the 800 ms SMMART.

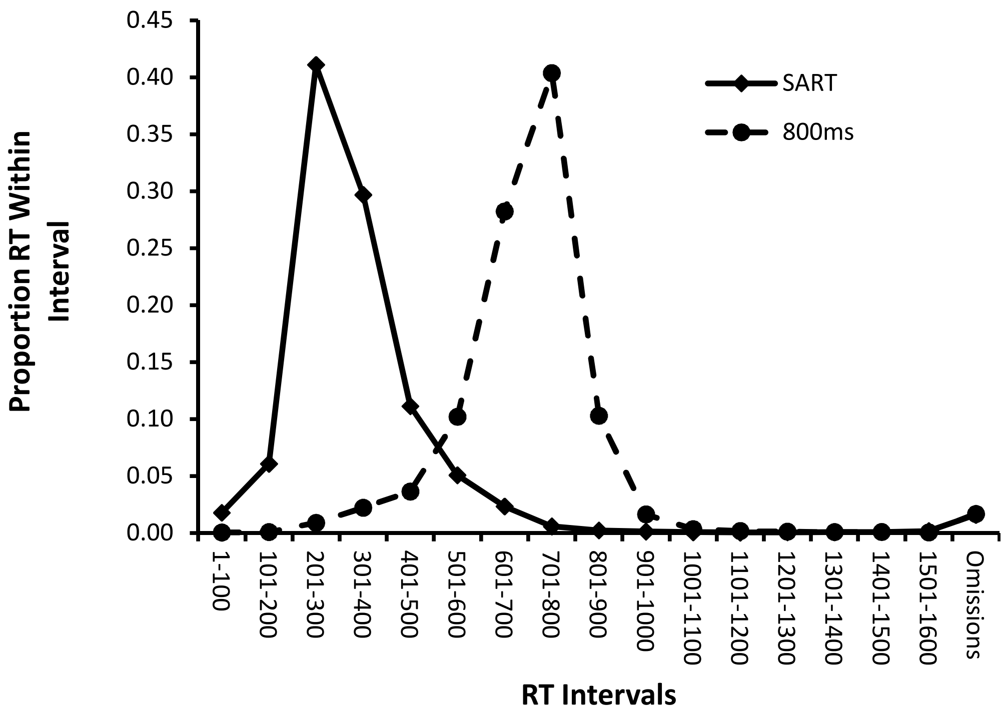
Procedure. Participants were randomly assigned to one two conditions: (1) standard SART condition, or (2) the 800 ms SMMART condition. Each set of instructions was visually presented on the monitor and was read aloud by the experimenter. All participants were instructed to respond to GO stimuli by pressing the spacebar on the keyboard.

Results and Discussion: Study 3

Parsing the RT distribution: Proportion of RTs within 100 ms intervals. As a manipulation check, I again examined, for each condition, the proportion of GO trials in which RTs fell within each of 16 intervals from 1 to 1600 ms plus the proportion omissions. As can be seen in Figure 4, the proportions of RTs under the 800 ms SMMART condition peaked in the 701-800 ms interval. This observation confirmed that participants were following the SMMART instructions.

Figure 4.

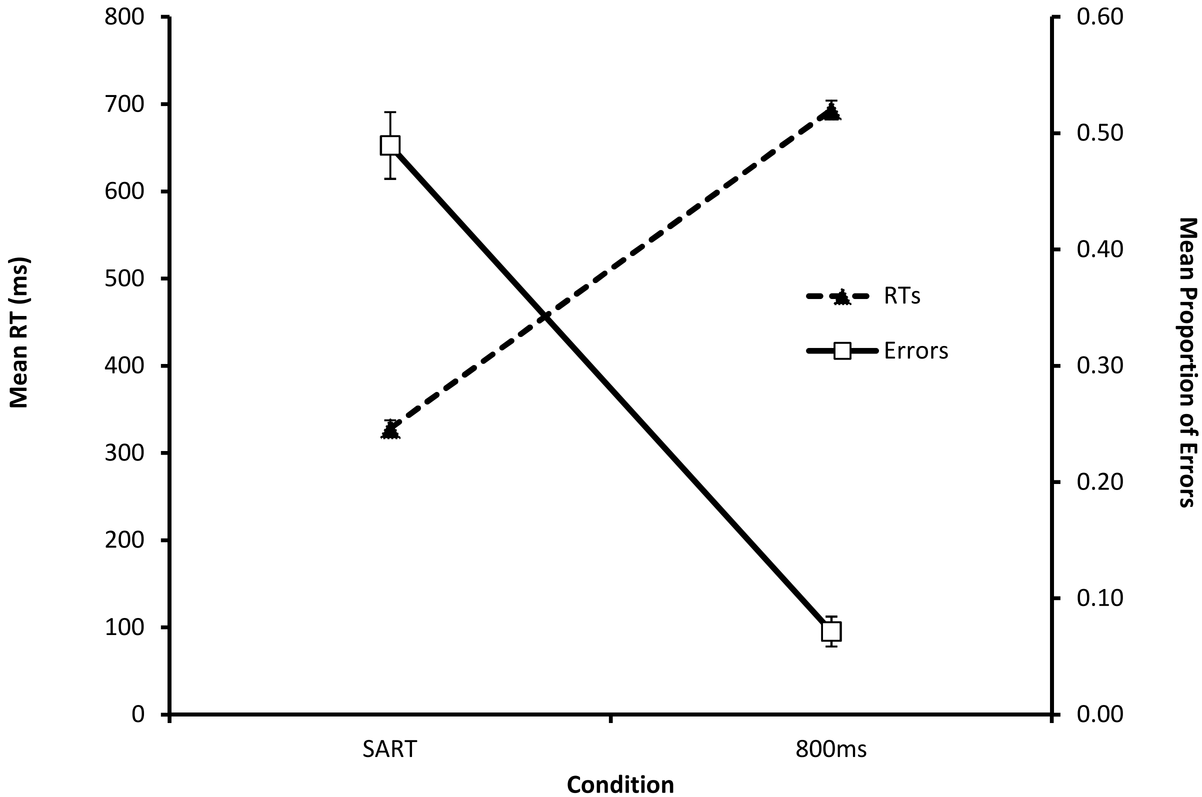
Figure 4. Proportion of GO RTs for standard SART and 800 ms SMMART conditions falling within each of 16 100 ms intervals, plus omissions.



***GO RT and NOGO Errors*.** Mean GO trial RTs and mean proportion of NOGO errors are presented in Figure 5. Mean RTs were analyzed with an independent samples *t*-test (standard SART and 800 ms SMMART). The analysis revealed that response times were significantly slower in the 800 ms SMMART condition, $t(90) = 25.31$, $SE = 14.43$, $p < .001$. A parallel analysis with mean proportion of NOGO errors as the dependent variable revealed that there were significantly fewer errors in the 800 ms SMMART condition relative to the standard SART condition, $t(90) = 13.09$, $SE = .03$, $p < .001$. Examination of the mean NOGO errors rates and GO trial RTs again showed that as mean RTs increased across conditions error rates decreased. In sum, these results replicated those from Study 2.

Figure 5

***Figure 5*.** Mean GO trial RTs and mean proportion of NOGO Errors for standard SART and 800 ms SMMART conditions. Error bars are standard errors.



General Discussion

There have been increased efforts to develop methods for improving attention across a range of tasks including those assessing sustained attention. Using a variety of techniques, researchers have reported modest reductions in errors on sustained attention tasks. However, published reports often have not documented changes in RTs that might accompany error reductions, which is problematic given that the error reductions could be mediated by a slowing strategy (i.e., speed-accuracy trade-off). In three studies, I explored the effects of speed-accuracy trade-offs in a sustained attention task (The Sustained Attention to Response Task; SART). In Study 1, I evaluated the role of such trade-offs by altering instructions (speed-accuracy versus accuracy) and found that instructions emphasizing accuracy over speed reduced NOGO errors and increased RTs.

Although these results suggest the possibility that error reductions are mediated by a slowing strategy, one limitation of the study was that the instructions were non-specific in that they simply encouraged “slow” responding – an admittedly ambiguous term that may have lead to individual differences in response strategy. Thus, in Studies 2 and 3, I remedied this potential problem by yoking responses to a fixed tempo. By doing so I was able to sample a number of points along the speed-accuracy trade-off curve in order to evaluate the role of such trade-offs in sustained attention tasks. That the RTs rather closely matched the metronome onsets suggests that participants were able to yoke their responses to the assigned tempo. A decrease in error rate of roughly 40% per 100ms held over the range of RTs studied, resulting in a near-elimination of errors by the 800 ms time.

Instructions and the Purposes of the SART

In a very direct sense, the standard instructions for the SART are misleading with regard to the ultimate interpretation of performance. Although participants are encouraged to respond both quickly and accurately, the major dependent variable is accuracy (rate of errors of commission on NOGO trials) and, in addition, fast response times are taken to reflect inattention to the task. Given the double-edged standard instructions, it is likely that individual participants varied in their interpretation of the joint emphasis on speed and accuracy. In previous research, for example, it was shown that younger participants make more errors on the SART than older participants but that this difference was largely accounted for by younger participants' much more rapid response style (Cheyne, Carriere, & Smilek., 2006; Carriere, Cheyne, Solman, & Smilek, 2010). Similar results across a comparable age-range have been reported for a variant of the Simon Task (Juncos-Rabadán, Pereiro, & Facal, 2008). Younger individuals appear to be willing, strategically, to trade off accuracy for speed, whereas older individuals may strive more for accuracy at the expense of speed (Salthouse, 1979). By behaviourally controlling participants' RTs with the SMMART, one might reduce, minimize, or even eliminate individual differences in response styles and obtain a more accurate estimate of sustained attention abilities.

Attention Training and Response Slowing

Results of the present studies demonstrated the effects of experimentally manipulating response slowing on error reduction in sustained attention tasks. These findings have important implications for researchers seeking to improve sustained attention performance because any intervention used to improve sustained attention could be mediated by a simple slowing strategy. In view of the present results, it is a matter of some concern that it has not been the norm for researchers who examine interventions aimed at improving sustained attention performance to report RT changes along with error performance measures. This is not to say that response slowing might not be a useful coping strategy for reducing errors in performance on laboratory tasks or even potentially for improving everyday attentional performance. It is, however, important to be aware that these improvements may be independent of changes in sustained attention ability.

I also note, in closing, another reason for serious consideration of changes in response delay following attention training. Some training methods may well affect sustained attention not directly, as intended by the therapy, but indirectly by modulating response tempo. In such cases, induced changes in response tempo might incidentally increase effective attention-to-task by, for example, allowing more time for decisions. This might well be a beneficial coping strategy to compensate for inherent attention deficits, but would not be a remediation of attention per se. Such complex issues will require sophisticated designs and multivariate analyses to sort out the precise benefits and costs of different training regimes, if any, but they also have the potential to enrich not only our understanding of the effects of attention training but also of the interactive role of attention and alternative coping strategies on performance.

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Appendix A

Instructions under Standard SART and Go-Slow conditions.

Go-Slow.

This task measures how people pay attention, and it takes approximately 25 minutes to complete.

For this task, a series of digits from 1 to 9 will appear in the centre of the screen. Your job is to press the space bar on the keyboard every time a digit appears, except when that digit is a 3. You will be given approximately 1 second to respond to each digit, after which time, another digit will appear.

So, for example, when the digit 9 appears, you press the space bar; 7, press the space bar; 3, don't press the space bar – withhold your response; 4, press the space bar, and so on. So the idea is to press the space bar every time a digit appears except when that digit is a 3, and when it is a 3, withhold your response and do not press the space bar.

The point of this task is to make as few errors as possible; that is to respond to all numbers except 3, and to avoid hitting the space bar when the 3 appears. So please DO NOT RUSH but respond carefully so that you make as few errors as possible.

I want to emphasize the importance of responding SLOWLY on this task. We would like you to SLOW DOWN so that you reduce the number of errors that you make. Now, you have approximately one second to respond before the next digit appears, so you'll still have to respond fairly quickly, but we would like you to take as much time as you can before responding to the digit. As long as you respond to one digit before the next appears, your response will count.

You should use your preferred hand to respond. To help you learn how to do the task, you will first be given a brief practice session. When the practice session is over, you will be given the opportunity to ask the researcher any questions that you may have.

When you are ready to begin the practice session, press the space bar.

Standard SART.

This task measures how people pay attention, and it takes approximately 25 minutes to complete.

For this task, a series of digits from 1 to 9 will appear in the centre of the screen. Your job is to press the space bar on the keyboard every time a digit appears, except when that digit is a 3. You will be given approximately 1 second to respond to each digit, after which time, another digit will appear.

So, for example, when the digit 9 appears, you press the space bar; 7, press the space bar; 3, don't press the space bar – withhold your response; 4, press the space bar, and so on. So the idea is to press the space bar every time a digit appears except when that digit is a 3, and when it is a 3, withhold your response and do not press the space bar.

Please give equal importance to SPEED and ACCURACY when completing this task. We would like you to respond as FAST as possible while maintaining a high level of ACCURACY.

You should use your preferred hand to respond. To help you learn how to do the task, you will first be given a brief practice session. When the practice session is over, you will be given the opportunity to ask the researcher any questions that you may have.

When you are ready to begin the practice session, press the space bar.