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Attention failures versus misplaced diligence: Separating attention lapses from speed–accuracy trade-offs

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ABSTRACT

In two studies of a GO–NOGO task assessing sustained attention, we examined the effects of (1) altering speed–accuracy trade-offs through instructions (emphasizing both speed and accuracy or accuracy only) and (2) auditory alerts distributed throughout the task. Instructions emphasizing accuracy reduced errors and changed the distribution of GO trial RTs. Additionally, correlations between errors and increasing RTs produced a U-function; excessively fast and slow RTs accounted for much of the variance of errors. Contrary to previous reports, alerts increased errors and RT variability. The results suggest that (1) standard instructions for sustained attention tasks, emphasizing speed and accuracy equally, produce errors arising from attempts to conform to the misleading requirement for speed, which become conflated with attention-lapse produced errors and (2) auditory alerts have complex, and sometimes deleterious, effects on attention. We argue that instructions emphasizing accuracy provide a more precise assessment of attention lapses in sustained attention tasks.

1. Introduction

Here we explore how altering speed of responding by instructing subjects to respond fast (without sacrificing accuracy) or slow (specifically emphasizing accuracy) influences performance in a theoretically informative manner on a task designed to measure sustained attention abilities: the Sustained Attention to Response Task (SART: Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). The SART has become a popular paradigm for assessing lapses of sustained attention and reverses the more common GO/NOGO procedure by requiring repeated responding (key press) to a series of digits (1–9) and withholding responding when a rare (NOGO) stimulus appears (e.g., "3"). Subjects are instructed to respond as quickly as possible while maintaining high accuracy. The critical SART measure is the proportion of NOGO trials in which a subject fails to withhold a response (i.e., SART Commission Errors). Other measures of performance include response time to GO trials (RT) and the within subjects variability of RTs such as SD or, when mean RTs and RT variances are positively correlated, the RT coefficient of variation (i.e., RT CV = RT SD/Mean RT) over trials. RT variability has become a widely used dependent measure in the SART literature as it is believed to reflect subtle differences in RTs that are produced by lapsing attention (Bellgrove, Hawi, Gill, & Robertson, 2006; Cheyne, Solman, Carriere, & Smilek, 2009; Johnson, Kelly, et al., 2007, Johnson et al., 2008; McVay & Kane, 2009; Molenberghs et al., 2009; O'Connell et al., 2008; van der Linden, Keijsers, Eling, & Van Schaijk, 2005).

We sought to explore the influence of instruction-induced speed–accuracy trade-offs in the SART for two reasons. First, SART performance is becoming a very popular measure of individual differences in sustained attention abilities. The SART has been used to assess sustained attention abilities in numerous special populations such as patients with traumatic brain

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injury (TBI; Chan, 2001, 2005; Manly, Hawkins, Evans, Woldt, & Robertson, 2002; Manly et al., 2003; McAvinue, O'Keefe, McMackin, & Robertson, 2005; O'Keeffe, Dockree, Moloney, Carton, & Robertson, 2007; O'Keeffe, Dockree, & Robertson, 2004; but see Willmott, Ponsford, Hocking, & Schönberger, 2009), attention-deficit/hyperactivity disorder (ADHD; Bellgrove et al., 2006; Dockree et al., 2004; Greene, Bellgrove, Gill, & Robertson, 2009; Johnson, Kelly, et al., 2007; Johnson, Robertson et al., 2007; Johnson, Barry, Bellgrove, Cox, Kelly et al., 2008; Mullins, Bellgrove, Gill, & Robertson, 2005; O'Connell, Bellgrove, Dockree, & Robertson, 2004; Shallice et al., 2002), depression (Farrin, Hull, Unwin, Wykes, & David, 2003), cortical lesions (Molenberghs Gillebert, Schoofs, Dupont, Peeter, 2009), affective disorders (Smallwood, O'Connor, Sudbery, & Obosawin, 2007), schizophrenia (Chan et al., 2009) and stress-related burnout (van der Linden et al., 2005). Performance on the SART has also been assessed as a function of intelligence (Farrin et al., 2003), exposure to natural disasters (Helton, Head, & Kemp, 2011) and normal development and aging (Carriere, Cheyne, Solman, & Smilek, 2010). A variant of the SART has also been used to assess the loss of self-agency during attention lapses (Cheyne, Carriere, & Smilek, 2009). Additionally, the SART has been used to investigate neurophysiological correlates of sustained attention, implicating brain areas such as the dorsomedial and ventromedial prefrontal cortices (both of which are linked to the default network; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009), as well as the anterior cingulate cortex (ACC; Cheyne, Cheyne, Bells, Carriere, & Smilek, 2009). A general assumption of these studies is that the SART provides an accurate measure of sustained attention abilities. Consistent with this assumption, a number of studies have reported significant associations between SART performance and self- and other-reported everyday cognitive and attention-related failures (for review see, Smilek, Carriere, & Cheyne, 2010a, 2010b). An advantage of the SART over older, traditional vigilance tasks (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956) is that it provides a positive behavioral measure on trials leading up to critical NOGO trials that have provided valuable information on changes in attentional state leading up to NOGO errors (Cheyne, Carriere, Solman, & Smilek, 2011; Cheyne, Carriere, et al., 2009).

There remains, however, a concern that SART performance might, in part, reflect strategic choices in responding along a speed–accuracy trade-off curve (see Helton, 2009; Helton, Kern, & Walker, 2009). One of the more venerable observations of experimental psychology is that errors tend to increase with response speed (Woodworth, 1899). This phenomenon has been observed in numerous tasks and at many levels of psychological functioning from the simplest motor movement to complex semantic processing (MacKay, 1971). Nonetheless, some studies provide evidence of limits and exceptions. The relation between speed and accuracy has been found, for example, to be reversed for highly practiced actions, skilled performers, and familiar tools (Beilock, Bertenthal, Hoerger, & Carr, 2008; Beilock, Bertenthal, McCoy, & Carr, 2004; MacKay, 1982; Smith-Chant & LeFevre, 2003) and for extremely slow responding (Newell, 1980). Indeed, it was noted rather early on that there can be an optimal speed for accuracy, with deviations in either direction adversely affecting performance (Rupp, 1932). Notwithstanding these complications, it remains true that experimentally induced alterations of speed of responding, such as by instruction, can significantly affect accuracy (Ridderinkhof, 2002; Wylie et al., 2009). An instruction-induced slowing strategy minimizing such trade-offs and hence providing a more accurate assessment of attention lapses would potentially increase the power of the SART to assess attention abilities.

The second reason to explore the impact of instruction-induced speed–accuracy trade-offs in the SART arises from recent efforts to test assumptions about top-down monitoring and control of attention and to remediate poor sustained attention performance in the context of the SART (e.g., Manly et al., 2004; O'Connell et al., 2004). Manly et al. (2004) have reported, for example, that SART performance, and by extension, sustained attention performance, can be improved by presenting subjects with periodic auditory alerts that putatively bring them back on task. However, as we explain below, the addition of alerts in these studies is often confounded with explicit or implied alterations of instructions that might shift responding along the speed–accuracy trade-off curve. Thus, in the present studies, we also explore the combined and separate influences of instruction-induced speed–accuracy trade-offs and periodic auditory alerts.

1.1. Speed–accuracy trade-offs in the SART

Typical SART instructions to the subjects state that speed and accuracy are of equal importance in the successful performance of the task. It has been remarked that such commonly used instructions (to equally focus on speed and accuracy) are contradictory as each often requires a mode of responding that is incompatible with the other (Edwards, 1961). In the context of the SART, this instruction is quite misleading as high accuracy (low rates of commission errors on NOGO trials) is considered successful and speeding is taken as an index of a failure of sustained attention. Although evidence exists that subjects sometimes interpret such instructions to emphasize accuracy (Howell & Kreidler, 1963), there are reasons to suspect important individual differences in interpretation of such speed–accuracy instructions according to such diverse variables as skill (Imbo & Vandierendonck, 2010) and age (Carriere et al., 2010).

Importantly, the inverse relation between speed and accuracy is central to the rationale underlying the SART. Robertson and colleagues (1997) argue that the tedium of the SART leads to lapsing attention expressed behaviorally as the automatic, and hence rapid, triggering of responses to stimulus onset prior to a detailed analysis of the stimulus. Rather obviously, more rapid responding provides less time for inhibitory processes to intervene (cf. van den Wildenberg et al., 2010). An important consequence of very rapid responding is therefore that even the briefest of attention lapses that delay, even minimally, the identification of the NOGO stimulus will allow the automatic response to terminate the trial in error (Seli, Cheyne, Barton, & Smilek, in press). Supporting this claim, numerous SART studies have consistently reported robust associations between