Acta Psychologica 146 (2014) 51–57

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/ locate/actpsy

Investigating sustained attention ability in the elderly by using two different approaches: Inhibiting ongoing behavior versus responding on rare occasions

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ARTICLE INFO

Article history:
Received 19 March 2013
Received in revised form 26 November 2013
Accepted 5 December 2013
Available online 28 December 2013

PsycINFO classification:
2340 Cognitive processes
2346 Attention

Keywords:
Vigilance decrement
Commission errors
Aging
SART
Mind wandering
Cognitive control

ABSTRACT

Previous studies on sustained attention ability in the elderly produced inconsistent results. The aim of this study was to evaluate sustained attention performance in younger and older individuals by using, in a within-subjects design, two versions of the same task (the sustained attention to response task, SART) in which only in the response mode differed: in a traditionally formatted task (TFT), subjects had to respond to rare targets, and in a Go/No-Go task they had to withhold response to rare targets. Results showed that in the TFT SART only the older group exhibited a vigilance decrement. On the contrary, only young individuals showed a vigilance decrement in the Go/No-Go SART. These results showed that older individuals, who also reported less mind wandering and a higher level of motivation, exhibited preserved sustained attention ability in the Go/No-Go SART, which could be explained by increased engagement of cognitive control mechanisms in this population. The discrepancy in performance depending on the approach used also underlines the need for further studies on the nature of attention failures and their underlying mechanisms.

1. Introduction

A large body of literature shows that normal aging is accompanied by a variety of cognitive deficits, including deficits in verbal and visuospatial memory, episodic and working memory, executive functions, problem solving, and decision making (Craik & Salthouse, 2008; Glisky, 2007; Grady, 2008). Conversely, few data are available on sustained attention, and previous studies actually produced inconsistent results highlighting either a reduction in (McAvinue et al., 2012; Mouloua & Parasuraman, 1995; Parasuraman, Nestor, & Greenwood, 1989; Surwillo & Quilter, 1964), or preservation of (Berardi, Parasuraman, & Haxby, 2001; Neal & Pearson, 1966; Tomporowski & Tinsley, 1996), or even improvement in (Brache, Scialfa, & Hudson, 2010; Carriere, Cheyne, Solman, & Smilek, 2010) this ability with age (for a review, see Staub, Doignon-Camus, Després, & Bonnefond, 2012). Nevertheless the ability to achieve and maintain the focus of cognitive activity on a given stimulation source or task, i.e. to sustain attention or vigilance, is a fundamental cognitive process that influences many other aspects of cognition, and therefore plays a critical role in goal-directed behavior (Parasuraman, 1998; Sarter, Givens, & Bruno, 2001). So, given the omnipresent need for sustained attention in people's daily lives (for hobbies and other pursuits, but also for safety-critical aspects of daily life such as driving), precise knowledge of the effects of normal aging on sustained attention is absolutely crucial.

A more detailed examination of the same literature revealed that two distinct approaches have been used to study sustained attention in the elderly. The majority of studies used the original approach developed by Mackworth (1948) in which participants must overtly respond to rare target signals and withhold responses to frequent non-signals. Tasks using this response format have been referred to as "Traditionally Formatted Tasks" (TFTs, Stevenson, Russell, & Helton, 2011). In this approach, sustained attention is precisely defined as a state of readiness to detect and respond to certain changes in the environment occurring at random time intervals over prolonged periods of time (Davies & Parasuraman, 1982; Mackworth, 1957; Parasuraman, 1986; Warm, 1984, 1993). Sustained attention ability is therefore evaluated by the vigilance decrement, typified by either a decrease in the number of correct detections (or an increase in false alarms/omissions) and/or an increase in reaction times to signals over the watch keeping period, and often associated with a change in the response criterion (β). Research on aging focused on sustained attention using TFTs has produced dissimilar results, but a large majority of authors reported more pronounced vigilance decrements in older adults than in younger subjects. With time on task, compared to younger individuals, older adults exhibited a greater decrease in hit rates and a greater increase in false alarms

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http://dx.doi.org/10.1016/j.actpsy.2013.12.003

(Deaton & Parasuraman, 1993) which may also be accompanied by an increase in response time (Thackray & Touchstone, 1981). Several studies indicated that these deficits in sustained attention in the elderly are even more accentuated when specific task parameters, such as increasing the event rate or decreasing stimulus discriminability (by increasing the spatial uncertainty of the stimulus or decreasing stimulus quality) are manipulated (Bunce, 2001; Mouloua & Parasuraman, 1995; Parasuraman & Giambra, 1991). These findings are in line with the processing resource view of cognitive aging (Craik & Byrd, 1982; Salthouse, 1991) and support the resource theory of the vigilance, according to which the vigilance decrement is caused by a decline in available cognitive resources with time on task (Helton et al., 2004). Other studies on this topic used tasks of a different nature, in which, contrary to a TFT, participants must overtly respond to frequent non-signals and withhold responses to rare target signals. In this approach, sustained attention is defined as the ability to inhibit a well-learned response on rare occasions. It is argued that the design of these tasks mimics real life situations in which an ongoing default behavior must be inhibited on the occurrence of rare unpredictable events and that this response format is more sensitive to failed sustained attention than TFTs (Dockree et al., 2006, 2004; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). The best-known task is the sustained attention to response task (SART), developed by Robertson and colleagues (Robertson et al., 1997). In such "Go/No-Go" paradigms, the errors themselves (referred to as action slips or errors of commission) are the indicators of sustained attention ability. Even though studies examining the effect of age on sustained attention using Go/No-Go tasks are less numerous than studies using TFTs, they mainly point to a better performance by older participants than by their younger counterparts. Older adults are generally slower (increased overall reaction time) but more precise than young individuals (Brache et al., 2010; Carriere et al., 2010; Jackson & Balota, 2012). For example, in the study conducted by Brache et al. (2010) in which a group of younger and older adults performed a task presented as a simulation of industrial inspection, older adults produced lower error rates (errors of commission) which also remained stable throughout the vigil, whereas increased error rates with time on task were observed in younger subjects. These findings are in line with those of studies showing that the elderly self-report less mind wandering and being less prone to boredom and to cognitive and action slips (Cheyne, Carriere, & Smilek, 2006; Giambra, 1989; Giambra, Camp, & Grodsky, 1992). Taken together, these results provide support for the mindlessness theory of vigilance, according to which sustained attention failures are related to the monotonous and non-arousing nature of the task, which leads subjects to become increasingly bored and more preoccupied with task unrelated thoughts, and to perform the task in a thoughtless and automatic manner (Manly, Robertson, Galloway, & Hawkins, 1999, Manly et al., 2004; O'Connell et al., 2008; Robertson et al., 1997).

So, given these contradictory results, what can conclusions can be drawn regarding the sustained attention ability of older individuals? Is it another altered cognitive ability with aging or on the contrary a preserved one? To try to answer that question, we evaluated sustained attention performance in young and old individuals by using those two different approaches in a within-subjects design. To that end, it was imperative that the two tasks used only differed in their response mode (TFT versus Go/No-Go). We selected the SART for our study, and administered both a TFT version and a Go/No-Go version of this task to the participants. In addition, while Go/No-Go tasks used in previous studies were quite short compared to TFTs, we opted for a longer duration in order to examine how the rate of commission errors varied with time on task. In light of data reported in the literature, we hypothesized that subjects would exhibit a vigilance decrement characterized by an increase in errors over time in both tasks, but we expected the decrement to be more pronounced in older subjects than in younger subjects on the TFT SART, and more pronounced in younger subjects than in older subjects on the Go/No-Go SART.

2. Materials and methods

2.1. Subjects

Thirty younger (21 females; mean age: 24.8 years; range: 18–32) and 30 older adults (16 females; mean age: 65.2 years; range: 60–74) participated in this experiment. All subjects declared that they were free of neurological and psychiatric diseases and had normal or corrected-to-normal vision. All subjects gave their written informed consent, and the study protocol was approved by the local Ethics Committee. Each subject participated in one experimental session, which lasted approximately 90 min. Younger and older adults did not differ in their years of education (completed years of school and university education), $t(58) = 1.45$, $p = .15$ (younger adults: $M = 15.2$ years, $SD = 2.38$; older adults: $M = 14.3$ years, $SD = 2.44$). Scores on non-verbal intelligence as assessed by Raven's progressive matrices (Raven, Raven, & Court, 1998) under time limited conditions (20 min) did not reveal any significant difference between the two groups, $t(58) = -.35$, $p = .73$ (younger adults: $M = 86.5$, $SD = 10.52$; older adults: $M = 87.5$, $SD = 11.65$).

2.2. Procedure and tasks

All participants completed two tasks (30 min each), with a 10-min break between the two, and a 2-minute practice period before each task. The order of presentation of the two tasks was counterbalanced within groups. One of the tasks was the sustained attention to response task (SART; Robertson et al., 1997), a Go/No-Go task in which digits ranging from "1" to "9" were presented in a random order. Subjects were instructed to respond as quickly and accurately as possible to the digits with a press on the control key of the keyboard upon presentation of each digit with the exception of the digit 3, which required response inhibition. Each digit was presented for 150 ms followed by an interstimulus interval (ISI) that varied randomly between 1500 and 2500 ms. All digits, including the 3, were presented with equal probability. Five randomly allocated digit sizes were presented to increase the demand for processing the numerical value and to minimize the possibility that subjects would set a search template for some perceptual feature of the target digit ("3"). Digit font sizes were 100, 120, 140, 160 and 180 in Arial font. The five allocated digit sizes subtended vertical angles of 1.39°, 1.66°, 1.92°, 2.18° and 2.45°, respectively, at a viewing distance of 70 cm. Digits were presented in black, 0.25° above a central yellow fixation cross on a gray background, on a standard 17 inch computer screen. The second task used only differed in the instructions given to the participant. Subjects were instructed to respond as quickly and accurately as possible only to the digit 3, and to withhold their response upon the presentation of the other digits. As typically in TFTs, the subject has to monitor a continuous stream of stimuli, and make an overt response on the rare occasions a target stimulus is presented. We thus use the term "TFT SART" when referring to the SART using this response mode, and the term "Go/No-Go SART" when referring to the regular SART. For each task, stimuli were presented in one block of 810 trials (90 of each of the nine digits) over a period of 30 min.

2.3. Subjective questionnaires

At different times during the experimental session, participants completed a series of questionnaires. Prior to starting the first task, participants completed the motivation component of the Dundee Stress State Questionnaire (DSSQ, Matthews et al., 1999), a 15-item questionnaire that assesses the participant's motivation to perform the task at hand. Such items were, for example, "I expect the content of the task will be interesting" or "I am eager to do well". Response scales ranged from "not at all" (0) to "extremely" (4). Participants were administered two further questionnaires after finishing each task. They first completed the thinking content component of the DSSQ, a 16-item questionnaire