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SHORT REPORT

Attention and working memory in elderly: the influence of a distracting environment

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Abstract The present work investigated the effect of a distracting environment in the performance of attentional and working memory (WM) tasks in elderly participants. To this end, forty elderly performed two attentional tasks (simple reaction time and go/no-go tasks), and three WM tasks (arithmetic, memory for digits and sequences of letters and numbers). Each participant performed the tasks in a distracting and a non-distracting environment, with an interval of 14–21 days between sessions. The results revealed better performance in the attentional tasks when these were done in the non-distracting environment, as compared to when they were done in the distracting environment. Specifically, participants provided more accurate responses, fewer false alarms and omissions when responding in the non-distracting environment than when responding in the distracting environment. Participants were also faster at providing correct responses in the go/no-go task when it was performed in the non-distracting environment. As for the memory tasks, the effect of type of environment was significant only in the memory for digits in a forward direction task. Our data suggest the need to consider the potential damaging consequences of distracting environments when the elderly have to perform tasks that demand their attention. Specific examples of such situations are presented in the discussion (e.g., distracting effect of environment on medical and on psychological evaluations).

Keywords Elderly · Distracting environment · Attention · Selective attention · Working memory

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Introduction

In the course of aging, anatomical and chemical changes are observed in the brains of a significant number of people, more markedly in the frontal regions (Pardo et al. 2007). Along with these brain changes, the elderly experience the deterioration of some cognitive functions, particularly attention, memory, as well as spatial and perceptual ability, executive function, and processing speed (Craik and Salthouse 2000; Lindeboom and Weinstein 2004; Salthouse et al. 2003). The present work focuses on the first two cognitive functions—attention and memory—that have been reported to decline substantially with aging (e.g., Craik and Salthouse 2000; Salthouse et al. 2003; Zanto et al. 2010).

Originally, attention, particularly selective attention (SA), and working memory (WM) were considered distinct cognitive processes from separate cognitive domains (e.g., Cabeza and Nyberg 1997; Moran and Desimone 1985). However, a growing number of empirical reports in experimental psychology and neuroscience have recently demonstrated that these processes are closely related and share some neuronal mechanisms (Gazzaley and Nobre 2012; Rutman et al. 2010). For example, some studies have shown that WM plays a role in the visual control of SA (e.g., de Fockert et al. 2001), whereas others have reported that SA is a fundamental process for the optimal performance of WM (e.g., Awh and Jonides 2001; Rutman et al.

2010). Currently, the most common view is that the relation between attention and memory is both bidirectional and multifaceted (Gazzaley 2011).

To better understand the relation between SA and WM, it is necessary to consider two types of processes that are activated when individuals interact with the environment: bottom-up and top-down processes. During the dynamic interaction between an individual and his environment, the individual has to deal with the external stimuli that are perceptually processed (bottom-up processing), as well as with the internal influences of the individual (top-down processing). Bottom-up processing typically dictates that external stimuli are processed according to their salience or novelty. On the other hand, top-down processing allows us to focus our attention on stimuli that are relevant for a given task and to inhibit others that are irrelevant (Zanto et al. 2010). This latter type of processing is responsible for controlling attentional processes and directly influences WM performance (Rutman et al. 2010; Zanto et al. 2011).

The impairments reported in SA and WM performance with normal aging seem to be associated with a decline in the ability of the elderly to inhibit irrelevant information, particularly visual information (e.g., Clapp et al. 2011; Craik and Salthouse 2000; Styles 2005). This decline seems to be a reflection of the functioning of specific mechanisms of top-down processing (Gazzaley et al. 2005; Gazzaley and D'Esposito 2007; Gazzaley and Nobre 2012; Zanto et al. 2010). Indeed, adequate cognitive functioning depends, to a large extent, on the ability of the individual to remain focused on goal-relevant stimuli in the presence of irrelevant information, commonly referred to as distractors (Lavie 2005). Thus, the presence of a high load of distractors while the individual is performing a task could be damaging to the individual's performance due to difficulties in ignoring those distractors (e.g., Wais et al. 2012).

In the literature, we can find different ways of studying and conceptualizing the influence of irrelevant information or distracting elements in cognitive performance. For example, it has been studied through the inclusion of distractors in the task being performed by the individual. The "response competition paradigm" would be an example of this type of study (e.g., Lavie 2005). Typically, in this paradigm, a target item to which the participant must respond is presented along with distracting items that compete for the participant's attention. By varying the similarity of the distractor or the complexity of the task, this paradigm allows for the study of SA. Target and distractors are usually both of visual nature and are presented in the same visual display (e.g., the computer screen). Research has also shown that a repeated exposure to distractors, especially of visual nature, can produce an effect of habituation which diminishes their negative effects on the task at hand (Forster and Lavie 2008). However, in our daily lives, distractors are usually not imbedded in the ongoing task but rather are a part of the surrounding environment. Although the latter type of distractors is different in nature from the former, in essence, they correspond to elements that are irrelevant to the task at hand and that should be ignored by the individual in order to obtain the best performance.

For many researchers, the study of the person–environment is crucial to fully understand human behavior (e.g., Gifford 2007; Kaplan 1983). For example, it has been suggested that the personal resources available at a given time (e.g., functional abilities, as well as cognitive and affective functioning) are different depending on the configuration of the external environment (e.g., Wahl et al. 2012). The physical environment, which includes sensory stimuli that can be perceived by the human senses, may be favorable to a particular task when it allows a perceptual organization of distinct elements (Gifford 2007; Kaplan 1983). However, it can also be damaging if the presence of certain elements capture the individuals' attention, decentralizing attention from the task at hand.

The person–environment interaction, particularly in scholar contexts, has become increasingly popular in the literature (e.g., Fisher et al. 2014; Godwin and Fisher 2011; Martin 2004). In this context, the physical learning environment has been considered a distinct causal factor of cognitive load which then affects cognitive performance. The cognitive load, that is, the quantity of stimuli presented to individuals, affects SA and WM, because these are processes with limited capacity (Paas and Merriënboer 1994). Some authors have suggested that a distracting environment can represent a situation of high cognitive load which negatively impacts learning (Choi et al. 2014; Paas and Merriënboer 1994).

Various elements of the environment have been considered in the educational context as possibly influencing learning. The design of the space, its color (Stone 2001), the level of noise (Higgins et al. 2005) and the number of persons per room (Ahrentzen and Evans 1984; Stone 2001) are aspects that seem to affect learning. The overload of certain elements in a space, such as posters, photographs, paintings, among others, has also been shown to have a negative influence on children's learning performance. In a within-subject study, Fisher and collaborators (Fisher et al. 2014; Godwin and Fisher 2011) created two classroom environments, one with a high number of distracting elements (posters, photographs, paintings, etc.) and another one with few distracting elements. In each environment, children were taught mini-lessons of 5/7 min and then they responded to questions about the content of those classes. The results were clear: children's performance was better in the environment with few distracting elements. The results also revealed that in the distracting environment, children spent longer periods of time looking at the distracting elements of the environment. This study reveals the impact environmental characteristics can have in the ability of children to pay attention to the central aspects of the task and, thus, to learn the material.

Although this seems to be a subject of high importance in this area and age level, it has not been translated into many other areas and age groups. We are particularly interested in the influence the characteristics of the environment can have in the elderly attentional and memory performance. This is an age group where the characteristics of the environment have a great potential to impair performance, because their attentional and WM capacities are declining (e.g., Hawkins et al. 1992; Kester et al. 2002; Klingberg 2006; Lehnert and Zimmer 2008). Additionally, as mentioned above, research has already shown that the elderly have difficulties ignoring irrelevant information when this is included in the display of the ongoing task. However, these studies are usually conducted in a laboratory setting using conditions that hardly mimic the elements present in their daily life, such as environmental distractors; thus, the data collected in such settings might not truly reflect the behavior and the performance they would have in a more natural environment.

In this study, we aimed to investigate the impact distracting elements in the environment outside of the task itself would have in the performance of the elderly, a procedure that more closely resembles the situations the elderly face in their day-to-day activities. As noted, a similar procedure has been used by Fisher and collaborators (Fisher et al. 2014; Godwin and Fisher 2011) where off-task elements were presented in the environment where the target activity was occurring (in their case a learning task). Additionally, their usage of a within-subject design seems the most appropriate to investigate this issue as individual characteristics will equally be present in both conditions making the type of environment the main variable potentially affecting the participants' performance. Also, akin to their study, rather than conducting the experiment in an unfamiliar laboratory setting, we conducted it in a context that is familiar to our elderly participants: a familiar room in the institution they attend to everyday—an element that provides an additional ecological validity to the data collected in this study. This paradigm has started to provide interesting insights on the interaction between the environment and learning in children (Fisher et al. 2014; Godwin and Fisher 2011), and we believe it will be equally fruitful in our case. To the best of our knowledge, no similar studies have been done with elderly.

Understanding whether the presence of visual distractors in the environment impairs the elderly performance in simple tasks is of potential importance in various areas. For example, when performing a cognitive evaluation, the neuropsychologist might need to consider the characteristics of the environment in which the testing is occurring in order to make a reliable assessment.[1] In a medical setting, this aspect might also be of relevance while transmitting information of major importance such as explaining a medication prescription or a specific medication schedule that needs to be followed carefully. Driving is another example where the external environment might have a great impact as it is a task that requires attention to a set of stimuli while ignoring irrelevant stimuli (Fofanova and Vollrath 2011); any condition that diminishes the ability of the elderly to respond adequately in this situation can be life-threatening to themselves as well as to others.

In sum, the goal of this study was to investigate the effect of a distracting environment on the performance of attentional and WM tasks when the surrounding environment includes visual distractors and when it is free of distractors. Different types of attentional processes can be evaluated using different tasks: simple reaction time (SRT) tasks can evaluate more generic attentional processes, and more specific tasks can evaluate SA, such as the go/no-go task (Styles 2005). In the latter task, the individual must respond to a target stimulus (go stimulus) and inhibit the response to a non-target stimulus (no-go stimulus); this task requires the ability to provide a specific response in the presence of a stimulus and to actively inhibit the response to another stimulus. In a SRT task, participants have to respond as quickly as possible to the presentation of any given stimuli. Previous research has shown some impairment in the ability of the elderly to respond in these tasks, as compared to young adults, which suggests these tasks are sensitive to the cognitive deterioration occurring at this age. For example, in both tasks, the elderly require a longer period of time to respond correctly to the stimuli than the young adults (Klingberg 2006; Majerus et al. 2010; Redfern et al. 2001). In the go/no-go task, the elderly show an increased difficulty to inhibit responses to the no-go stimuli (Styles 2005). Thus, these tasks seemed good candidates to be affected by the presence of external distractors. In the current experiment, we evaluated more general attentional abilities (measured using a SRT task), as well as selective attention (measured using a go/no-go task). We expected elderly performance to be worse when the tasks were performed in the distracting environment as compared to when they were performed in the non-distracting environment. Specifically, we expected to obtain longer response times in the SRT and the go/no-go tasks, as well as more omissions and false alarms (in the go/no-go task) in the

[1] We thank one anonymous reviewer for suggesting the inclusion of this potential practical application of this paradigm.

distracting environment as compared to the non-distracting environment.

Several tasks have been used to evaluate WM performance in the elderly, particularly verbal memory tasks, such as memory for digits and/or letters (Bopp and Verhaeghen 2005). The WM tasks of the Wechsler Intelligence Scale for Adults—3rd Edition (WAIS-III; Wechsler 2008) have been shown to be sensitive to the cognitive deterioration of the elderly (e.g., Kaufman 2001; Menezes and Nascimento 2011). Thus, in the current study, we used the arithmetic, the digit span and the sequences of letters and numbers tasks from the WAIS-III (Wechsler 2008). We expected to obtain lower scores in these tasks when they were performed in the distracting environment than when performed in the non-distracting environment.

In this experiment, each participant performed all the attentional and WM tasks just described in different sessions. Importantly, in one of these sessions, the participants' surrounding environment included a set of visual distractors (distracting condition), and in the other no visual distractors were present (non-distracting condition). By using a within-subject procedure, the individual's characteristics will equally contribute to both the distracting and non-distracting condition, making the setting condition the main variable of interest.

Methods

Participants

Our sample was composed of 40 (21 male) elderly recruited from two social institutions of the Estarreja county (Portugal). Participants were aged between 60 and 95 years[2] ($M = 72.98$, $SD = 8.45$). With regard to marital status, 14 participants were married, five were single, 18 widowed and three divorced/separated. Regarding academic qualifications, three participants had no formal education, 13 had fewer than 4 years of education, 17 had completed 4 years of school, 4 had completed about 6 years of education and three had completed 12 years. All interested users from the two cooperating institutions were allowed to participate since their level of education did not prevent the completion of the tasks (the participants with no formal education were found to have the required knowledge to perform the tasks). The exclusion criterion was the inability to recognize the colors used in the SRT and go/no-go tasks. This last evaluation was conducted before beginning the tasks using a brief and informal visual screening. In this task, participants were simply presented with the colors used in the SRT and go/-no-go tasks as they were presented in the tasks themselves and asked to name the colors; this procedure was done twice in an alternated fashion. Two volunteers were excluded based on this criterion. According to the normative data for the MoCA portuguese population (Freitas et al. 2012; instrument described in the Materials section), on average, our sample was within the mean +/− 1 standard deviation. However, on an individual level, five participants were identified at a clinical level as their performance was lower than 1.5 *SD*s of the normative data.

[2] According to the World Health Organization, the beginning of old age is between 60 and 65 years (WHO 2012).

Materials

In this research, we used paper and pencil tasks, computer tasks (attentional tasks) and oral tasks (WM tasks). A 17'' laptop computer, a chronometer, record sheets and distracting materials (photographs, posters, etc.) were also used.

Sociodemographic Questionnaire and MoCA

In this study, we applied the following two paper and pencil instruments: a Sociodemographic Questionnaire (SQ) and the Montreal Cognitive Assessment (MoCA; Portuguese version; Simões et al. 2008b). The first aimed to characterize our sample, and it consisted of questions about age, gender, marital status and education level. The MoCA (Portuguese version; Simões et al. 2008b) is a brief instrument developed for the screening of mild forms of cognitive impairment, with an internal consistency measured by a Cronbach alpha of 0.78, revealing its good psychometric properties (Freitas et al. 2012). Currently, it is one of the most widely used cognitive screening instruments in the assessment protocols of different clinical conditions, such as mild cognitive impairment and Alzheimer's disease. Its administration takes approximately 10–15 min, and its score may reach a maximum of 30 points (Simões et al. 2008a). For both instruments, all questions were presented orally by the experimenter who also registered the participant's responses and timed the tasks, with the exception of three of the tasks from the MoCA which require a direct response by the participant.

Attentional tasks

The attentional tasks (SRT and go/no-go tasks) were programmed and run using the software E-Prime 2.0 (Schneider et al. 2002) and performed on a 17″ laptop.

Simple reaction time task (SRT) Following the usual procedures of the area (e.g., Redfern et al. 2001), this task consisted of the following: the colors blue, red and green were randomly presented with a maximum duration of 1,000 ms on the computer screen; each stimuli occupied the entire laptop screen. The presentation of each stimulus was preceded by one of five intervals that varied between 500–2,500 ms, with 500 ms intervals to avoid response anticipations. Participants were instructed to press the keyboard key "space" as soon as possible whenever one of the colors appeared, whatever it was. Before beginning the task itself, participants trained the task over 10 trials; these were then followed by 100 experimental trials. The reaction times were recorded by the program when the participant pressed the "space" key. The reaction times corresponded to the time between the onset of the imperative stimulus and the registration of the "space" key. Participants were allowed to respond within the 1,000 ms time window of the stimuli presentation.

Go/no-go task Following the procedures typically used in studies assessing attentional processes (e.g., Kawashima et al. 1996), two different colors were randomly presented on the computer screen: red and green; each color occupied the entire laptop screen. Participants were instructed to respond as quickly as possible to the red stimulus (go stimulus) by pressing the keyboard key "space" and not to respond to the green stimulus (no-go stimulus). The target stimulus was presented in 50 % of the trials. Each stimulus was presented for a maximum of 1,000 ms, with one of five inter-trial intervals that ranged between 500 and 2,500 ms to avoid response anticipations (with 500 ms intervals). A total of 150 trials were presented after 10 training trials. The reaction times were the times between the onset of the stimulus and the participant's response; participants had to respond within the 1,000 ms time window of the stimulus presentation.

Working memory tasks

WM was assessed using the tasks that correspond to the "Working Memory Index" of the Wechsler Intelligence Scale for Adults—3rd Edition (WAIS-III; Wechsler 2008) that we describe next.

Arithmetic In this test, participants were asked to solve a series of mental arithmetic problems of increased level of difficulty. The test consists of 20 items scored with one point for each correct response; the last 2 problems can have a score of 2 points if the correct response is given within 10 s after the question is presented or 1 point if the correct response is given after 10 s. The experimenter used a chronometer to register how long the participant took to provide each response. The maximum score for this test is 22 points.

Digit memory This test consists of two tasks that are administered independently: digits in forward direction (FD) and digits in backward direction (BD). In the first, the participant is instructed to repeat the presented sequence of numbers in the same order of presentation, whereas in the second, the participant is instructed to repeat it in backward sequence. In both cases, the numbers present in the sequence increase (i.e., the first sequence is composed of two digits, the second of three digits, and so on) and each sequence of each length was tested twice; the task is ended by the experimenter when the participant fails to respond correctly on two trials of the same length. The longest sequence in the FD task has nine digits, and in the BD eight digits. Overall, the digits task in the FD consists of a maximum of 16 trials (8 sequences of different length, each tested twice) and the digits task in the BD consists of a maximum of 14 trials (7 sequences of different length, each tested twice). In both tasks, the investigator read the sequence of numbers aloud and the participant also responded orally. Each correct response was assigned 1 point. The maximum score for the FD is 16 points and for the BD is 14 points, resulting in a total of 30 points.

Sequences of letters and numbers In this task, a combination of letters and numbers is read aloud. The participant must reconstruct the sequence also orally, outputting the numbers first in ascending order, and secondly, the letters in alphabetical order (e.g., if the researcher says F-7-L, the participant should respond 7-F-L). The complexity of the sequences increases as the participant goes further in the task: the first sequence consists of one letter and one number, and the last sequence of four letters and four numbers. Thus, this task is composed of 7 sequences of different length, each tested three times, totaling 21 trials. The task ends when the participant fails on the three trials of a given length. Each correct response is scored with 1 point; the maximum score is 21 points.

Environmental conditions

Each institution made available a room isolated from the other activities of the institution, where each participant performed the tasks individually with the investigator present in both sessions. The rooms of each institution had similar characteristics regarding size, color and brightness of the walls. The room was modified by the researcher to comply with the two conditions: distracting environment and non-distracting environment (see Fisher et al. 2014; Godwin and Fisher 2011). The distracting environment consisted of the room with high load of distracting visual elements, such as posters and drawings, which were placed on the wall by the experimenter when a distracting

Fig. 1 On the *left*, an example of the non-distracting environment. On the *right*, the same room, but turned into a distracting environment

condition was to occur (see Fig. 1). Care was taken to ensure that the distractors were the same and organized the same way in all of the distracting sessions. The non-distracting environment consisted of the same room, but without any distracting visual elements (also illustrated in Fig. 1).

Procedure

After obtaining written authorization from the two cooperating institutions, we invited their users to collaborate in the research. Signed consent (via signature or fingerprint registration) was obtained from the participants who volunteered to participate. All participants experienced the two conditions with an interval ranging between 14 and 21 days. Each participant performed his/her session during the same period of the day (i.e., both sessions were done during the morning, early afternoon or late afternoon. Before implementing the tasks, the brief visual screening described in the participants section was conducted to ensure they could see and correctly identify the visual stimuli.

The type of environment used in each session was counterbalanced such that half of the participants (20 participants) performed the first session in the distracting environment and the other half performed the first session in the non-distracting environment. The order of tasks was also counterbalanced, to ensure that each task was performed in the first, second, third, fourth and fifth place the same number of times, thus avoiding the influence of factors such as fatigue or interference between tasks. The WM tasks were also alternated with the attentional tasks to minimize interference among tasks of a given type. For example, the first session of participant 1 was held in the distracting condition and the tasks were administered in the following order: arithmetic, SRT task, digits tasks (FD and BD), go/no-go task, and sequences of letters and numbers. This same participant, 15 days later, performed the same tasks in the same order but in the non-distracting environment. In addition to these tasks, the two pencil and paper instruments mentioned above were also administered. The SQ was always applied in the distracting environment[3] and the MoCA in the non-distracting environment; this distribution was done to prevent a potential influence of the distracting environment in the cognitive evaluation and also to create sessions of similar duration. A schematic illustrating of the study procedure is presented in Fig. 2.

Data analyses

Statistical analyses of the data were performed using the Statistical Package for the Social Sciences (SPSS) version 17.0. The level of statistical significance was set at $p < .05$ for all comparisons. The data from both conditions (distracting and non-distracting environment) were compared using paired t tests and repeated measures ANOVAs.

Results

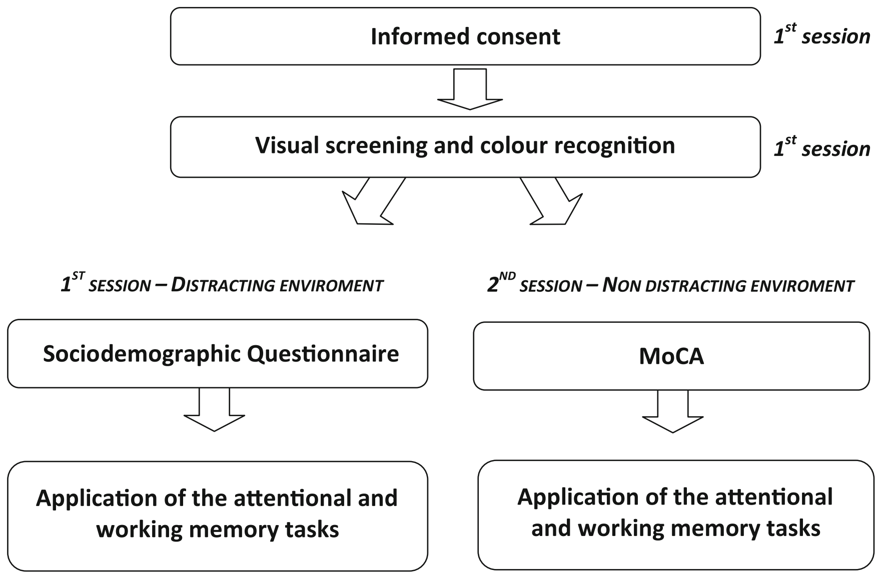
Simple reaction time

Omissions

Participants had a higher percentage of omitted responses (i.e., not pressing the "space" key when a color appeared) in the distracting environment than in the non-distracting

[3] An additional questionnaire not related to the remaining tasks was employed with the SQ to ensure a similar duration of the two sessions. Because this questionnaire does not relate to the remaining tasks, it is not reported here.

Fig. 2 Example of the procedure followed with a participant whose first session occurred in the distracting environment and the second in the non-distracting environment



environment (see Table 1 for the descriptive values); this difference was statistically reliable, $t(39) = 5.67$, $p < .001$, $d = 0.959$.

Reaction times

On average, participants responded in less than 500 ms to the appearance of the stimuli. They took slightly longer to provide their responses in the distracting environment than in the non-distracting environment, but the difference was not statistically significant, $t(39) = 0.91$, $p = .37$, $d = 0.145$ (see Table 1 for descriptive values).

Go/no-go task

Correct responses

Correct responses correspond to trials in which the participant hit the "space" key in the presence of a red stimulus (go stimulus) and refrained to press it when a green stimulus (no-go stimulus) was presented. A higher percentage of correct responses was obtained in the non-distracting environment compared to the distracting environment, as described in Table 1. This difference corresponds to a statistically significant advantage for the performance in the non-distracting condition, $t(39) = -3.68$, $p < .001$, $d = -0.951$.

False alarms

We also examined false alarms, i.e., cases in which the participant pressed the "space" key when a green stimulus (no-go stimulus) was presented. As predicted, participants performed significantly more false alarms in the distracting environment than in the non-distracting environment (see Table 1 for descriptive values); this difference was statistically significant, $t(39) = 2.27$, $p < .05$, $d = 0.364$.

Omissions

The omission of responses corresponds to the number of times the participant failed to hit the "space" key when the red color appeared (the go stimulus). The descriptive data presented in Table 1 reveal participants missed more targets in the distracting environment as compared to the non-distracting environment; this difference in performance was also highly statistically significant, $t(39) = 5.89$, $p < .001$, $d = 1.047$.

Reaction times

Regarding the reaction times for the correct responses, participants were significantly faster at providing their responses when in the non-distracting environment than in the distracting environment, $t(39) = 2.84$, $p < .01$, $d = 0.468$. On the other hand, the type of environment did not affect significantly the response times when false alarms were committed, $t(27) = -1.13$, $p = .27$, $d = -0.216$, although there was a tendency for participants to falsely respond to a non-target stimuli faster in the distracting environment than in the non-distracting environment. The descriptive data for these response times are presented in Table 1.

Working memory tasks

In order to verify that the performance of our participants was within the average performance values of the Portuguese population with similar characteristics, we

Table 1 Mean values (and *SDs*) for the various dependent variables of the simple reaction time task, the go/no-go task and the working memory tasks

	Distracting environment	Non-distracting environment
Simple reaction time task		
Omissions (%)**	47.53 (37.47)	11.38 (17.78)
Reaction times (ms)	440.47 (100.26)	424.52 (96.03)
Go/no-go task		
Correct responses (%)**	75.38 (18.44)	93.52 (9.53)
False alarms (%)*	6.87 (5.59)	4.03 (7.00)
Omissions (%)**	42.37 (34.98)	8.93 (12.86)
Reaction times: correct responses (ms)**	584.52 (125.24)	530.14 (84.06)
Reaction times: false alarms (ms)	395.90 (117.88)	438.62 (156.23)
Working memory tasks		
Arithmetic	7.93 (1.79)	8.20 (1.68)
Digits memory task: forward direction*	7.85 (2.29)	8.45 (2.45)
Digits memory task: backward direction	4.20 (1.77)	4.18 (1.81)
Sequences of letters and numbers	4.23 (2.40)	4.25 (2.38)

** $p < .001$; * $p < .05$

calculated the WM Index according to the WAIS-III manual (Wechsler 2008). By consulting the corresponding Portuguese norms, we verified that their performance was in the percentile 50 and 45 for the data collected in the non-distracting and distracting environment, respectively. These data indicate the tasks were not too difficult (or easy) to our participants, leaving enough room for our manipulation to have an effect in performance. All descriptive values for all these tasks are presented in Table 1.

Arithmetic

Regarding the arithmetic task, participants performed better in the non-distracting environment than in the distracting environment, although the difference was not statistically significant, $t(39) = -1.51$, $p = .14$, $d = 0.235$.

Digit memory tasks

The analysis on the results of the digit memory task in the FD revealed a statistically significant difference between the two conditions of the study, $t(39) = -3.07$, $p < .05$, $d = 0.489$. This difference reflects a higher number of successfully recalled items in the non-distracting environment as compared to the distracting environment. For the recall of digits in BD, participants performed about the same in both environments, $t(39) = 0.14$, $p = .89$, $d = 0.018$.

Sequences of letters and numbers

The data indicated no significant effect of type of environment for this task, $t(29) = 0.77$, $p = .45$, $d = 0.129$, although descriptively, the data suggest better performance in the non-distracting than in the distracting environment.[4]

Overall, unlike the findings for the attentional tasks, environmental distraction had little effect on WM performance. Although, on average, the level of performance in the WM tasks was at the expected level for our population, it is possible that the distracting environment might have a greater potential to affect performance for the participants who have more difficulty in these tasks. Thus, to further explore this general null effect of the environment on the performance of the WM tasks, we divided our sample into high and low performers in each of the tasks, based on the average performance (considering the standardized values) obtained in the distracting and the non-distracting environments. For the digits task (which includes the FD and the BD), only one standardized value was used according to the Wechsler Intelligence Scale for Adults—3rd Edition manual (WAIS-III; Wechsler 2008); for this task, the high- and low-performers groups included 20 participants. For the Arithmetic and the Sequences of letters and numbers, because of tied values, the low-performers group included 19 participants and the high-performers group included 21 participants. We then re-analyzed the data using repeated measures ANOVAs, including level of performance (high and low) as a between-subjects variable and keeping the type of environment as a within-subject variable. The descriptive data for each WM task, level of performance

[4] As noted in the participants' section, 5 of our participants could be classified as being on a clinical level according to the MoCA results as their performance was below 1.5 *SD* of the normative value. In order to assure our main results were not being driven by the results of these participants, all analyses were repeated excluding these participants. The pattern of the results remained the same with the exception of the False Alarms in the go/no-go task that is now only marginally significant ($p = .056$).

and type of environment are presented in Table 2. In all cases, a main effect of group based on level of performance was significant (lowest F value = 31.93, for the digit memory task in BD). Additionally, a statistically significant main effect of type of environment and a reliable interaction were obtained in the digit memory task in FD, $F(1,38) = 10.29$, $MSE = .70$, $p = .003$, $\eta_p^2 = 0.213$, and $F(1,38) = 3.69$, $MSE = .62$, $p = .039$, $\eta_p^2 = 0.107$, respectively. These data reflect overall worse performance in the distracting environment as already noted above, but also a more damaging effect of the distracting environment for the high performers than for the low performers. The only other interaction that approached statistical significance was for the arithmetic task, $F(1,38) = 3.69$, $MSE = .62$, $p = .062$, $\eta_p^2 = 0.089$, but in this case. the distracting environment hurt the performance of the lower performers to a greater extent than it did for the high performers. Thus, we did not find a systematic trend on how the distracting environment might differentially affect the performance of the WM tasks depending on level of performance.

It is also possible that participants were able to adapt to the distracting environment as the session progressed; this adaptation would lessen the potential effect of the distracting environment when the WM tasks were performed later in the session. To explore this issue, we identified the participants who performed each WM task in the first half of the session and those who performed the tasks in the second half of the session (when the WM task was performed right in the middle of the session, it was not considered). The descriptive data broken down by beginning/ending of session and distracting/non-distracting environment are presented in Table 3. These data were reanalyzed using repeated measures ANOVAs, including time of the session (first vs. second half of the session) as a between-subjects variable and type of environment as a within-subject variable. The main effect of type of environment was significant for the digit memory task in FD, $F(1,30) = 6.52$, $MSE = .96$, $p = .016$, $\eta_p^2 = 0.179$. No other main effect of environment was reliable (all Fs < 1). Time of session and interaction also did not return any statistically significant result (highest F value = 1.77, for the interaction on the digit memory task in BD). Thus, it seems unlikely that adaptation to the distracting environment was responsible for the lack of an effect of the distracting environment on WM performance.

Discussion

The environment is a central aspect of the everyday living of all age groups and understanding its impact is of great importance. Indeed, there has been a growing recognition of the environment as a determinant in human performance (e.g., Wahl et al. 2012). In educational contexts, researchers have begun to study the effect of the real environment in children's learning abilities, such as the color, design and architecture of the rooms, as well as the presence of distracting elements (Ahrentzen and Evans 1984; Fisher et al. 2014; Godwin and Fisher 2011; Higgins et al. 2005). However, no research exists on the interaction between the characteristics of the external environment on the cognitive performance of the elderly, a gap we intend to start filling with this first study. The elderly is an age group

Table 2 Mean values (and SDs) for the working memory tasks for high and low performers and by type of environment

	Low performers		High performers	
	Distracting environment	Non-distracting environment	Distracting environment	Non-distracting environment
Arithmetic	6.79 (0.79)	7.32 (0.67)	8.95 (1.83)	9.00 (1.92)
Digits memory task FD	6.38 (1.28)	6.57 (1.29)	9.47 (2.06)	10.53 (1.58)
Digits memory task BD	2.95 (0.86)	3.05 (1.16)	5.58 (1.46)	5.42 (1.57)
Sequences of letters and numbers	2.50 (0.83)	2.60 (1.05)	5.95 (2.21)	5.90 (2.20)

Table 3 Mean values (and SDs) for the working memory tasks when these were performed in the first and second half of the session and by type of environment

	First half of session		Second half of session	
	Distracting environment	Non-distracting environment	Distracting environment	Non-distracting environment
Arithmetic	7.63 (1.78)	8.00 (1.97)	8.56 (1.86)	8.56 (1.79)
Digits memory task FD	7.81 (2.23)	8.44 (2.66)	8.13 (2.53)	8.75 (2.54)
Digits memory task BD	4.25 (1.81)	4.50 (2.16)	4.31 (1.92)	4.06 (1.81)
Sequences of letters and numbers	4.44 (1.90)	4.13 (1.75)	4.06 (2.49)	4.25 (2.82)

of particular importance given the rapid aging of our population which poses challenges that require appropriate responses to afford them the best quality of life.

Given that most cognitive abilities decline with age (Salthouse et al. 2003), the elderly might be particularly vulnerable to the effect of the characteristics of the environment in their performance. The most recent studies on cognitive changes occurring with "normal" aging indicate that, among others, the processes of attention (more precisely SA) and WM are negatively affected (Clapp et al. 2011; Craik and Salthouse 2000; Styles 2005; Zanto et al. 2010). Attention and WM, processes that seem to be closely related (Gazzaley and Nobre 2012; Rutman et al. 2010), are also the pillar of most everyday tasks and, thus, their impairment has huge potential impacts on the daily lives of the elderly.

The results of our study suggest that the elderly are sensitive to the environmental characteristics when performing tasks that demand their attention. Specifically, the elderly missed more target stimuli (i.e., had a higher percentage of omissions in the two attentional tasks), responded more frequently to non-target stimuli (i.e., had a higher percentage of false alarms) and also showed more incorrect responses when the task required a discrimination between stimuli (i.e., the go/no-go task), when the tasks were performed in the distracting environment as compared to the non-distracting environment. Additionally, participants took more time to respond correctly in the go/no-go task when the task was performed in the distracting environment than when performed in the non-distracting environment.

The increased percentage of omissions during the SRT task found in our study when participants were facing a distracting environment can be due to disruption caused by the details present in the environment. Our elderly performance in the go/no-go task, particularly the greater number of correct responses when in the non-distracting environment, and a greater number of false alarms and omissions when in the distracting environment, indicate that the elderly might have had some difficulty inhibiting irrelevant information during the task. Some studies that have revealed similar patterns of results have suggested that this difficulty is particularly noticeable when information is processed visually (Clapp et al. 2011; Kester et al. 2002); this is consistent with our study in which both the distractors and the attentional tasks involved visual stimuli. This difficulty to inhibit irrelevant information seems to be related to the suppression of top-down processing, which is mediated by the prefrontal cortex, an area usually affected in the elderly (Zanto et al. 2010, 2011). The worse performance obtained in the distracting environment can be the result of a failure to ignore the distracting environment which diminishes the elderly ability to stay focused to the relevant stimuli; this difficulty is also reflected in the need for longer times to respond correctly to the stimuli in our study. Consistent with this idea, Madden and Langley (2003) have shown that the elderly take longer to respond to attentional tasks when the perceptual load increases. Our results indicate that, as with children (Fisher et al. 2014; Godwin and Fisher 2011), the environment can have a significant effect in the elderly performance, particularly when attention is required.

It is worth noting that, although we hypothesized that our distracting environment would cause distraction—which in turn would hurt performance—as compared to the non-distracting environment, we have no independent measure that allows us to state that the performance differences obtained between the distracting and the non-distracting environment were indeed due to distraction. Future studies should include other forms of measurement (e.g., eye tracking, subjective reports) that could help to understand how the surrounding environment affects performance.

Several authors argue in favor of a strict link between attention, particularly SA, and WM (Styles 2005; Zanto et al. 2011). For this reason, in addition to evaluating performance in attentional tasks, we also explored how performance in various WM tasks would be influenced by a distracting environment. A negative impact of the distractors on the WM performance, as observed for the attentional tasks, would support the connection between these two cognitive processes. Our results in the WM tasks generally indicate no significant influence of the environment; the only exception occurred in the task of digits memory in the FD where performance in the non-distracting environment was better (i.e., more digits were recalled) than that in the distracting environment. Our additional analysis exploring a possible relation between level of performance and the influence of the environment did little to help explain the overall pattern of results. Also, the analysis investigating the possibility that participants might have habituated to the distracting environment throughout the session (Forster and Lavie 2008), thus minimizing its effect on WM performance, did not support this hypothesis. These results fail to demonstrate a strong relation between these two cognitive processes, at least as assessed by the selected tasks. The literature supports the idea that the elderly have attentional difficulties (Kester et al. 2002; Hawkins et al. 1992); these, in turn, lead to difficulties in WM tasks, particularly when these tasks involve the processing of visual stimuli (Clapp et al. 2011; Gazzaley and D'Esposito 2007; Zanto et al. 2010, 2011). One might also question whether the selected WM tasks required the type of attentional processes involved in our SRT and SA tasks; a differential effect of the distracting environment on these tasks might also be related to this issue. Studies that support the relation between these two cognitive processes typically involve attention to faces (e.g., Gazzaley 2011), which differs in many ways from the attentional tasks we used.

The absence of a significant influence of the environment in the WM tasks performance in our study may have to do with the fact that the memory tasks we used involved mainly auditory stimuli—all instructions and answers were given orally by the experimenter and the participant, respectively—which is at odds with the visual nature of the distractor environment. Some support has been found for modality-specificity in cognitive processing according to which the cognitive processes work independently from one another if they involve different sensory modalities (e.g., visual and auditory stimulus; Lehnert and Zimmer 2008). However, other studies have shown that there could be shared cognitive processes in tasks that draw on different sensorial modalities, and thus, there could be interference between them (e.g., Berti and Schröger 2001). It would be interesting, in future studies, to use WM tasks that involve the same sensorial modality of the distractors.

The influence of our environmental manipulation in the WM tasks performance might also have been minimized by the fact that these tasks demanded the elderly to directly interact with the experimenter, rather than with a computer, which might have helped them focus their attention in the tasks. As previously mentioned, the difficulties to inhibit irrelevant stimuli by the elderly are particularly strong when visual stimuli are involved (e.g., Zanto et al. 2011). Also, it is likely that during these tasks participants were focusing more on the experimenter as he was presenting the tasks orally. During the sessions, the experimenter was sitting next to them and not so much in the area where the distractors were placed (on the wall in front of the computer desk); thus, it is possible that the distractors were less noticed by the participants during these tasks.

In addition to contributing to the understanding of the cognitive processes considered, this type of study also has potential practical implications. Based on the evidence that a distracting environment significantly affects the ability of the elderly to detect and respond appropriately to visual stimuli, we can, for example, think of daily activities that require attention and that also deal predominantly with visual stimuli, such as driving. For example, our data suggest that while driving in an environment overloaded with visual stimuli (e.g., high frequency of advertising boards), the elderly might be more likely to miss important information or to take longer to correctly react to an important stimulus than they would if the environment was less distracting. Taking the example of the USA, it is estimated that by the year 2024, one out of four drivers will be over the age of 65 (National Highway Traffic Safety Administration, 1988, cit. by Ball et al. 1998), and promoting independent living of the elderly, which often depends on their ability to drive on their own, provides them better quality of life. Most of the work relating age, ability to drive and number of accidents has focused mainly on variables of the elderly themselves (e.g., eye health status, visual sensory function, and cognitive status; Ball et al. 1993) or concurrent tasks to driving (Kaber et al. 2012), overlooking the potential effect of the external environment.

Another example where the environment can have a direct impact on the elderly lives are the medical context and evaluation situations. For example, completing a psychological evaluation in a distracting environment may not translate the best reality of the person's abilities, particularly if the task involves visual stimuli; faulty results can jeopardize the suitability of the consequent treatment or intervention. In a medical context, if a clinician is explaining a medication prescription based on a visual schema to an elderly patient in an office crowded with visual stimuli (i.e., a distracting environment), the ability of the elderly to correctly apprehend the information can be diminished, thus having potential negative consequences for the health of the elderly.

To the best of our knowledge, this is the first study investigating the impact the characteristics of the surrounding environment can have in elderly performance, particularly when performing simple attentional and WM tasks. Our results revealed that the elderly ability to respond to the attentional tasks that involved visual stimuli is diminished when distractors are present, as compared to when they are absent. Although these results have many potential applications, more needs to be done before specific practical implications can be stated. Additionally, it would be interesting to apply this paradigm to different age groups in future studies. Besides the potential applications these studies could have in various contexts (e.g., educational, work setting), they would provide a developmental perspective about the interaction between the environment and cognitive performance.

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