Journal of Environmental Psychology 31 (2011) 99–105

Contents lists available at ScienceDirect

Journal of Environmental Psychology

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

Benefits of indoor plants on attention capacity in an office setting

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ARTICLE INFO

Article history:
Available online 10 December 2010

Keywords:
Human issues in horticulture
Interior plants
People–plant interactions
Working memory
Workplace design

ABSTRACT

This research studied possible benefits of indoor plants on attention capacity in a controlled laboratory experiment. Participants were 34 students randomly assigned to one of two conditions: an office setting with four indoor plants, both flowering and foliage, or the same setting without plants. Attention capacity was assessed three times, i.e. immediately after entering the laboratory, after performing a demanding cognitive task, and after a five-minute break. Attention capacity was measured using a reading span test, a dual processing task known to tap the central executive function of attention. Participants in the plant condition improved their performance from time one to two, whereas this was not the case in the no-plant condition. Neither group improved performance from time two to three. The results are discussed in the context of Attention Restoration Theory and alternative explanations.

1. Introduction

Within the field of ergonomics, the impact of negative environmental factors like noise and bad lighting on cognitive performance has been studied for several decades (Cohen, Evans, Stokols, & Krantz, 1986; Finkelman & Glass, 1970; Griffith & Boyce, 1971; Knez & Hygge, 2002), but few studies have investigated possible beneficial environmental factors such as green plants on work performance, and in particular, cognitive functioning. Office workers are reported to be less tired (Khan, Younis, Riaz, & Abbas, 2005) and more healthy (Fjeld, Veiersted, Sandvik, Riise, & Levy, 1998; Kaplan, 1993) when they have access to plants or window views, and prefer work environments with living plants and window views (Dravigne, Waliczek, Lineberger, & Zajicek, 2008; Kaplan, 2007; Shoemaker, Randall, Relf, & Geller, 1992; Wotten, Blackwell, Wallis, & Barkow, 1982), compensating for a lack of window view by decorating with more indoor plants (Bringslimark, Hartig, & Patil, in press). Psychological benefits of indoor plants on students in classrooms have also been reported (Doxey, Waliczek, & Zajicek, 2009; Han, 2009). Inspired by these findings, the present study examines effects of indoor natural elements, and plants in particular, on cognitive performance.

Attention Restoration Theory (ART) (Kaplan, 1995; Kaplan & Kaplan, 1989) states that natural environments can have a restorative effect on attention. The theory sees attention as divided into two subsystems; directed (voluntary) and undirected (involuntary) attention, and is based on the attention model by James (1892) (in James, 2001). Directed attention is seen as having finite capacity, one that can be depleted after cognitively demanding tasks that cause mental fatigue. The complexity in patterns or movements found in natural scenes may offer a particular kind of stimulation that does not demand directed attention. Instead, it triggers undirected attention, enabling the directed attention system to rest. This phenomenon is referred to as *soft fascination* and leads to restoration of attention capacity (Kaplan & Kaplan, 1989).

According to ART, being in contact with outdoor vegetation, views of natural elements through windows, and indoor plants may all contribute to attention restoration (Kaplan, 1993). Exposure to plants may have a restorative effect on attention during short or long breaks from work, leaving directed attention to rest more effectively (Kaplan & Kaplan, 1989). In fact, Kaplan (1993) introduces the term 'micro restorative' experiences and suggests that undirected attention can be activated during very short breaks such as glancing out of a window while working. Although several experiments have been conducted to examine restorative effects of indoor nature interventions (e.g. Berto, 2005; Hartig, Book, Garvill, Olsson, & Gärling, 1996; Hartig, Evans, Jamner, Davis, & Gärling, 2003; Laumann, Gärling, & Stormark, 2003), very few studies have looked at possible benefits of indoor plants in an office setting on cognitive performance (Larsen, Adams, Deal, Kweon, & Tyler, 1998; Lohr, Pearson-Mims, & Goodwin, 1996; Rich, 2007; Shibata & Suzuki, 2001, 2002, 2004). Of those studies, results are mixed. Lohr et al. (1996) and Shibata and Suzuki (2001) reported positive effects of plants, Shibata and Suzuki (2002, 2004) reported effects moderated by gender, and no effects are reported by Rich (2007), or

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doi:10.1016/j.jenvp.2010.11.005

Shibata and Suzuki (2002) on one of the tasks. Contrarily, beneficial effects of a no-plant condition are reported by Larsen et al. (1998).

The inconsistent results may partly be explained by the use of different instruments, as well as their relation to different cognitive functions. Referring to research within neuropsychology, attention can be divided into at least three different functions or processes: *orienting*, the process of detecting changes in the environment; *alerting*, the process of staying vigilant during tasks; and *central executive*, the coordination between the memory and response systems (Parasuraman, 1998; Posner & Petersen, 1990). According to Kaplan and colleagues (Berman, Jonides, & Kaplan, 2008), the central executive function is the most vulnerable to mental fatigue, and would profit most from exposure to restorative environments. Among the studies using plants as natural interventions Rich (2007) used the so-called Digit Span Backward (DSB) test, a dual processing task measuring vital components of the central executive function (Baddeley & Hitch, 1974; Engle, 1996; Lezak, 1995), but found no effects of plants. Shibata and Suzuki (2002, 2004), who found gender moderated effects of indoor plants on cognitive performance, used a word association test which involves a component of creativity; deliberate control which can also be related to central executive functioning (Dietrich, 2004). The other studies examining indoor plant effects on cognitive performance used key response tasks (Lohr et al., 1996; Shibata & Suzuki, 2001), sorting tasks (Larsen et al., 1998; Shibata & Suzuki, 2002), and a letter identification task (Larsen et al., 1998). None of these tasks are known to tap central executive functions.

Despite the use of a task tapping central executive function, Rich (2007) failed to demonstrate any effect of plants. This could be attributed to the poor statistical power as she used a cross-sectional design with only 36 participants. By and large, cross-sectional design has been widely used for studying the effect of indoor plants on cognitive performance (Larsen et al., 1998; Lohr et al., 1996; Rich, 2007; Shibata & Suzuki, 2002, 2004), with a sole exception (Shibata & Suzuki, 2001). In contrast to Rich (2007), these studies used larger sample sizes, i.e. from 81 in Larsen et al. (1998) to 146 in Shibata and Suzuki (2004).

The overall aim of the present study was to examine possible effects of plants on cognitive performance in a working office setting, with the use of a task tapping central executive function, as suggested by Kaplan and colleagues (Berman et al., 2008). First, we wanted to examine whether plants present in an office during the actual work had a positive effect on attention capacity. In accordance with Kaplan's (1993) suggestion that looking at natural elements might affect attention restoration, and findings that plants present during work can have a positive effect on cognitive performance (Lohr et al., 1996; Shibata & Suzuki, 2001, 2002, 2004), we hypothesized that working in a room where plants were present might be more beneficial than working in an environment without plants. We chose a repeated measure design in order to strengthen the statistical power and to establish a baseline measure of attention capacity.

Short breaks between tasks are a common feature in office environments. A number of other studies have examined possible restorative effects of the exposure to natural elements during a break between demanding tasks (Berman et al., 2008; Berto, 2005; Hartig et al., 1996; Laumann et al., 2003; Shibata & Suzuki, 2001), the breaks varying in length from 3 min (Shibata & Suzuki, 2001) to approximately 20 min (Laumann et al., 2003). The second aim of the study was therefore to test possible effects on performance of having plants present during a 'five-minute', i.e. a relatively short break between attention demanding tasks, where the participants had to stay in the office during the break. We expect that the participants would pay more attention to the surrounding during a break compared to the working session, and that the presence of plants during a break may trigger undirected attention. We therefore hypothesized that performance on the attention demanding task would improve after the break.

The present study used a task intending to tap the central executive function of attention. DSB is used in several studies with nature interventions (Berman et al., 2008; Bodin & Hartig, 2003; Cimprich & Ronis, 2003; Kuo, 2001; Ottosson & Grahn, 2005; Tennessen & Cimprich, 1995), and has detected effects in some of them (Berman et al., 2008; Cimprich & Ronis, 2001; Kuo, 2001; Ottosson & Grahn, 2005). Despite the prevalent use of the DSB task, it was decided to use the Reading Span Task (RST) developed by Daneman and Carpenter (1980). Participants read out loud sentences presented on a computer screen and are asked to memorize the last word in each sentence. Similar to the DSB task, the RST is a dual processing task that requires information storage as well as manipulation. Contrary to the DSB task RST is usually scored as the percentage of correctly memorized words over a large number of trials. Hence, it is by itself mentally fatiguing, can resemble stressful office work, and can provide a more realistic measure of attention capacity than the DSB. RSTs are increasingly used as assessments of central executive functioning (Engle, Kane, & Tuholski, 1999; van den Noort, Bosch, Haverkort, & Hugdahl, 2008).

The present study intends to explore if the plants affect attention capacity in an office setting by the use of a task tapping central executive function and a repeated measure design with a baseline measure.

2. Method

2.1. Design

An experimental study was conducted with two independent variables. The between-subjects variable was the presence or absence of plants, while attention capacity was measured three times as a within-subjects variable. Attention capacity was tested immediately after entering the room to obtain a baseline level (T1), after a fifteen-minute proofreading task (T2), and after a five-minute break (T3). The proofreading task was introduced to cause further attention fatigue and to provide a measure of the effect of having plants present during a working session. The participants were separated by gender, then randomly assigned to the two between-subject groups.

2.2. Participants

A total of 34 students from a university in Norway participated in the study. Participants were recruited through announcements in classes, on the students' internal web page and by direct communication. They were informed that it was a study of attention in work related situations, and that they would be given some tasks to solve on a computer. No information about the environmental factor was mentioned. The data collection occurred between November 2008 and March 2009. Twenty-two participants were women with an average age of 25.0 (SD = 5.8), with thirteen participants in the intervention (plant) group and nine in the control (no-plant) group, and twelve participants were men, with an average age of 23.3 (SD = 3.9), five in the intervention group and seven in the control group. Participants were native Norwegians, and were rewarded by participating in a drawing of two gift tokens at the local bookstore being worth NOK 500 (ca. 85 USD) each.

2.3. Apparatus and instruments

Attention capacity was tested using a Norwegian version of the Reading Span Task (Daneman & Carpenter, 1980) made for the purpose. The participants were presented with sequential sentences on the computer screen in trials of four or six, and instructed to read the sentences aloud as well as to remember the last word in each sentence. Each completion of the RST contained a total of 96 sentences, i.e. twelve trials of four sentences followed by eight trials of six sentences. After each trial, the participants wrote down the last word from each sentence in a given space on an answer sheet, the spaces being numbered according to trial and sentence. The participants were instructed to recall the target words in the same order as presented.

Sentence presentation was programmed with Superlab (produced by Cedrus, San Pedro, CA, USA) and run on a Microsoft Windows platform. The sentences were printed in lower case letters, displayed on a Targa 21" screen in approximately 10 mm tall Helvetica, black on a grey background, providing high legibility.

Presentation time for each sentence was 2000 ms with no interstimulus interval between the sentences in the same trial. After each trial, the prompt 'Write down the words. Press green button when you want to continue' was presented and remained on the screen until the green button on the RB 830 Response Box (produced by Cedrus) was pressed. The next trial started after an interval of 1000 ms.

All sentences were in the form: subject – verb – object. All subjects and objects were frequently used nouns that were easy to visualize (see Paivio, Yuille, & Madigan, 1968). Three different versions of the stimulus material comprising the 96 sentences were constructed. No words were repeated or used as both subject and object in the same version, and all sentences were unique throughout the three versions. The sequence of the three stimulus material versions was random and different for each participant, allocated to the three presentation times referred to as the within-subject variable. The sequence of the presentation of the sentences in each trail of four and six sentences was randomized in each presentation. Three unique groups of four sentences and one of six sentences were constructed to use as practice trials.

A proofreading task was presented between time T1 and T2. Proofreading tasks have been shown to involve the central executive function (Larigauderie, Gaonac'h, & Lacroix, 1998), and are used in other nature intervention studies to measure cognitive performance (Hartig, Mang, & Evans, 1991) and produce mental fatigue (Laumann et al., 2003). Text was taken from the Norwegian translation of the book "The image-makers. Power and persuasion on Madison Avenue" by Meyers (1984, 1987). Participants were asked to insert commas and passage breaks in the text.

A questionnaire was provided after completion of the third RST, consisting of totally 18 items, including room assessment questions. Data from the questionnaire will be published separately.

2.4. Setting and intervention

The experiment took place in an office used as a laboratory at the university, sized 390 cm (d) $\times$ 210 cm (w), and 360 cm height (see Fig. 1 and Fig. 2). The room was on the second floor of an early 20th century university building, and had a large window facing towards northeast that did not allow direct sunlight into the room. It was equipped with standard office lighting. The room was painted in light grey (Natural Colour System: S 0500-N) and had white curtains that were drawn back. The view from the window was towards deciduous trees, other buildings, and a large lawn. The study took place during winter, when there were no leaves on the trees. The room contained a wooden desk with the monitor, and a small wooden shelf. The walls were unadorned, except for binders on the shelf. In order to initiate the proofreading task and the second (T2) and third (T3) reading span tasks without further breaks or interruptions the experimenter was present in the room throughout the session. She was sitting in the background behind the shelf, not facing the participant (see Fig. 1). The experimenter was occupied with reading when she was not initiating the tasks.

The following plants were used in the intervention: two flowering pink colored plants of *Phalaenopsis*, each with two flowering stems, placed in white pots on the window sill, one *Aglaonema commutatum* in a white pot, approximately 30 cm tall, standing on the desk, and one tree-shaped *Schefflera arboricola,* approximately 120 cm tall in an anthracite-colored pot, standing on the floor between the desk and the shelf (see Fig. 1, panel B and Fig. 2).

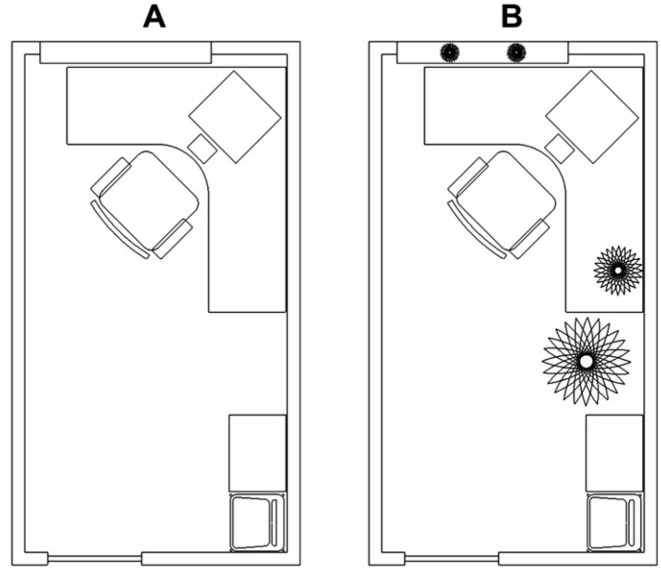

Fig. 1. Room arrangement for the no-plant condition (panel A) and the plant condition (panel B).

Fig. 2. Illustration of office interior with plants.

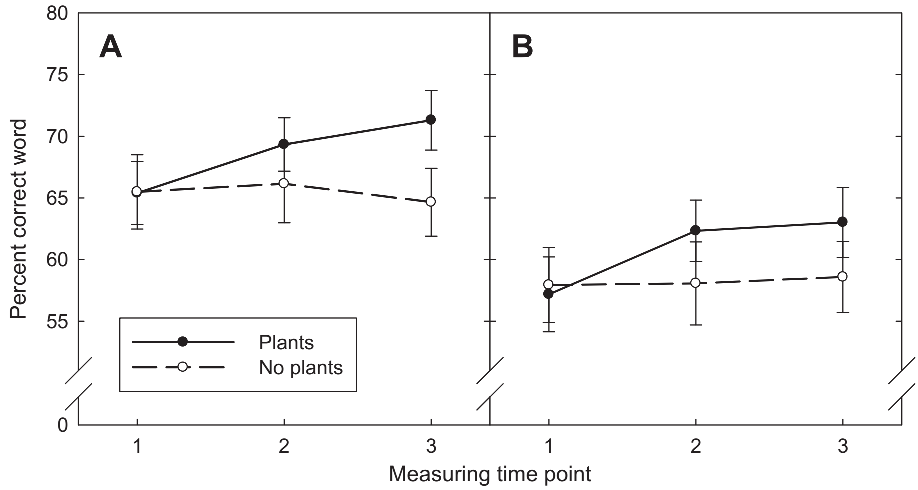

Fig. 3. Percent correctly memorized words recalled in any order (panel A) and recalled in correct order (panel B) as a function of measuring time and the plant intervention. Data from the 4 and 6 sentence condition are collapsed. The error bars show standard errors.

2.5. Procedure

The participants were tested individually, and the total procedure lasted approximately 60 min. Participants were first instructed by the experimenter about the procedure. They were also instructed to turn off mobile phones and music players and not to eat or exit the room during the session. An informed consent was signed, stating they could withdraw from the experiment at any time. Instructions for the RST were then presented on the monitor. Three practice trials of four sentences were presented to familiarize the participants with the experimental procedure. After finishing the 12 four sentence trials, a short instruction was presented on the screen informing participants that the next trials were based on six sentences. They were given one practice trial of six sentences, before they were presented the 8 six sentence trials.

Participants performed the RST three times, each lasting approximately 10 min; at the beginning of the session, after a 15 min proofreading task, and after a five-minute pause. When participants finished the first test, a short instruction was given by the experimenter about the proofreading task, and participants were then given 15 min to work on the task. After finishing the RST the second time, they were informed that they could have a five-minute break, the purpose of which was to rest in order to perform well on the final test. After the final attention test, they were presented with a short questionnaire.

2.6. Data analysis

Words interpreted as correct, but spelled incorrectly, were coded as correct. Dependent variables were the percentage of correctly memorized words recalled in any order, and recalled in the same order as presented. The percentage of words recalled was first calculated for the four and six sentence trials separately. Then a mean score was calculated for all trials. The scores ranged from 0 to 100%. In order to test whether there were effects of plants during work paired sample *t*-tests comparing the performance at T1 and T2 were reported for the plant and the no-plant group. To examine effects of plants during a break between demanding tasks, paired sample *t*-tests comparing the performance at T2 and T3 were reported for the plant group and the no-plant group. To ascertain whether performance for the two groups was similar at the baseline level, an independent sample *t*-test comparing the plant and the no-plant group at T1 was reported. In order to examine whether performance was better in the plant group relative to the no-plant group at T2 and T3, independent sample *t*-tests were run to compare the level of performance. Repeated measures analysis of variance (RM-ANOVA) was used to assess the effects of plants, measuring time point and the interactions for the intervals T1–T2 and T2–T3. The data were analyzed in SPSS version 17.

3. Results

Preliminary analysis indicated that there were no main or interaction effects of gender, therefore, this variable was not considered further.

The average number of correctly memorized words recalled in any order for the 4 and 6 sentence condition collapsed as a function of measuring time and the plant intervention is represented in Fig. 3, panel A. Performance of the plant group improved from T1 to T2 (see Table 1), however, performance did not improve from T2 to T3 (see Table 1). Performance of the no-plant group did not improve from T1 to T2 or from T2 to T3 (see Table 1). There were no difference between the plant and the no-plant condition when conducting an RM-ANOVA. Both conditions improved from T1 to T2 as indicated by a moderate effect of time from T1 to T2, and a non-significant time × plant interaction (see Table 2). The overall improvement from T2 to T3 was negligibly, and also there was no difference between the groups (see Table 2). The performance levels for the plant and no-plant groups are similar at T1 ($t\ (32) = 0.03$, $p = 0.98$) and at T2 ($t\ (32) = 0.85$, $p = 0.40$), whereas a moderate difference between the two groups appears at T3 ($t\ (32) = 1.82$, $p = 0.08$).

Table 1
Comparisons between attention capacity at T1 and T2, and T2 and T3 for the plant and no-plant condition. Attention capacity is measured as number of correctly memorized words in any order, and in the same order as presented.

	Plant (df = 17)		No-plant (df = 15)	
	t	p	t	p
Any order				
T1–T2	−2.81	0.01	−0.29	0.78
T2–T3	−1.25	0.23	−1.03	0.32
Same order				
T1–T2	−3.14	0.01	−0.07	0.95
T2–T3	−0.36	0.72	−0.36	0.73

Table 2
Effects of measuring time point (T1–T2, and T2–T3), plants and interactions on attention capacity. Attention capacity is measured as number of correctly memorized words in any order, and in the same order as presented.

		F(1,32)	p	Partial η^2
Any order				
T1–T2	Time	3.17	0.09	0.09
	Plant	0.18	0.67	0.01
	Time × Plant	1.62	0.21	0.05
T2–T3	Time	0.05	0.83	<0.01
	Plant	1.93	0.18	0.06
	Time × Plant	2.56	0.12	0.07
Same order				
T1-T2	Time	4.46	0.04	0.12
	Plant	0.19	0.67	0.01
	Time × Plant	4.03	0.05	0.11
T2-T3	Time	0.24	0.63	0.01
	Plant	1.24	0.27	0.04
	Time × Plant	0.01	0.94	<0.01

Fig. 3, panel B represents the average number of correctly memorized words recalled in correct order for the 4 and 6 sentence condition collapsed as a function of measuring time and plants. The pattern is similar as for correctly memorized words recalled in any order. There was an overall improvement in performance from T1 to T2 as indicated by a main effect of time (see Table 2), while there was no overall improvement from T2 to T3. Further, the plant group improved their performance from T1 to T2, but not from T2 to T3 (see Table 1), while the control group with no-plant neither improved their performance from T1 to T2 nor from T2 to T3 (see Table 1). The difference between the plant and no-plant group in performance was confirmed by a significant time × plant interaction from T1 to T2, while no statistical difference between the groups was found for that time interval (see Table 2). The performance level for the plant and no-plant groups were similar at T1 ($t\,(32) = 0.18$, $p = 0.86$), T2 ($t\,(32) = 1.03$, $p = 0.31$), and T3 ($t\,(32) = 1.09$, $p = 0.28$).

4. Discussion

The present study analyzed the possible benefits of the presence or absence of plants on attention capacity while working and taking breaks. Attention capacity was measured by the Reading Span Task (Daneman & Carpenter, 1980) known to tap the central executive function of attention (Engle et al., 1999). There are few studies that have evaluated effects of plants on cognitive performance in a working office situation (Larsen et al., 1998; Lohr et al., 1996; Rich, 2007; Shibata & Suzuki, 2001, 2002, 2004), and the present study aims to contribute to this field. Attention capacity was measured consecutively three times with RSTs, the first measure being used as a baseline. Then an intended to be fatiguing task was introduced before attention capacity was measured a second time. After a five-minute break, attention capacity was measured a final time. The research examines whether the presence of plants during a working session, and/or during a break between demanding tasks, led to improved performance relative to a no-plant condition.

No difference between the plant and the no-plant groups at time T1 indicates that there were no pre-experimental differences between the groups and that T1 did indeed function as a baseline.

Improved performance during work from T1 to T2 was observed in the plant group but not in the no-plant group. This finding was true when attention capacity was measured as number of correctly memorized words in the same order as presented, or in any order. The findings were contrary to the hypothesis that a main effect of fatigue from T1 to T2 should have occurred. The proofreading task may not have been demanding enough to cause attention fatigue. Although detecting syntactic errors is found to involve central executive functions of attention, errors more complex than commas and page breaks may be more demanding to detect (Larigauderie et al., 1998). Two different processes may have operated between T1 and T2: a practice effect in both the plant and the no-plant condition and a fatiguing effect that was larger in the no-plant condition. Thus, it is possible that improvement due to practice in the no-plant condition was canceled out by the decrease in performance due to fatigue. In the plant condition, however, the improvement due to practice was not canceled out by a fatiguing effect, supporting assertions of ART that indoor plants can have a restorative effect on cognitive performance. In the ART framework, if attention restoration can occur during 'micro restorative' experiences like looking at natural elements while working as suggested by Kaplan (1993), the lack of fatigue found for the plant condition may have been caused by small lapses of attention or mind wandering (Smallwood, Nind, & O'Connor, 2009) that helps to restore directed attention. Short interval switches of directed and undirected attention is supported by neuropsychological studies (e.g. Shiffrin, Diller, & Cohen, 1996). In addition, the positive effect of presence of plants on cognitive performance during a work session is also supported by Lohr et al. (1996) and Shibata and Suzuki (2001, 2002, 2004). As also reported by Shibata and Suzuki (2002, 2004), the present study confirms that central executive functions can be restored by environmental factors. The divergence between the present findings and the lack of plant effects reported by Rich (2007), who also used a task tapping central executive function, can be explained by the repeated measure design used in the present study and the strengthening of the statistical power.

In the present experiment the no-plant condition was an unusually barren environment. It is possible that the effect of plants would have been different if the plant intervention was compared to a more visually rich office. Further, the observed effects of the plants could also be ascribed to the visual distraction from the presence of the researcher during the work, and not by the plants as such. On the other hand, both groups had window view to nature and thus had the opportunity to draw the attention away from the researcher. However, the possible restorative effects of looking out the window did not seem to outrange the restorative effects of the indoor plants.

In the present study, attention capacity did not improve from T2 to T3 for either the plant or the no-plant group, this was true when attention capacity was measured as number of correctly memorized words in the same order as presented, or in any order. Therefore, the present study does not support the hypothesis that plants will improve attention capacity when present during a defined five-minute break. ART is based on the tenet that directing attention on a task causes fatigue, and that attention capacity can be restored by a shift to undirected attention triggered by a fascinating environment. If a defined break between demanding tasks is necessary for undirected attention to be triggered, the present results fail to confirm such a phenomenon. However, there may be several reasons for the failure of attention restoration to occur during the break inserted between attention demanding tasks in the present study. Because the proofreading task used in the present study was obviously not very fatiguing, it may be that the students at T2 are performing their best and that a break cannot improve their performance. Other explanations for the lack of improved performance after the break may be that the plant environment was not fascinating enough to cause attention restoration, or the break may need to be longer than 5 min to elicit the onset of undirected attention. The presence of the experimenter throughout the session, although occupied with reading, may have been stressful and reduced the participants' experience of having a break.

An alternative model to ART could also explain why performance was better for the plant group during work. The arousal approach to cognitive performance (Cohen et al., 1986; Küller, 1991; Mehrabian & Russell, 1974) states that the environment, mediated by the arousal-level it elicits, can affect cognitive performance. Studies have demonstrated that environmental factors such as noise, light, color and temperature can affect arousal level (Küller & Laike, 1998; Küller, Mikellides, & Janssens, 2009; Taylor, Allsopp, & Parkes, 1995; van Kempen, Kruize, Boshuizen, Ameling, Staatsen & de Hollander, 2002) as well as cognitive performance (Cohen et al., 1986; Easterbrook, 1959; Hockey, 1979; Küller et al., 2009). Effects of natural environments on physiological state have also been documented in several studies (see Parsons, 2007). These studies have focused on the stress-reducing effects of nature, and utilized experimental designs where stress-reduction is measured after presenting participants with natural environments after first being psychologically stressed (e.g. Kim & Mattson, 2002; Ulrich, Simons, Losito, Fiorito, Miles & Zelson, 1991). Perceiving the environment as pleasant is argued to give rise to positive emotions, lower blood pressure, and affect stress level directly (Ulrich et al., 1991). Thus, the difference found in performance between the two groups may have been caused by a buffering or stress-reducing effect of the indoor plants.

The present study confirms that natural elements can affect cognitive performance in an office work environment. However, the processes of how the presence of the plants affects cognitive performance cannot fully be answered by the present study. The results can be understood in the context of ART, as well as an environment-arousal model of cognitive performance. More research is recommended to examine what and how the work environment affects cognitive processes.

Acknowledgements

We thank the anonymous reviewers for their constructive comments to the manuscript.

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