The Speed of Visual Spatial Attention Shifting:
A clinical based study

Inga Kooi, BSc
ANR: 647253

Running head: Speed of Visual Spatial Attention Shifting
Number of words: 5232

Concept Version Master's Thesis Medical Psychology
Department of Medical Psychology, Clinical Neuropsychology
Tilburg University
1st reviewer: Prof. Dr. M.M. Sitskoorn
2nd reviewer: Prof. Dr. J.H.M. Vroomen

Department of Clinical Psychology
Canisius Wilhelmina Hospital
Weg door Jonkerbos 100
6532 SZ Nijmegen
The Netherlands

Abstract

In this study we examined whether a 'Digital Clock Reading Test' was sensitive to detect deficits in the speed of visual spatial attention shifting in clinical patients diagnosed with a neurological disorder. We were also interested whether the Digital Clock Test is of clinical diagnostic value when compared to an often used attention test, namely the Trail Making Test. Patients and normal controls were presented with two clocks on each side of a central fixation cross. Within each clock, a unique single digit was displayed in rapid serial visual presentation (RSVP). Participants were asked to report the digit that they saw in a target clock at the time an exogenous cue (a red rim turning red) or an endogenous cue (an arrow pointing toward a target clock) was presented. A spatially uninformative sound was presented simultaneously with the cue or was absent. Furthermore, each of the participants was instructed to complete the Trail Making Test. Visual latency was calculated for each trial as the difference between the reported and the actual time on the target clock. The group of patients was, in general, slower than healthy control subjects. Visual latency was slower in both groups when the target clock was cued endogenously and when the target clock was far from fixation. The visual latencies of trials with sound were not faster than those without sound. In contrast to the normal control group, in the patient group slow visual latency is not associated with a longer time to complete the Trail Making Test. These results demonstrate that the Digital Clock Test is sensitive enough to detect deficits in the speed of visual attention shifting in clinical patients and is of clinical relevance.

Keywords: speed visual spatial attention shifting, digital clock test, trail making test, endogenous cueing, exogenous cuing

Introduction

The ability to orient attention to a visually relevant scene is of crucial importance in everyday activity. It is generally thought that there are two distinct types of attentional orienting, namely endogenous (internal) and exogenous (external) orienting (Mayer, Dorflinger, Rao & Seidenberg, 2004). Endogenous, or top-down orienting, refers to the controlled, voluntary allocation of attention, whereas exogenous, or bottom-up orienting, refers to the automatic, involuntary allocation of attention (Peelen, Heslenfeld & Theeuwes, 2004). Because the orientation of attention is crucial in everyday activity, it has been examined repeatedly by a frequently used paradigm for assessing attentional selection, namely the spatial-cuing paradigm introduced by Posner (1980). In his orienting cuing paradigm, subjects have to respond as fast as possible to a central or peripheral target. Each target, however, is preceded by a cue, which can be a valid or an invalid cue and will (in case of a valid cue) predict the location of a spatial target. It is commonly found that subjects are faster and more sensitive at detecting targets at a cued location when compared to an uncued location (Tales, Muir, Bayer & Snowden, 2002). However, the speed and sensitivity of target detection does not only depend on the cued or uncued location, it also depends on the type of cue that is being used. For instance, in Posners' paradigm, this cue is not homogenous and is either exogenous or endogenous. In the endogenous orienting condition, a central cue (usually an arrow pointing at the cued stimulus) points to the most likely location of the subsequent target. In the exogenous orienting condition, a brief peripheral onset cue (for example a red rim lighting up) is presented at one of the target locations (Peelen et al., 2004). These different cues are not only different by appearance, but they also have a different influence on attention shifting. For instance, it has been found that endogenous cues can shift attention at around 100-300 ms (Keetels & Vroomen, 2010), whereas exogenous cues can shift attention usually faster, at around 75-175 ms. (Keetels & Vroomen, 2010).

Apart from cuing type, the speed of visual attention shifting, can also be influenced by the presence of a sound. For example, in healthy participants a spatially non-informative sound, presented 100 ms before a cue, can shift the perceived time of occurrence by attracting the temporal occurrence of a visual cue, i.e. temporal ventriloquism (Vroomen & Keetels, 2010; Keetels & Vroomen, 2008; Keetels & Vroomen, 2007; Morein-Zamir, Soto-Faraco, & Kinston, 2003; Vroomen & Keetels, 2006). Furthermore, a spatially non-informative sound can also speed up the velocity of the attentional shift toward a target in younger adults;

however it is relatively unknown how a sound might affect the velocity of attentional shifts in older adults over the age of sixty years (Keetels & Vroomen, 2010; Eriksen & Collins, 1969; Müller & Rabbitt, 1989).

Apart from cue type and the presence of a sound, it is also thought that internal factors can contribute to the speed of attention shifting. An important internal factor that can influence the speed of attention shifting is the brain. To understand how the brain might affect attention shifting, it is first of all important to know how spatial attentional processes work on a neuroanatomical basis. A commonly held and generally acknowledged attention network was introduced by Posner (1990). He describes a hierarchical organization of the posterior attention network which is thought to play a major role in visual-spatial attention. According to this model, a posterior attentional network controls three separate component processes of spatial attention: (1) disengaging attention from a spatial location controlled by the posterior parietal lobe; (2) shifting attention to a target at a new spatial location dependent on the superior colliculus; and (3) engagement of attention on a new target dependent on the thalamus (Newman, 1995; Farah, Wong, Monheit & Morrow, 1989; Hao, Li, Li, Zhang, Wang, Yang, Yan, Shan & Zhou, 2005). Also other brain structures are thought to play a role in both forms of spatial orienting, namely a fronto-parietal network consisting of premotor cortex, posterior parietal cortex, medial frontal cortex and the right inferior frontal cortex (Peelen et al. 2004).

It is known that many disorders of higher level cognitive functioning are caused by deficits in attention. These disorders include Alzheimer's Disease, stroke, neglect, schizophrenia, closed head injury, and attention-deficit disorder (Posner, 1990; Perry & Hodges, 1999; Bartolomeo & Chokron, 2001; Delbeuck, van der Linden & Collete, 2003; Delbeuck, Collete, van der Linden, 2007; Drago, Foster, Ferri, Arico, Lanuzza & Heilman, 2008). These clinical patients are often tested for deficits in complex attention, visual scanning, psychomotor speed, executive functioning and mental flexibility by using the Trail Making Test (TMT) (Allen & Haderlie, 2010; Tombaugh, 2004). However, little is known about the actual speed of attention shifts in these disorders and if the speed of attention shifting is impaired. Therefore it is interesting to know whether clinical patients have deficits in the speed of visual attention shifting, apart from problems with complex attention itself.

To measure the speed of visual spatial attention shifting in clinical patients, Posners' paradigm it is not ideal. For example, the time necessary to shift attention is estimated from the function relating performance or reaction time to stimulus onset asynchrony (SOA), but with Posners` paradigm it is not possible to sample a lot of different cue-target SOA's and only a few SOA's are taken into account. Secondly, Posner uses valid and invalid cues, which can create biases and expectancies on the subjects' behalf. These biases and expectancies can positively influence the speed of attentional shifting, which is not a correct representation of the actual speed of attention shifting. Thirdly, by using a long cue-target SOA, it is possible that a lot of external processes have an influence on the speed of attention. For example, subjects can oppress or make unwanted eye movements and in an exogenous orienting condition it is likely that inhibition of return occurs (Peelen et al., 2004). A possibly more refined method for assessing the speed of attention shifting was recently developed by Carlson et al. (2006). The method they used was a version of Wundt's complication clock, the apparatus first used in some first studies on the time course of attention. Their method lets participants view an array of moving clocks and report the time on one of the clocks when it is cued by one of a number of different types of cues, namely an endogenous or exogenous cue. This is a very simple and precise method to estimate the speed of attention shifts and it can be applied to estimate the duration of exogenously and endogenously cued attentional shifts (Carlson et al., 2006).

To investigate the speed of visual attention shifting in clinical patients, the Digital Clock Method, as developed by Carlson et al. (2006), will be used in this study to investigate whether this method is sensitive enough to detect deficits in the speed of visual spatial attention shifts in clinical patients when compared to a normal control group. When we do find deficits in the speed of visual spatial attention shifting, it is the question how clinical patients differ (e.g. do they perform worse) in comparison to a normal control group. The second aim of this study is to investigate whether a spatially non-informative sound, as previously has been shown in healthy subjects, can influence (e.g. speed up) the speed of visual spatial attention shifting in an impaired brain. The third aim of this study is to investigate whether clinical patients perform differently on the TMT when compared to the Digital Clock method. The Trail Making Test is designed to measure complex attention, psychomotor speed, visual scanning and mental flexibility, whereas the Digital Clock Method is designed to assess the speed of visual spatial attention shifting. So, theoretically, these tests are supposed to measure different aspects of attention, so one would expect only a small relationship between these two tests.

Method

Participants. Nine clinical patients participated, which were recruited from the Clinical Psychology Department at Canisius-Wilhelmina Hospital in Nijmegen. All the patients were formally assessed and diagnosed by clinical psychologists and neurologists. An overview of these diagnoses is shown in table 1. All reported normal or corrected-to-normal hearing and normal or corrected-to-normal vision. They were free of medication deemed likely to affect cognitive function.

Table 1
Demographics of patient group by sex, age (in years), level of education (according to Verhagen) and diagnosis.

	Sex	Age	Level of Education	Diagnosis
1	Male	74	4	Multi System Atrofie
2	Female	81	2	Fronto Temporal Dementia
3	Male	42	6	Multiple Sclerosis
4	Male	52	6	Multiple Scleoris
5	Female	57	5	Cardio Vascular Accident
6	Female	66	3	Progressive Supranuclear Palsis
7	Male	72	5	Hart surgery with lung-heart machine
8	Male	75	6	Vascular Dementia
9	Female	43	2	Cardio Vascular Accident

The age-matched control group consisted of 14 individuals who were recruited from the Clinical Psychology Research Department at Tilburg University.

Stimuli. Participants sat a table in a dimly lit and sound-proof room and were asked to keep their head as still as possible. Stimuli were displayed on a CRT monitor (100 Hz, 800 x 600 resolution) controlled by a PC running E-prime 1.2 software. The visual stimulus consisted of two circular white placeholders (a ‘clock’) in which digits (0.5 cm) were presented in rapid serial visual presentation at 5 Hz. One clock was presented at the left of the central fixation cross and one clock was presented at the right of the central fixation cross. Both clocks were arranged at either 5 or 15 degrees of visual angle from fixation. The auditory stimulus consisted of a 30-ms white noise burst presented at 84 dB by a headphone so that the sound appeared to come from the middle.

Procedure. Participants were tested individually and were unaware of the purpose of the experiment. They were asked to read out loud the task instructions displayed on an instruction form in front of them and were asked to describe the fixation cross, the cues, and the targets.

The participants were instructed to maintain fixation on the central fixation cross at the centre of the screen. At the beginning of a trial, the fixation cross disappeared and the two clocks appeared. Within each clock, a unique single digit was displayed in rapid serial visual presentation (RSVP) mode changing every 200 ms (5 Hz). The two digits changed progressively, counting up by 1 (e.g., 7, 8, 9, 0, 1, 2,..). The initial digit displayed in each of the clocks was determined randomly. In the exogenous cue condition, at a randomly selected digit position in the second or third revolution, an exogenous cue event that consisted of a randomly determined target clock rim turning red for 100 ms occurred. After randomly 8-10 RSVP´s, both clocks disappeared (figure 1). The participant's task was to judge the time on the target clock when it turned red. Responses were collected by using the 0 to 9 keys on the keyboard (1 for digit 1, 2 for digit 2, etc). The endogenous cue consisted of an arrow starting from the central fixation cross and pointing toward one of the two target clocks (extending 2 degrees) for 100 ms. After randomly 8-10 RSVP´s, both clocks disappeared (figure 2). The participant's task was to read the target clock at which the arrow was pointing. Responses were collected by using the 0 to 9 keys on the keyboard (1 for digit 1, 2 for digit 2, etc).

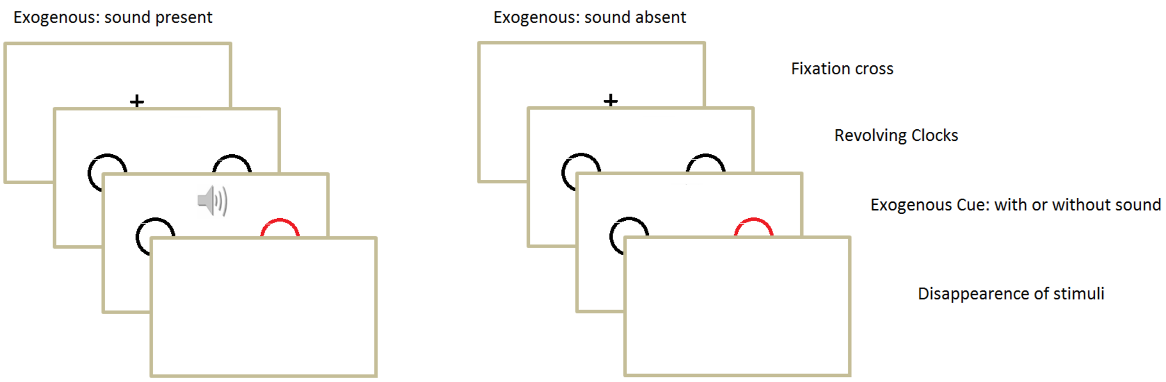

Figure 1: Visual presentation of stimuli in the exogenous cuing condition

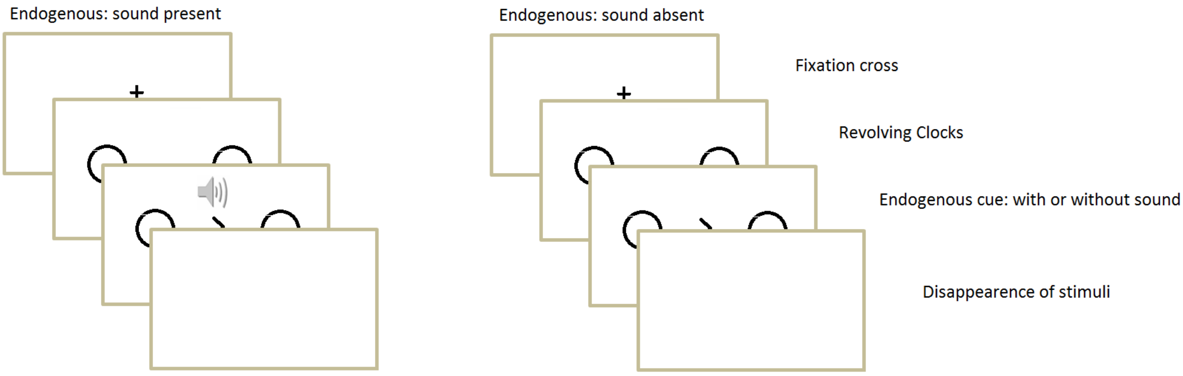

Figure 2: Visual presentation of stimuli in the endogenous cuing condition

After the clock task, participants were asked to complete the Trail Making Test (TMT). Trails A and B were administered according to the guidelines presented by Spreen and Strauss (1998). Participants were instructed to complete the two parts of the TMT. Both parts of the Trail Making Test consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1 – 25, and the participant is asked to draw lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L); as in Part A, the participant is asked to draw lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). The participants were further instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. When an error was made, the participant was instructed to return to the "circle" where the error originated and continue. Time to complete each part was recorded in seconds (Tombaugh, 2004).

Design. One between-subjects factor was used: group (patients vs. control group). Three within-subjects factors were used: cue-type (endogenous vs. exogenous), sound interval (with or without sound) and position of the target clock (near vs. far from fixation). The sound was presented simultaneously with the cue or was absent. The silent condition served as the baseline. The position of the target clock was either at the left or the right of the central fixation cross. Half of the targets were presented near fixation (at an eccentricity of 5 degrees), the others far (at an eccentricity of 15 degrees). The cue-type was either exogenous or endogenous. Both cue-types were presented in different blocks, to prevent any confusion with the identification of the target clock. The whole test consisted of four blocks of 80 trials, in which each of the two target clocks positions was randomly presented 20 times for each sound interval. Complete counterbalancing (ABBA) was used to balance the effect of cue type order. A practice session (12 trials) proceeded the first block of trials with endogenous and exogenous cues.

After the initial Clock procedure participants were instructed, according to the guidelines presented by Spreen and Strauss (1998) to complete both parts of the Trail Making Test. A practice trail preceded each part of the Trail Making Test. In the test trial of the TMT-A participants were shown 8 circles (numbered 1 – 8) and were instructed to connect the circles in ascending order as quickly as possible, without lifting the pen or pencil from the paper. When an error was made, the participant was instructed to return to the “circle” where the error originated and continue. The same procedure was followed in the test trial of the TMT-B, only this time participants were shown 8 circles including both numbers (1 – 4) and letters (A – D).

Results

For the clock-reading task, visual latency was calculated for each trial as the difference between the reported and the actual time on the target clock. The data from the peripheral target clocks were pooled over the left and right positions because preliminary analysed showed that there was no difference between these two positions ($p > 0.789$). Responses that deviated by more than 3 digits (corresponding to a visual latency of 800 ms or more) were considered as lapses and were excluded from further analyses. Table 2 presents the mean visual latency for each group.

Table 2

Mean (M) and standard deviation (SD) of the visual latencies in the Digital Clock Reading task (in ms), TMT A and TMT B (speed in seconds and errors) in patients (N = 12) and controls (N = 14). The bold values are with p < 0.05.

	Patients (N=9)		Controls (N=14)		Comparison	
	M	SD	M	SD	*t*(30)	*p*
Digital Clock	302.4	89.4	211.5	59.9	13.2	**.008**
TMT A						
Errors	.22	.4	0	0	1.5	.168
Speed	64.0	13.4	37.1	16.1	8.6	**<.001**
TMT B						
Errors	.78	.97	0	0	2.4	**.043**
Speed	155.8	80.9	77.9	43.4	5.8	**.007**

An overall three-way-ANOVA on the visual latencies was conducted with group (patients vs. normal control group) as between-subjects factor, and cue type (endogenous vs. exogenous), sound (present vs. absent), and distance (near vs. far) as within-subjects factors. The group of patients were, in general, slower than healthy control subjects (302 ms vs. 212 ms, a 90 ms difference), $F(1,30) = 8.60$, $p < 0.008$, $\eta p2 = 0.30$ (as shown in table 2). Furthermore, endogenously cued targets had slower visual latencies than exogenously cued targets (319 ms vs. 175 ms, a 144 ms difference), $F(1,30) = 48,78$, $p < .001$, $\eta p2 = .70$, and targets far from fixation had slower visual latencies than targets near fixation (275 ms vs. 219 ms, respectively a 56 ms difference), $F(1,30) = 20,38$, $p < .001$, $\eta p2 = .492$. The visual latencies of trials with sound were not faster than those without sound (241 ms vs. 253 ms, a 12 ms difference), $F(1,30) = .764$, $p = .392$, $\eta p2 = .035$. There was no overall difference between targets in the left and right visual fields ($F < 1$).

Further analyses showed that patients did not have a specific impairment in their visual latency, e.g. patients were, when compared to the controls, not poorer on targets presented far from fixation (interaction: group x distance F = 1.6, p = .22). Patients were also not specifically impaired on endogenous rather than exogenous targets (group x cue type interaction, F <1), as shown in figure 1.

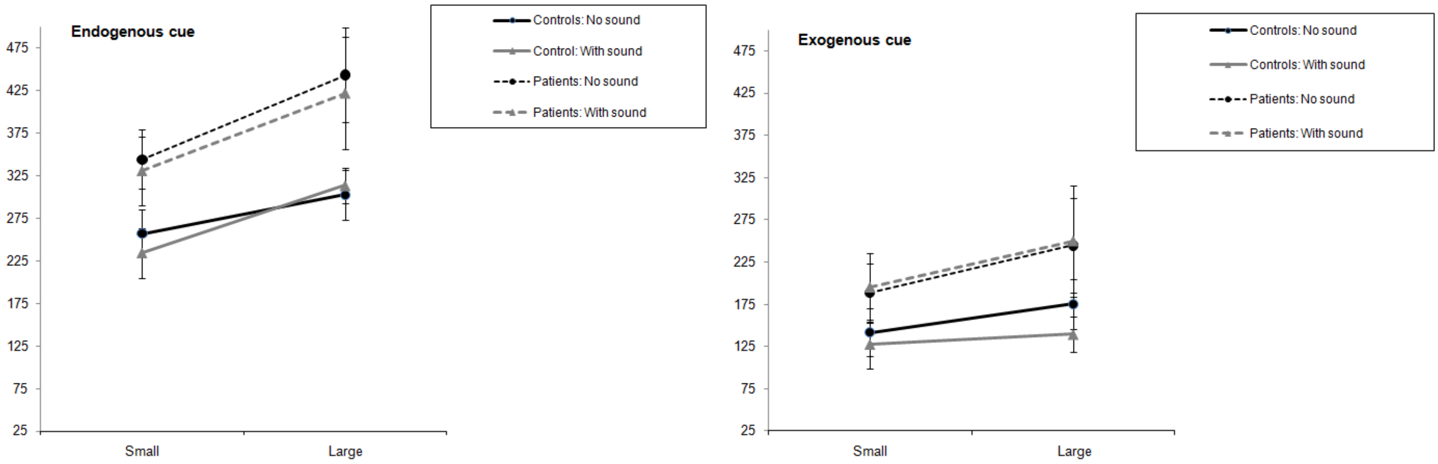

Figure 1Mean speed of attentional shifting for endogenous and exogenous cues

TMT-scores were calculated for each participant as the actual time in seconds it took participants to complete the TMT-A and TMT-B. An independent-samples t-test was conducted to compare the TMT-scores between patients and the healthy control group. On the Trail Making Test-A patients were slower than normal controls (Patients: TMT-A M = 64.00, SD = 13.4; Normal controls: M = 37.14, SD = 16.1; t(23) = 4.158, p = <.001 (two-tailed)), which indicates that, when compared to the normal control group, it took patients longer to complete the TMT-A. In the TMT-B scores, there was also a significant difference between patients (M = 155.78, SD = 80.89) and the control group (M = 77.93, SD = 43.473; t(23) = 3.001, p = 0.007 (two-tailed)), which indicates that patients also performed significantly worse (e.g. it took longer to complete) on the TMT-B when compared to the normal control group. The zero-order correlation coefficient (Pearson r) showed that within the patient group there is no significant relationship between scores on the TMT-A and TMT-B (r(9) = -.270, p = .482), in contrast to the healthy control group (r(14) = .873, p <.001).

We also computed the zero-order correlation coefficient (Pearson r) between the digital clock test and the Trail Making Test A and B. If computed across both groups, then scores on the digital clock test and the Trail Making Test A and B correlated strongly with each other (($r(23) = .55$, $p < .007$) and ($r(23) = .732$, $p < .001$)), thus indicating that a large visual latency is associated with a long time to complete the Trail Making Test A and B. However, the correlations between the Trail Making Test and the average visual latency where not significant anymore for patients when computed separately for each of the two groups (Patients: TMT A: ($r(9) = -.063$, $p = .872$; TMT B: ($r(9) = .636$, $p = .066$), thus indicating that within the patient group, slow visual latency is not associated with high scores on the Trail Making Test. The correlation between the Trail Making Test and the average visual latency is however significant for the control group when computed separately (Control group: TMT A: ($r(14) = .587$, $p = .027$; TMT B ($r(14) = .601$, $p = .023$). This indicates that for the control group, slow visual latency is associated with high scores on the Trail Making Test.

Discussion

The results of this study show that the Digital Clock task is a sensitive method to detect deficits in the speed of visual attention shifts in clinical patients. The main findings to emerge from this research were the following: First, patients had much longer visual latencies than a normal control group (a 90 ms difference). Secondly, endogenously cued targets had slower visual latencies than exogenously cued targets, which is in correspondence with previous findings (Keetels et al., 2010). Furthermore, targets near fixation point had much shorter visual latencies than targets far from fixation point, presumably because targets near fixation were fixated and did not need an additional attention shift, which has been shown previously with healthy subjects (Keetels et al., 2010).

An interesting finding to emerge from this study is the fact that a sound did not enhance performance (e.g. speed up visual spatial attention shifting) on the digital clock task. This is true for both patient and control group. This is contrary to our original idea that a sound is likely to speed up the speed of visual spatial attention shifting, as has been shown in previous studies (Keetels et al., 2010). One explanation for this finding could be age. When we look at the overall mean age of both groups in our experiment (respectively 62 and 65 years of age), and compare those to the mean age of the group of students used in the study of Keetels et al. (2010), we come to the conclusion that the mean age in their study is significantly lower than the mean age in the present study. It is the question whether age could be the explanatory factor for these rather unexpected results. To explore this idea further, it is important to know how older adults (over 60 years of age) might differ from younger adults regarding attention processes.

Research has shown that attention control settings change with age, with higher settings for older adults leading to delayed disengagement from spatial cues (Langley, Friesen, Saville & Cierna, 2011) and older adults find it more difficult to disengage attention from cues (Castel, Chasteen, Scialfa & Pratt, 2003). When looking at attention processes on a neuroanatomical basis, neuroimaging studies of older adults have shown that there is an age-related change within the dorsal component of the fronto-parietal network (Madden, 2007). It is thought that during cognitive tasks, regions of the frontal lobe tend to increase as a function of adult age. These regions tend to mediate the top-down attentional-control processes, which may reflect older adults' increased emphasis on the top-down attentional-control processes (Cabeza, 2002;

McIntosh, Sekule, Penpeci, Rajah, Grady, Sekuler & Bennett, 1999). In contrast with top-down attentional-control processes, the quality of the bottom-up sensory input may show a decline in older adults. This is presumably because cortical regions of the occipital lobe, mediating visual processing, tend to show less activation (Madden, 2007). So these findings suggest that there is indeed an age-related difference in attentional processes.

Because a sound is thought to influence attentional processes, it is interesting to know whether a sound also has a different impact on older adults' attentional processes when compared to younger adults, regarding the above mentioned differences. To further explore this idea, it is relevant to investigate multisensory integration. Multisensory integration refers to the influence of one sensory modality over another in the form of enhancement or suppression relative to the strongest "unimodal" response (Ghazanfar, Maier, Hoffman & Logothetis, 2005). Surprisingly little data exists on how multisensory interactions change as a function of age and mixed results have been found. Some studies did find an age-related effect (Peiffer, Mozolic, Hugenschmidt & Laurienti, 2007). One possible explanation for the result that there is indeed an age-related effect on multisensory integration could be the effectiveness of the individual stimuli (Laurienti et al., 2006). It has been shown that the multisensory gain is increased when the effectiveness of unimodal sensory stimuli is decreased. This phenomenon is also referred to as inverse effectiveness (Laurienti et al., 2006). It could be that the stimulus effectiveness differs between the younger and older adults and therefore might lead to different multisensory enhancement magnitudes (Laurientie et al., 2006). For instance, according to the Attention Control Setting (ACS) theory (Folk, Remington & Johnston, 1992), people allocate more attentional resources for longer periods of time when a task is more difficult than when the task is simpler (Langly et al., 2011). Langly et al. (2011) found that, while using a Posner cuing task, older adults attended to cued locations with greater intensity than younger adults did, presumably because older adults perceived the task to be more difficult, leading them to raise their attentional control settings. This could potentially lead to changes in stimulus effectiveness, resulting in an age-related effect on multisensory integration. Regarding our study, it is a plausible explanation that the participants show an enhanced effectiveness of the visual stimuli, resulting in a decreased multisensory gain, leading to the unexpected finding that a spatially non-informative sound did not speed up visual attention shifting.

A second explanation for the non-existing sound effect in our research is presented by Commodara & Guarnera (2008). They have found that subjects over 60 years of age show progressive slowing in processing of complex tasks and have a reduced capacity to inhibit irrelevant stimuli. Furthermore, older adults commonly report that they find unknown and extraneous stimuli more distracting than they used to (Pokiakoff, Ashworth, Lowe & Spence, 2006). These findings have led to the idea that older adults view the sound as a distracting stimulus, leading to non-congruency of the visual and auditory stimuli, despite spatial and temporal congruency. This could potentially lead to differences in multisensory integration. However, future research is necessary to investigate age-related effects on multisensory integration.

The third aim of this study was to investigate whether clinical patients performed differently on the TMT when compared to the Digital Clock method. In our study we did find that there was only a small correlation between performance on the Digital Clock test and the Trail Making Test in the patient group, in contrast to the normal control group where a large effect was found. These results lead to the conclusion that in clinical patients the Digital Clock Test and the Trail Making Test indeed measure different aspects of attention. Therefore it is necessary to investigate the clinical relevance of the Digital Clock Test and extensive research is needed to investigate in what type of clinical population the Digital Clock Test could be used as a measurement of visual spatial attention shifting. This research is necessary because during the includation period, it was found that the Digital Clock Test could not be used as a test for visual spatial attention shifting deficits in patients suffering from Alzheimer’s disease. For them, the task was too hard to comprehend and they could not accomplish the test trials which were shown before the actual task trials. However, it is the question whether this is due to test limitations or whether this could rather be explained by patient’s cognitive inabilities. For instance, attention deficits are frequently present in patients with Alzheimer's Disease and it is one of the key diagnostic features in Alzheimer's Disease, as stated within the DSM-IV. Therefore, when attention is already confined within these patients it is impossible to measure the speed of visual spatial attention shifting accurately. Drago, Foster, Ferri, Arico, Lanuzza and Kenneth (2008) suggest that there are several types of attentional disorders that might manifest in Alzheimer’s Disease patients. First, they suggest that damage to the cortex might lead to disinhibition of the colliculus, which is sensitive to movement. This disinhibition of the colliculus might lead to increased distractibility to moving stimuli or blinking lights in patients with cortical degeneration. Second, patients with Alzheimer’s Disease might be impaired at disengaging from non-relevant lateral stimuli (Drago et al., 2008), and thirdly, patients with Alzheimer’s Disease appear to have more problems with global than focal attention, suggesting that they might have a reduced attentional window. Furthermore, research has shown that patients with Alzheimer's Disease have a reduced spatial attentional window and have a reduced capacity to spatially re-allocate their attention. (Drago et al., 2008). Delbeuck et al. (2007) suggest the occurrence of a specific, audio-visual integration deficit in AD, which might be the consequence of a connectivity breakdown which might lead to crossmodal deficits between the auditory and visual modalities in this population. Due to these specific attentional problems that might manifest in Alzheimer's Disease, the Digital Clock Test is not appropriate to test for visual spatial attention deficits in these patients.

Apart from the fact that the Digital Clock Test is not suitable to test for deficits in attention shifting in Alzheimer patients, it still remains the question in which type of patient groups this test could be administered. For instance, our study has shown that it is possible to administer the Digital Clock Test to a number of different patients suffering from different neurological diseases: multiple sclerosis, cardio vascular accident, Frontal Lobe Dementia, Vascular Dementia, Progressive Supranuclear Palsis and multisystem atrophy. However, because of the small sample size, it still remains the question how patients with different neurological disorders actually differ in the speed of visual spatial attention shifting. Therefore, in the future, it is highly recommended to explore the differences in visual spatial attention shifting within different neurological patients.

Because of the possible underlying deficits in the posterior attention network, it is especially interesting to know how patients with parietal damage, for instance neglect and stroke patients, perform on the Digital Clock Test. It is expected that especially these patients have deficits in visual spatial attention shifting, resulting in a slow visual latency (Newman, 1995; Farah, Wong, Monheit & Morrow, 1989; Hao, Li, Li, Zhang, Wang, Yang, Yan, Shan & Zhou, 2005). By using the Digital Clock Method, these specific deficits can be measured and within these different neurological disorders, specific visual spatial attention deficit patterns can be identified. Therefore it is thought that in the future, the Digital Clock Test could be of high diagnostic and perhaps discriminative value within clinical patients with parietal damage.

References

Allen, D. N. & Haderlie, M. M. (2010). Trail-Making Test. Corsini Encyclopedia of Psychology. 1.

Bartolomeo, P. & Chokron, S. (2002). Orienting of attention in left unilateral neglect. *Neuroscience and Biobehavioral Reviews, 26,* 217-234.

Cabeza, R. (2002). Hemispheric asymmetry reduction in older adults: the HAROLD model. *Psychology and Aging, 17,* 85-100.

Carlson, T.A., Hogendoorn, H. & Verstraten, F.A.J. (2006). The speed of visual attention: What time is it? *Journal of Vision, 6*, 1406-1411.

Castel, A.D., Chasteen, A.L., Scialfa, C.T. & Pratt, J. (2003). Adult age differences in the time course of inhibition of return. *Journal of Gerontology: Psychological Sciences, 58*, 256-259.

Commodara, E. & Guarnera, M. (2008). Attention and aging. *AgingClinical and Experimental Research, 20*(6), 578-584.

Delbeuck, X., Collette, F. & Van der Linden, M. (2007). Is Alzheimer's disease a disconnection syndrome? Evidence from a crossmodal audio-visual illusory experiment. *Neuropsychologia, 45,* 3315-3323.

Delbeuck, X., Van der Linden, M. & Collete, F. (2003). Alzheimer's Disease as a Disconnection Syndrome? *Neuropsychology Review, 13*(2), 79-92.

Drago, V., Foster, P.S., Ferri, R., Arico, D., Lanuzaa, B. & Heilman, K.M. (2008). Distractibility and Alzheimer Disease: The "Neglected" Phenomenon. *Journal of Alzheimer's Disease, 15*, 1-10.

Eriksen, C.W. & Collins, J.F. (1969), Temporal course of selective attention. *Journal of Experimental Psychology, 80,* 254-261.

Farah, M.J., Wong, A.B., Monheit, M.A. & Morrow, L.A. (1989). Parietal lobe mechanisms of spatial attention: modality-specific or supramodal? *Neuropsychologia, 27*(4), 461-470.

Folk, C.L., Remington, R. & Johnston, J.C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18*¸1030-1044.

Ghazanfar, A.A., Maier, J.X., Hoffman, K.L. & Logothetis, N.K. (2005). Multisensory Integration of Dynamic Faces and Voices in Rhesus Monkey Auditory Cortex. *The Journal of Neuroscience, 25*(20), 5004-5012.

Hao, J., Li, K., Li, K., Zhang, D., Wang, W., Yang, Y., Yan, B., Shan, B. & Zou, X. (2005) Visual attention deficits in Alzheimer's disease: an fMRI study. *Neuroscience Letters, 385,* 18-23.

Keetels, M. & Vroomen, J. (2007). No effect of auditory-visual spatial disparity on temporal recalibration. *Experimental Brain Research, 182,* 559-565.

Keetels, M. & Vroomen, J. (2008). Tactile-visual temporal ventriloquism: No effect of spatial disparity. *Perception & Psychophysics, 70*(5), 765-771.

Keetels, M. & Vroomen, J. (2010). Sound Affects the Speed of Visual Processing. *Journal of Experimental Psychology: Human Perception and Performance,*

Langley, L.K., Friesen, C.K., Saville, A.L. & Ciernia, A.T. Timing of reflexive visuospatial orienting in young, young-old, and old-old adults. *Attention, Perception, & Psychophisics, 73,* 1546-1561.

Laurienti, P.J., Burdette, J.H., Maldjian, J.A. & Wallace, M.T. (2006). Enhanced multisensory integration in older adults. *Neurobiology of Aging*, *27*, 1155-1163.

Madden, D.J. (2007). Aging and Visual Attention. *Current Directions in Psychological Science*, *16*(2), 70-74.

Mayer, A.R., Dorflinger, J.M., Rao, S.M. & Seidenberg, M. (2004). Neural networks underlying endogenous and exogenous visual-spatial orienting. *NeuroImage 23*, 534-541.

McIntosh, A.R., Sekuler, A.B., Penpeci, C., Rajah, M.N., Grady, C.L., Sekuler, R. & Bennett, P.J. (1999). Recruitment of unique neural systems to support visual memory in normal aging. *Current Biology*, *9*(21), 1275-1278.

Morein-Zamir, S., Soto-Faraco, S., & Kingstone, A. (2003). Auditory capture of vision: Examining temporal ventriloquism. *Cognitive Brain Research*, *17*(1), 154-163.

Müller, H.J. & Rabbitt, P.M.A. (1989). Reflexive and voluntary orienting of visual attention: Time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 315-330.

Newman, J. (1995). Thalamic Contributions to Attention and Consciousness. *Consciousness and Cognition, 4*(2), 172-193.

Peelen, M.V., Heslenfeld, D.J. & Theeuwes, J. (2004). Endogenous and exogenous attention shifts are mediated by the same large-scale neural network. *NeuroImage, 22*, 822-830.

Peiffer, A.M., Mozolic, J.L., Hugenschmidt, C.E. & Laurienti, P.J. (2007). Age-related multisensory enhancement in a simple audiovisual detection task. *Neuroreport*, *18*, 1077-1081.

Perry, R.J. & Hodges, J.R. (1999). Attention and executive deficits in Alzheimer's disease. A critical review. *Brain, 122*, 383-404.

Poliakoff, E., Ashworth, S., Lowe, C. & Spence, C. (2006). Vision and touch in ageing: Crossmodel selective attention and visuotactile spatial interactions. *Neuropsychologia, 44*, 507-517.

Posner, M.I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*(1), 3-25.

Posner, M.I. (1990). The Attention System of The Human Brain. *Annual Review of Neuroscience, 13*, 25-42.

Robertson, I.H., Mattingley, J.B., Rorden, C. & Driver, J. (1998). Phasic alerting of neglect patients overcomes their spatial deficit in visual awareness. *Nature, 395*, 169-172.

Spreen, O., & Strauss, E. (1998). *A compendium of neuropsychological tests: Administration, norms and commentary* (2nd ed.). New York: Oxford University Press.

Tales, A., Muir, J.L., Bayer, A. & Snowden, R.J. (2002). Spatial shifts in visual attention in normal ageing and dementia of the Alzheimer type. *Neuropsychologia, 40*, 2000-2012.

Tombaugh, T.N. (2004). Trail Making Test A and B: Normative data stratified by age and education. *Archives of Clinical Neuropsychology, 19*, 203-214.

Vroomen, J. & Keetels, M. (2006). The Spatial Constraint in Intersensory Pairing: No Role in Temporal Ventriloquism. *Journal of Experimental Psychology, 32*(4), 1063-1071.

Vroomen, J. & Keetels, M. (2010). Perception of intersensory synchrony: A tutorial review. *Attention, Perception, & Psychophysics, 72*(4), 871-884.