Mobility in People with Hemianopia: Effect of Dual Tasking on Walking Speed and Scanning Behavior

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Abstract

Introduction: Homonymous hemianopia is a visual field defect characterized by a loss of vision on one side of the visual field in both eyes. These people have difficulty detecting objects in their blind hemifield while walking, which might be amplified during dual tasking due to inadequate scanning behavior. This study aims to assess the influence of dual tasking on scanning behavior, walking speed and detection performance in people with and without hemianopia.

Methods: A single task, an attentional dual task, and cognitive dual task were used to assess the influence of dual tasking on scanning behavior in seventeen people with hemianopia and seventeen people with normal vision. The single task consisted of identifying targets. Attentional dual task consisted of walking through a cone while identifying targets and avoiding a confederate. Cognitive dual task required participants to identify targets and take the digit span backwards test. An eye tracker was used to record scanning behavior. We examined differences in walking speed, detection performance and scanning behavior (i.e., saccadic exploration, saccadic amplitude, and dispersion of scans) between tasks and groups.

Results: People with normal vision walked slower in the cognitive dual task condition than in the attentional dual task condition, while those with hemianopia showed no difference in their walking speed. A significant negative effect of dual tasking was found on scanning behavior and walking speed, but not on detection performance.

Conclusion: Future rehabilitation can supplement compensatory scanning training with dual task training to attenuate the negative impact of dual tasking on scanning behavior. People with hemianopia can be trained to make larger saccades during dual tasking to enhance scanning behavior.

Keywords: hemianopia, compensatory scanning, walking speed, dual task, saccades

The effect of dual tasks on walking speed and scanning behavior in people with hemianopia

Introduction

The term “visual impairment” refers to a reduction in vision and could either be congenital or a result of a brain injury. At least 2.2 billion people worldwide are affected by visual impairments (World Health Organization: WHO, 2022). Homonymous hemianopia (HH) is one of these impairments, characterized by a loss of vision on the same side of the visual field in both eyes and is caused by the presence of a lesion in the visual pathway posterior to the optic chiasm, usually in the occipital lobe (40%), parietal lobe (30%), temporal lobe (25%), and in rare cases, the optic tract and lateral geniculate nucleus (5%) (Huber, 1992). The most commonly affected group are stroke patients (69.7%), while other causes may include head trauma, lesions, invasive surgical procedures, and neurodegenerative disorders (Ruddy, 2022).

An individual suffering from HH can experience significant long-term effects caused by the visual-field defect (VFD) in their day-to-day activities (Warren, 2009; Wee & Hopman, 2008). They face difficulties with detecting objects or people in their affected visual field, consequently leading to difficulties in navigating around obstacles or people (De Haan et al., 2015), and in worst case scenarios collisions (Pambakian & Kennard, 1997). This could negatively impact the quality of life (QoL) of an individual with HH (Jones & Shinton, 2006) and can have far-reaching consequences in their everyday lives. Given the high prevalence of HH, particularly after a stroke, with 10% of the people developing chronic HH (Zhang et al., 2006), it is essential that we help improve the quality of life of people with hemianopia.

To overcome these difficulties, people with HH exhibit compensatory scanning behavior. Previous research has shown that people with HH are biased towards their blind hemifield (BHF) when scanning the environment (Elfeky et al., 2021). This suggests that they try to compensate for their VFD by scanning their affected side more. However, the compensatory scans made towards their affected side seem to be insufficient as around 60% of individuals with HH are not able to adequately compensate for their VFD using compensatory scanning behavior (Zihl, 1995; Zihl, 1999; Zihl, 2000). Taken together, these findings suggest that although people with HH try to compensate for their VFD using compensatory scans, this compensatory scanning behavior might still be inadequate.

Although the majority of individuals with HH experience difficulties with daily-life mobility activities, there are individuals with HH who perform similarly to people with normal vision. This variability can be explained by differences in scanning behavior. A wide body of literature has found that compared to low performing HH group, participants in the high performing HH group make more saccades (Bahnemann et al., 2015), have a larger saccadic amplitude (Papageorgiou et al., 2012; Bahnemann et al., 2015), and a wider dispersion of scans (Bahnemann et al., 2015). Similar results have been found in another study conducted in a supermarket, where high performing HH participants directed their gaze towards their BHF more compared to low performing HH participants (Kasneci et al., 2014b). Taken together, these findings suggest that successful task performance is associated with adequate and effective scanning behavior.

To ensure that the scans made by people with HH towards their BHF are adequate, individuals with HH can be trained to use a wide, systematic horizontal scanning pattern (De Haan et al., 2016). This compensatory training is based on the rationale that increasing the number and size of scans towards the BHF can improve the detection of information in the affected visual field of an individual with HH. This can help in reducing the impact of the VFD (De Haan et al., 2015).

A randomized clinical trial has shown that participants who underwent this compensatory scanning training (CST) showed an improvement in the detection of stimuli in their peripheral visual field when compared with the waiting list control group (De Haan et al., 2015). These findings are congruent with an exhaustive body of literature, alluding to the functional benefits of CST for people with hemianopia (Bouwmeester et al., 2007; Mannan et al, 2010).

Although CST can help people with HH in adequately scanning their environment, dual tasking can have a negative impact on mobility and target detection in people with HH. Navigating in a naturalistic environment is a complex task that requires multiple cognitive resources (Warren et al., 2001) and allocating attention to salient targets (Broman et al., 2004). People with acquired brain injury show significant gait decrements when engaged in dual tasks compared to single task (Haggard et al., 2000). A gait decrement suggests that the participants might experience reductions in their walking speed. In a more recent study, participants with HH had to detect a target (i.e., basketballs) in a virtual reality (VR) environment while sitting and walking. Results showed that participants detected less targets (basketballs) while walking compared to sitting (Iorizzo et al., 2011). Interestingly, they were more focused on the walking path than detecting basketballs. Similar results were found in a previously mentioned study where participants with HH took more time to finish the task (Kasneci et al., 2014b). This suggests that participants were walking slower while performing dual tasks. Taken together, these findings indicate that dual tasking can negatively affect walking speed and target detection performance in people with HH.

The present study aims to investigate the influence of dual tasks on scanning behavior and mobility in people with HH and unimpaired vision. More specifically, the current study assesses the influence of dual tasking on dispersion of scans, length of saccades towards their BHF, saccadic exploration, walking speed, and targets missed. If the findings of the study show that dual tasking negatively influences mobility and scanning behavior for people with HH, then clinical interventions can focus on supplementing CST with dual tasking. This may improve dual task performance during mobility tasks in day-to-day activities, consequently improving the QoL of people with HH.

Method

Participants

Thirty-four participants (29 males and 6 females) participated in this study. Out of these, one participant was excluded from the experiment due to technical reasons, making the final sample size thirty-five. Of these, 17 participants were in the homonymous hemianopia (HH) group, and 17 participants were in the control group (UN). Demographical information of the participants is presented in Table 1. A convenience sampling method was used to recruit participants. The clinical sample, comprising people with hemianopia, was recruited from the pool of people undergoing or who have already undergone rehabilitation for homonymous hemianopia at Royal Dutch Visio. Furthermore, age and gender-matched controls were recruited via advertisements on social media. All participants took part in two other studies on scanning behavior in street crossing and cycling.

Participants gave their informed consent before the commencement of the experiment. Inclusion criteria for people with HH included a visual acuity above 0.5. Next, their homonymous visual field impairment should have a neurological cause, at least at the quadrantanopia level, without any other visual field impairment on the ipsilesional side, and the time since onset should be at least 3 months. To be eligible for the study/experiment, all participants had to be at least 18 years of age, show no signs of visual neglect, not have any other visual or neurological disorders, not have a diagnosis of a severe psychiatric condition, should have a >24 MMSE score and not have any impairments relating to eye movements, head movements, cognitive abilities, orientation, communication in Dutch or balance. The experiment was approved by the Ethics Committee of the University Medical Center Groningen.

Table 1

Demographic Characteristics

	HH	UN
Total (N)	17	18
Age Mean (SD)	61.88 (18.23)	61.72 (16.57)
Gender (%)		
Male	82.35	83.33
Female	17.64	16.66
Type of Hemianopia (%)		
Left Quandrantopia	29.41	
Left Hemianopia	23.53	
Right Quandrantopia	11.76	
Right Hemianopia	35.29	
Cause of Hemianopia (%)		
Stroke	76.47	
TBI	17.65	
Tumor	5.88	
Rehabilitation Status (%)		
Walking Training	17.65	
Cycling Training	5.88	

	HH	UN
Finished	41.18	
Not Started	11.76	
Not Necessary	23.53	
Macular Sparing (%)		
Yes	35.29	
No	64.71	

Note. HH: People with homonymous hemianopia; UN: People with unimpaired vision; TBI: Traumatic brain injury

Apparatus

Eye movements were recorded using a head-mounted eye-tracker, Pupil Invisible (Pupil Labs, Berlin, Germany, sampling rate of approx. 200 Hz, scene camera with 82x82° visual field, including gyroscope and accelerometer, accuracy of 4 degrees). The device could estimate gaze data without any calibration using a deep learning neuronal network (for more information, see Tonsen et al., 2020). A phone was connected to Pupil Invisible and put in a phone holder around the neck of the participants. Other materials used in the experiment include cones, cardboard sheets taped together on the wall to form obstacles, and bright red paper cut into small squares to act as targets. These were used to set-up the tasks. Figure 1 depicts the set-up for the experiment. The experiment consisted of four tasks, which were repeated twice.

Additionally, the Digit Span Test (Petermann & Wechsler, 2012) was used to assess and baseline participants' working memory. For the purpose of this study, the digit span backwards was used, where the individual is asked to repeat an increasing span of digits in a reverse order.

One of the main advantages of the digit span backwards is that it has strong test-retest reliability (Waters & Caplan, 2003).

Figure 1: The set-up of the hallway for the experiment.

Protocol

The experiment was conducted in the hallway at Royal Dutch Visio. The digit span backwards test was administered to baseline the working memory for cognitive dual task (CDT). The test would be stopped if the participant would not be able to repeat a span of digits in a reverse order two subsequent times. After establishing a baseline working memory, the participants had to wear the eye-tracker, which was automatically calibrated. The participants were instructed to walk across the hallway twice to record their baseline walking time. After the walking time was baselined, the experimenters set up the hallway according to the tasks. Information about the tasks is described in Table 2.

After the set-up was done, the participants were given instructions pertaining to the task (see Table 2). Prior to the next task, the participants were asked to turn around, facing their backs to the hallway, so that the next task could be set up. This was done so that the participants would not be aware of the placement of the targets. The time taken by the participants to perform each task was tracked to calculate walking speed. The order of the task was single task (ST), simple attentional task (SAT), attentional dual task (ADT), and cognitive dual task (CDT). All tasks were performed twice. During the repetition, the reverse order was followed. The whole procedure took 40 minutes.

Data Analysis

Data analysis was performed using MATLAB (version 2022b). Data gathered from the eye-tracker on eye-orientation was provided in pixels in the distorted scene camera reference frame, which makes it difficult to interpret this data. Therefore, the eye-movement data was undistorted, and the eye-orientation data was converted to angles in degrees, where x-axis and y-axis represent horizontal eye-orientation and vertical eye-orientation respectively. The data was then processed to generate information on scanning characteristics. After the signal processing was done, variables relevant for the hypothesis were created.

For this study, we are looking at scanning characteristics and walking speed across different tasks. Walking speed was calculated as the percentage of baseline walking speed, where a percentage value above 100% indicated slower walking pace compared to baseline and a percentage value lower than 100% indicated a faster walking pace during tasks. The variable targets missed was generated by taking into account the failure of the participants to accurately point at the targets while performing the experiment.

The saccades were detected using a velocity algorithm with a variable velocity threshold by Hooge and Camps (2013). Saccades with an amplitude of >1° were included in the data set. Using this data and the eye-orientation data, we computed the scanning behavior variables. One such variable is the saccadic amplitude towards the BHF. This refers to the length of eye movements made by the participants. Another scanning characteristic was saccadic exploration. This refers to the number of rapid eye movements made by the participant when performing the tasks and is represented by the variable number of saccades per min. Furthermore, dispersion of scans (i.e., the area of the environment scanned by people) was investigated by the variance in horizontal eye-orientation.

Table 2

Task Description and Instructions

	Task	Task Setup	Instructions
ST	Targets	Targets are placed on either side of the hallway.	Walk across the hallway and point at the targets.
SAT	Targets and Cones	Targets are rearranged and placed on either side of the hallway. Two cones are put under each for the participants to walk in between them.	Walk across the hallway and point at the targets while walking in between the cones.
ADT	Targets, Cones, and Person	Targets are rearranged and placed on either side of the hallways. The cones remain the same from the previous task.	Walk across the hallway and point at the targets. Walk in between the cones whenever you see them. A

Task		Task Setup	Instructions
		A confederate will walk in the opposite direction of the participant during the task.	confederate will walk in the opposite direction as you. Avoid bumping into them.
CDT*	Targets and Numbers	The cones are removed. Targets are rearranged and placed on either side of the hallway. The researcher will read numbers aloud for the participants. At the end of the task, the participants have to repeat the numbers read out to them in a reverse order.	Walk across the hallway and point at the targets. Numbers will be read out aloud while you are doing the task. You have to remember these numbers as you will be asked to repeat them in a reverse order upon reaching the end of the hallway.

Note. ST: Single task; SAT: Simple attention task; ADT: Attentional dual task; CDT: Cognitive dual task

*WAIS digit span backwards is used for this task

Statistical Analysis

Statistical analyses will be performed in SPSS. To test the influence of dual tasks on mobility and scanning characteristics and compare it between groups, a repeated measures ANOVA (RM-ANOVA) analysis will be utilized with the three tasks as within group factor, the two groups as between group factor and an interaction effect. To test the influence of dual tasking on scanning behavior and walking speed, performance on the single task, attentional dual task, and cognitive dual task will be compared with the within group effect. Next, the difference in the influence of dual tasking on mobility and scanning behavior between the HH and UN will be assessed using the interaction effect.

After the initial statistical analyses, a post-hoc analysis using significant results will be performed to further delineate the specific influence of ADT and cognitive CDT on scanning characteristics and walking speed, and whether this influence differed between the HH and UN groups. To assess which dual task had a higher effect on the scanning variables and walking speed, paired t-test analyses will be performed comparing ADT and CDT with ST. A significant result on ADT and CDT compared to ST respectively would establish that dual tasking does have an impact on task performance or scanning behavior. A significant result on ADT compared to CDT would suggest that there is a difference in the influence exerted by ADT compared to CDT.

Furthermore, to determine which dual task had a significant impact on scanning behavior, mobility, and target detection between the groups, the differences between the means of ST and ADT, ST and CDT, ADT and CDT will be calculated and evaluated for the HH and UN groups. Then an independent t-test will be conducted, comparing the difference in the influence of dual tasking between the HH and UN groups. Effect sizes were calculated using Cohen's d. The range of effect sizes can be interpreted in the following way: small ($d = 0.2$), medium or moderate ($d = 0.5$), large ($d = 0.8$) (Cohen, 2013). Alpha was set on p-value $<.05$. For a result to be considered significant, the p-value calculated must be $<.05$.

Results

Table 3

Mean (SD) and results from the within-group and between-group comparisons.

		Mean (SD)				
		Saccades (n/min)	Dispersion of Scans (degrees)	Length of Saccades in BHF (degrees)	Walking Speed (percentage)	Total Targets Missed (N)
HH	ST	173.03 (32.49)	239.41 (78.32)	16.00 (3.32)	138.24 (22.99)	0.32 (0.76)
	ADT	176.69 (29.74)	215.77 (79.08)	15.53 (3.59)	158.10 (30.07)	0.38 (0.60)
	CDT	156.21 (28.61)	194.04 (72.58)	13.88 (2.59)	157.09 (31.55)	0.41 (0.65)
UN	ST	156.25 (38.98)	230.03 (66.99)	15.48 (4.28)	119.81 (13.43)	0.15 (0.43)
	ADT	157.29 (37.65)	185.71 (47.27)	14.92 (3.39)	132.55 (17.43)	0.32 (0.58)
	CDT	157.85 (27.03)	170.08 (46.93)	13.19 (4.03)	154.95 (42.84)	0.12 (0.32)
Groups	Total HH	168.49 (31.06)	218.02 (78.23)	15.15 (3.26)	151.15 (29.63)	0.37 (0.67)
	Total UN	156.84 (34.34)	197.91 (62.05)	14.63 (4.03)	135.77 (31.16)	0.19 (0.46)
Tasks	Total ST	164.64 (36.59)	234.72 (72.46)	15.74 (3.81)	129.03 (20.87)	0.24 (0.62)

		Mean (SD)				
		Saccades (n/min)	Dispersion of Scans (degrees)	Length of Saccades in BHF (degrees)	Walking Speed (percentage)	Total Targets Missed (N)
	Total ADT	166.99 (35.06)	200.74 (66.39)	15.23 (3.47)	145.33 (27.58)	0.35 (0.59)
	Total CDT	157.03 (27.63)	182.06 (61.83)	13.53 (3.38)	156.02 (37.35)	0.26 (0.53)
Main effect - Task	F (df)	**4.512 (2,128)**	**44.141 (2,128)**	**18.246 (2,128)**	**30.480 (2,132)**	1.310 (2,132)
	P-value	**.013***	**<.001***	**<.001***	**<.001***	.273
	Effect Size	0.066	0.408	0.222	0.316	0.019
Interaction effect - Task*Group	F (df)	**5.478 (2,128)**	1.750 (2,128)	.028 (2,128)	**5.938 (2,132)**	1.209 (2,132)
	P-value	**.005***	.178	.972	**.003***	.302
	Effect Size	0.079	0.027	0.000	0.083	0.018

Note: HH: People with homonymous hemianopia; UN: People with unimpaired vision; ST: Single task; ADT: Attentional dual task; CDT: Cognitive dual task

p<.05

The Effect of Dual Tasking

Dual tasking had a significant impact on all scanning characteristics and walking speed, which is indicated by the significant task-effect for the variable's dispersion of scans, length of saccades in BHF, number of saccades per minute, and walking speed (Table 3, Figure 2-5). However, no significant task effect was reported for the number of targets missed, indicating that dual tasking did not have an influence on the targets missed by the participants across different tasks (see Table 3, Figure 6).

Post-hoc analyses showed that compared to ST, CDT had a significant negative effect on walking speed, dispersion of scans, saccadic amplitude, and the number of saccades made by the participants, as indicated by the p-value in Table 4. This indicates that compared to ST, CDT decreases walking speed, saccadic lengths, saccadic exploration, and the area scanned by the participants.

Next, ADT was compared with ST. We found a significant negative effect of ADT on walking speed, dispersion of scans, and the number of saccades made by the participants (Table 4). This indicates that compared to ST, ADT decreases saccadic exploration, area scanned by the participants, and walking speed. However, no significant effect of ADT was reported for saccadic amplitude (Table 4), indicating that compared to ST, ADT does not have any influence on saccadic length.

Moreover, CDT had a significant negative effect on dispersion of scans, walking speed, saccadic amplitude, and saccadic exploration compared to ADT, as indicated by the p-value in Table 4. This indicates that CDT reduced saccadic length, area scanned by the participants, saccadic exploration, and walking speed more than attentional dual tasking.

Table 4

Post-hoc results: main task effect

	Paired t test			
	T-value	df	P-value (two-tailed)	Effect Size
Walking Speed (%)	**-6.93**	67	**<.001***	-.84
ST-ADT	**-6.59**	67	**<.001***	-.80
ST-CDT	**-2.611**	67	**.011***	-.31
ADT-CDT				
Saccades (N/min)				
ST-ADT	-.78	66	.436	-.09
ST-CDT	**2.039**	66	**.04***	.249
ADT-CDT	**2.74**	65	**.008***	.33
Length of saccades in BHF (degrees)				
ST-ADT	1.49	66	.139	.18
ST-CDT	**5.26**	66	**<.001***	.64
ADT-CDT	**4.69**	65	**<.001***	.57
Dispersion of Scans (degrees)				
ST-ADT	**6.20**	66	**<.001***	.75
ST-CDT	**8.63**	66	**<.001***	1.05
ADT-CDT	**3.41**	65	**.001***	.42

Note. *$p<.05$

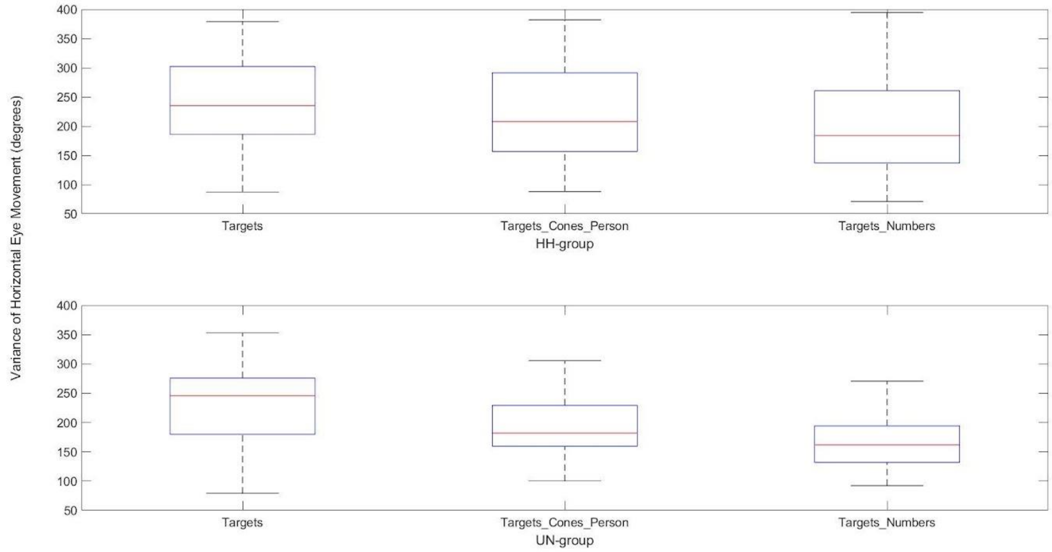

Figure 2: Y-axis represents the scanning characteristic dispersion of scans for both the plots. X-axis represents the different tasks. Box plot on the top depicts dispersion of scans in the HH group across different tasks and the bottom one represents the dispersion of scans in the UN group across different tasks.

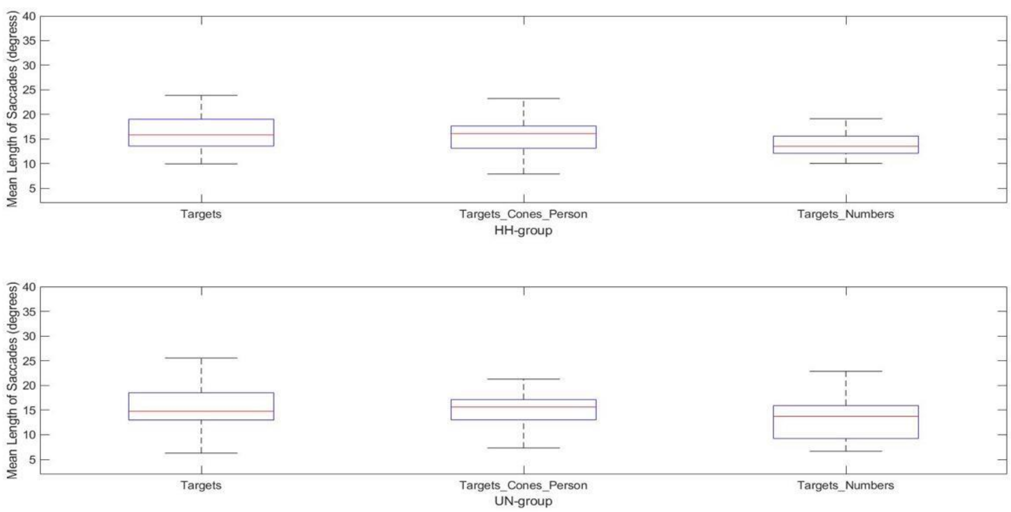

Figure 3: Y-axis shows the independent variable length of saccades in BHF in both box plots and x-axis illustrates the different tasks for both boxplots. The top box plot represents the mean length of saccades towards BHF across different tasks in the HH group whereas the bottom box plot depicts the mean length of saccades towards BHF across different tasks in the UN group.

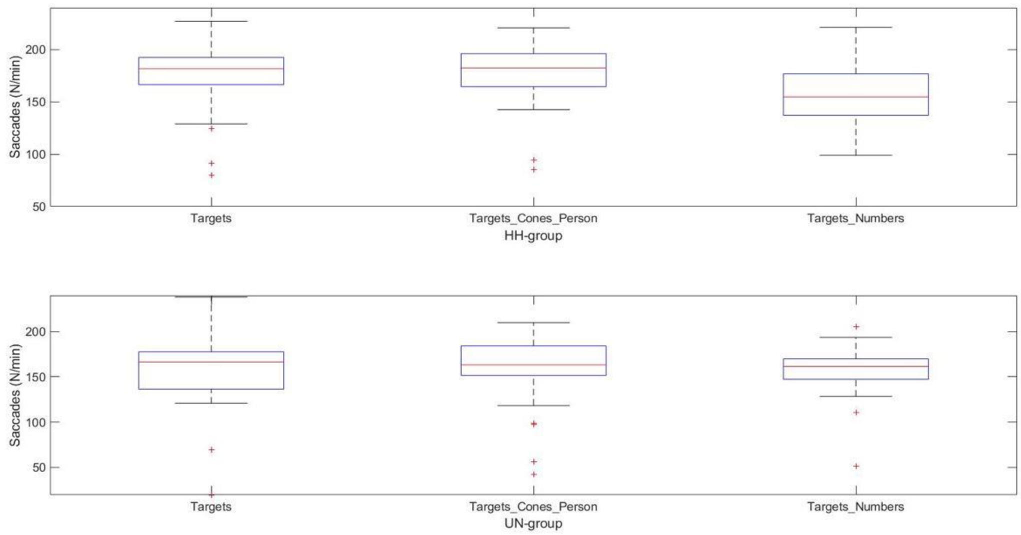

Figure 4: Y-axis represents the dependent variable saccadic exploration per minute in both boxplots. X-axis represents the different tasks. Saccadic exploration per minute in the HH group across different tasks is illustrated by the top box plot and the bottom box plot depicts the saccadic exploration in the UN group across different tasks.

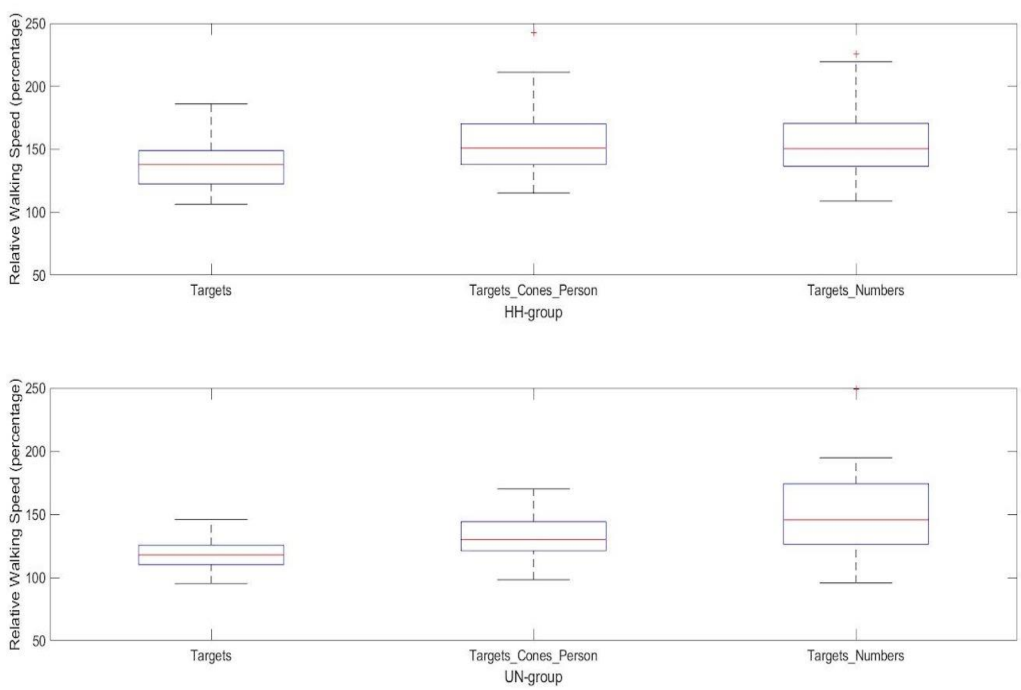

Figure 5: Y-axis displays the independent variable relative walking speed in percentage and x-axis illustrates the different tasks. The top box plot represents the relative walking speed percentage of the HH group across different tasks whereas the bottom box plot depicts the relative walking speed percentage of the UN group across different tasks.

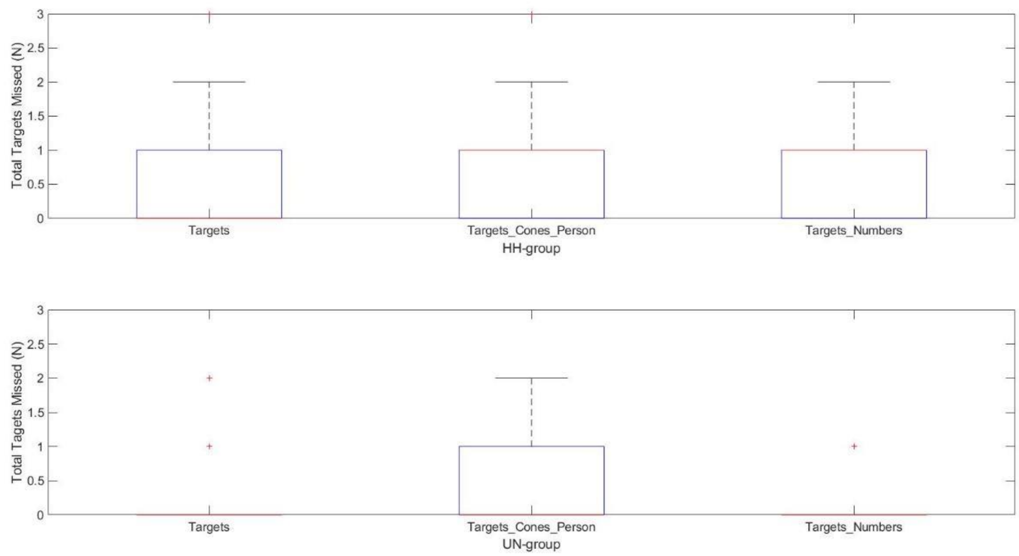

Figure 6: Y-axis illustrates the independent variable total targets missed whereas the x-axis shows the different task paradigms. The top box plot shows the total number of targets missed by people in HH group across different tasks whereas the bottom box plot represents the total number of targets missed by the people in the UN group across different tasks.

Group Differences in the Impact of Dual Tasking

Results indicate that the influence of dual tasking did not differ significantly between HH and UN groups when it comes to dispersion of scans (Figure 2), the length of saccades made in BHF (Figure 3), and the total number of targets missed (Figure 6). This can be seen from the non-significant interaction effect reported in Table 3. A significant difference in the impact of dual tasking between the HH and UN groups was reported for saccadic exploration (Figure 4) and walking speed (Figure 5), as indicated by the significant interaction effect (See Table 3).

Post-hoc analyses showed no significant differential effect of CDT compared to ST on saccadic exploration between both groups (Table 5). However, there was a trend showing that saccadic exploration was reduced more in people with HH compared to the UN group when CDT is compared with ST, as indicated by the p-value in Table 5. On the other hand, we found a significant negative effect of CDT on walking speed when compared to single tasking between the HH group and the UN group (Table 5). The walking speed was more reduced for the HH group compared to the UN group.

Furthermore, ADT was compared with ST. We found no significant difference in the influence of ADT compared to ST on the number of saccades and walking speed between the HH group and UN group (Table 5). This indicates that there was no difference in the influence of ADT between the HH group and the UN group on saccadic exploration and walking speed.

Next, when CDT was compared with ADT, a significant difference in the effect of cognitive dual tasking between the HH and UN groups was found on walking speed, as indicated by the p-value (Table 5). We found that walking speed in the HH group stayed similarly relative to ADT. On the other hand, the walking speed of the UN group decreased when CDT was compared with ADT. Lastly, there was no significant difference in the differential effect of CDT on saccadic exploration between the HH and UN groups when compared with ADT.

Table 5

Post-hoc results: interaction effect

Header 1	HH Mean (SD)	UN Mean (SD)	T-value	df	P-value (two-sided)	Effect Size
Saccades (N/min)						
ST-ADT	1.47 (38.08)	-1.34 (28.03)	.34	66	.729	.08

Header 1	HH Mean (SD)	UN Mean (SD)	T-value	df	P-value (two-sided)	Effect Size
ST-CDT	16.91 (26.67)	2.46 (40.43)	**1.74**	66	**.08**	**.42**
ADT-CDT	15.44 (38.24)	3.80 (39.25)	1.23	66	.22	.30
Walking Speed (%)						
ST-ADT	-19.85 (22.94)	-12.73 (14.48)	-1.53	66	.13	-.37
ST-CDT	-18.84 (22.40)	-35.13 (40.92)	**2.03**	66	**.046***	.49
ADT-CDT	1.00 (17.67)	-22.39 (41.48)	**3.02**	66	**.004***	.73

Note. HH: People with homonymous hemianopia; UN: People with unimpaired vision

*p<.05

Discussion

The present study aimed to assess the influence of dual tasking on mobility and scanning behavior in people with hemianopia and normal vision. The findings of this study show that both cognitive dual tasking and attentional dual tasking reduced scanning behavior for both the groups. The impact of cognitive dual tasking on scanning behavior was more profound in people with hemianopia. Compared to ADT, we found that CDT reduced saccadic exploration, saccadic amplitude, dispersion of scans and walking speed. We found that CDT reduced saccadic exploration more in people with hemianopia compared to people with normal vision. With regards to walking speed, people with normal vision exhibited a decrease in their walking speed when comparing CDT with ADT. At the same time, people with hemianopia did not show much difference in their walking speed when CDT is compared with ADT. No influence of dual tasking on target detection was found.

Effect of Dual Tasking in General

Our results show that both CDT and ADT reduced saccadic exploration. However, CDT had a more profound negative effect on saccadic exploration compared to ADT, suggesting that CDT reduces saccadic exploration more than ADT. Our results are congruent with existing literature suggesting that more complex tasks lead to increased fixation (Hardiess et al., 2010), which can reduce saccadic exploration. It is plausible that the reduction in saccadic exploration can be attributed to the task complexity. as CDT requires more cognitive resources than ADT, which can explain the reduction in the number of saccades made by the participants.

Next, we found that dual tasking, especially CDT, reduced saccadic amplitude in BHF. These results are consistent with previous studies reporting a decrease in saccade amplitude in the affected area (Kerkhoff, 1999; Tant et al., 2002). It is unclear as to why this could be the case. However, one plausible explanation could be the head movements made by the participants. It is possible that participants made larger head movements, which eliminated the need to make larger saccades towards their BHF. Nonetheless, further exploration is needed to understand the effects of dual tasking, especially CDT, on saccadic amplitude.

Furthermore, our results show that dual tasking reduced the area scanned by the participants. This effect was more pronounced for CDT, which is partially congruent with existing literature on low performing people with hemianopia (Bahenmann et al., 2015; Papageorgiou et al., 2012). This negative effect of dual tasking can be attributed to the task demands. Dual tasking requires the participants to allocate their cognitive resources to multiple stimuli. During ADT, it is plausible that participants were focused more on the task demands such as not bumping into the confederate and walking in between the cones. This could have led to narrowed attention, which can decrease the area explored by the participants. With regards to

CDT, the participants might have devoted most of their cognitive resources to the task demand, i.e., WAIS digit span backwards test. This could have exerted a negative effect on dispersion of scans.

Moreover, our results show that dual tasking decreases walking speed. This effect was more pronounced for CDT. These findings are in accordance with previous research showing decrements in gait speed under dual task paradigms (Hennah et al., 2021). This decrease in walking speed can be attributed to cognitive load. As both ADT and CDT require the participants to do multiple tasks simultaneously, it is credible that the cognitive load of the task increases as the individual has to process multiple stimuli at once. This increase in cognitive load can have an impeding effect on walking speed.

Interestingly, we did not find any effect of dual tasking on target detection. This result is in disagreement with the previous findings where dual tasking led to a decrease in the number of targets (basketballs) identified for people with HH in a VR setting (Iorizzo et al., 2011). This discrepancy in findings might be due to the nature of the stimuli presented. It is plausible that the targets used in the present study were too salient due to the bright color, and hence, easily detectable for participants with HH.

Differential Effect of Dual Tasking Between the Groups

Our results indicate that there was a differential effect of dual tasking on saccadic exploration between both the groups HH and UN. However, when we compared with ST with CDT, we did not find any difference on the effect of dual tasking between both the groups, but we found a trend: people with hemianopia had a reduction in their saccadic exploration compared to UN group, suggesting that people with HH explored less under CDT paradigm than

ST. These findings are in line with the results mentioned for low performing people with HH in the Kasneci et al. (2014b) study, which found a reduction in saccadic exploration for people with HH. It is an interesting finding considering that most of our participants are undergoing or have already undergone compensatory scanning training. Further exploration is needed to understand this phenomenon.

Next, we found that neither ADT nor CDT exerted any differential effect on saccadic amplitude between the groups HH and UN. These findings contradict the existing literature suggesting that people with HH are biased towards their BHF when scanning the environment (Bowers et al., 2014; Elfeky et al., 2021; Jahnke et al., 1995). This discrepancy can be explained by the head movements of the participants. It is plausible that people with HH might have made longer head movements when scanning stimuli in their BHF, which might have led to shorter saccades. Similarly, no difference in the effect of dual tasking between the groups was found on the area scanned.

Furthermore, CDT has a more profound negative effect on walking speed in people with unimpaired vision compared to people with hemianopia. These results contradict the previous studies reporting decrements in walking speed for people with HH compared to controls under dual task conditions (Kasneci et al., 2014b; De Haan et al., 2016). One way of explaining these findings is that participants in the HH group prioritized their walking speed in the CDT paradigm whereas UN group participants prioritized their performance on the CDT paradigm. Moreover, De Haan et al. (2016) found that people in the HH group exhibited a slight increase in walking speed after compensatory scanning training, which is congruent with our findings pertaining to the HH group. Given that most of the participants in the HH group have undergone compensatory scanning training, it is plausible that the increased percentage walking speed can be attributed to their rehabilitation efforts. It is important to note that no significant influence of ADT on walking speed was found, suggesting that only CDT has a noticeable impact on participants' walking speed.

Interestingly, we found that neither CDT nor ADT had a differential influence on object detection between the HH group and UN group. This result contradicts previous findings suggesting difficulties with object detection for people with HH (Iorizzo et al., 2011). This discrepancy might be attributed to the nature of the task. It is plausible that a simple target identification task used in this study might be undemanding compared to basketballs used in the other study.

Clinical Implications

The findings of this study highlight the negative influence of dual tasking on scanning behavior, which can have some important clinical implications. As our results indicate a profound decrease in scanning behavior under CDT paradigm, future rehabilitation could supplement compensatory scanning training with dual task training to ensure that dual tasking does not interfere with compensatory scanning training. This can also lead to an improved QoL. Furthermore, the dual task paradigm could be used to test the efficacy of compensatory scanning training in people with HH who are undergoing rehabilitation. Next, people with HH can be taught to scan a wider area and make wider scans to enhance their scanning, even in dual-task situations. This will also help in attenuating the impact of dual tasking on exploration. Furthermore, a threshold can be established to classify individuals with HH undergoing rehabilitation as either high performing or low performing. This classification might help in identifying inadequate scanning characteristics and tailor rehabilitation programs in a manner that will help strengthen these scanning characteristics. Eye-movement tracking instruments such as the one used in this study can also be an effective rehabilitation tool. It will help in analyzing the eye-movements of people with HH in different settings and in informing rehabilitation therapists on what changes could be made to further enhance their scanning.

Limitations

Although our results provide interesting insights on the effect of dual tasking on scanning behavior and mobility for people with HH, it is important to acknowledge certain limitations of our study. In comparison with the real world, the task was simplistic (identify targets accurately) and possibly, the targets were too salient (bright red). Next, this study did not take head movements into account. It is plausible that head movements might have influenced the scanning behavior observed in the participants (Kasneci et al., 2014a). Lastly, performance on digit span backwards during CDT was not taken into account. It is likely that participants in the HH group might have prioritized walking speed over successful performance on digit span task and the opposite might have been the case in the UN group. On the positive side, our sample size was bigger compared to previously mentioned studies, thus increasing the reliability of our test results.

Conclusion

To conclude, this study emphasized the influence of dual tasking on walking speed and scanning behavior. Findings from this study can help in developing interventions focusing on dual tasking in people with hemianopia, especially the younger population. Building on these findings, dual task training can be used as an add-on to CST to ensure that dual tasking does not interfere with adequate scanning behavior. It will also assist in improving dual task performance, consequently leading to an improved QoL. Future research should take head movements and performance on digit span backwards test while assessing scanning behavior in people with HH.

More subtle targets can also be used to make the task more representative of real-world stimuli. Our results suggest that dual tasking, especially cognitive dual tasking, overrides the compensatory scanning training given to people with HH. Future rehabilitation should look at ways to attenuate these effects. At the same time, future research can look into the effects of dual tasking on task detection and saccadic amplitude as there is a big gap in the body of literature for these domains. This will help us in gaining new insights into the effects of dual tasking and can assist in developing new dual-tasking rehabilitation strategies. Furthermore, tests of executive functioning can be used in dual task paradigms in future studies with people with HH. This will help us in obtaining more knowledge on dual tasking with more complex tasks.

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