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ORIGINAL ARTICLE

Can older adults' balance and mobility improve with visual attention training?

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Abstract

Purpose We hypothesize that training older adults with a structured visual attention task will result in improved balance and mobility, potentially reducing their risk for falls.

Methods Healthy older adults aged 70 + took part in the study (mean age 80.3 ± 6 years). In this randomised control trial (NCT02030743), 15 participants were randomly assigned to a visual attention training group and 15 to a control group. Visual attention training was undertaken twice a week (45 min sessions) for 3 weeks (= six sessions) using versions of a selective attention useful field of view test and attended field of view test. The outcome measures were postural sway using a force plate, the Mini-Balance Evaluation Systems Test, the One-Legged Stance test, the 5 Meter Walking test, the Sit to Stand test, the Timed Up and Go test without and with a concurrent cognitive task.

Results There was a greater improvement in visual attention after training in the intervention group compared to the control group ($p < 0.01$). However, a mixed ANOVA (2× groups, 2× visit) showed no main effect of visit or group or any interaction for any of the force plate parameters. *T* tests of the changes over time between the intervention group and the control groups for the other balance and mobility assessment tools showed no improvement after the visual attention training.

Conclusion It was found that there was no improvement in either mobility or balance after the visual attention training and no difference between the intervention and the control groups.

Keywords Ageing · Balance · Falls · Mobility · Visual attention

Abbreviation

OLST	One-Legged Stance test
5MWT	5 Meter Walking test
STST	Sit to Stand test
TUG	Timed Up and Go test
TUGco	Timed Up and Go test with a cognitive task
UFV	Useful field of view
AFOV	Attended field of view

Introduction

Falls are not random events and are quite common among seniors. It is projected that one in every three seniors experience a fall every year (Choy et al. 2003; Dolinis et al. 1997; Lord and Clark 1996), and some experience multiple falls annually (Lord and Ward 1994; Lord and Dayhew 2001). In institutional settings the falls rate increases to 60% of all residents experiencing a fall at least once a year (Lord et al. 2003). Falls are a major cause of injury or even death among older adults in Canada (Centers for Disease Control and Prevention 2015; Public Health Agency of Canada 2014). The injuries sustained after a fall can cause loss of independence, immobilization, impaired daily function, reduced health status, early institutionalization and even death (Alegre-Lopez et al. 2005; Cumming et al. 2000; Davidson et al. 2001;

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Dunn et al. 2002; Koski et al. 1998; Tinetti et al. 1988; Tinetti et al. 1994).

Given the epidemiological data and potential catastrophic results after a fall (Centers for Disease Control and Prevention 2015; Public Health Agency of Canada 2014) it is not surprising that falls are a major concern for seniors and the health care system; clearly, falls prevention is an important matter that needs to be addressed. Studies on fall prevention have typically included either an intervention that targets vision, exercise, environment modification, education intervention or a combination of these interventions grouped together. Many studies have found that exercise is effective for falls prevention (Barnett et al. 2003; Cadore et al. 2013; Fitzharris et al. 2010; Karlsson et al. 2013; see Sherrington et al. 2017 and Sherrington et al. 2019 for reviews), with programs that include multiple types of exercise probably being most effective (Sherrington et al. 2019). Others report that improving vision (e.g.: cataract surgery) is effective in reducing falls (Brannan et al. 2003; Harwood et al. 2005; Schwartz et al. 2005), although not all studies are in agreement (McGwin et al. 2006). Others found that the most effective falls prevention programs may be those with a multi-component approach (Kenny et al. 2011; Clemson et al. 2004; Day et al. 2002; Fitzharris et al. 2010) and a multi-component risk assessment followed by management of identified risk factors is the recommendation of the American and British Geriatrics Society. A 2012 Cochrane systematic review of falls prevention for community-dwelling older adults found that there was good evidence that multiple-component exercise intervention programs (in a group or at home) significantly reduce the risk and rate of falls, and multifactorial intervention programs reduced the rate of falls but not the risk of falling (Gillespie et al. 2012). Note that the studies do not directly compare these interventions. A more recent Cochrane systematic review found that multifactorial intervention programs (which usually include an exercise plus environment modifications or assistive technologies, medication review and psychological interventions) or multiple-component programs (exercise plus one other component in the intervention) may reduce the rate of falls (Hopewell et al. 2018).

It is interesting that many studies have reported a strong association with reduced visual acuity (Lord and Dayhew 2001), contrast sensitivity (Ivers et al. 1998; Klein et al. 1998), depth perception (Lord and Menz 2000; Nevitt et al. 1989) and field of view (Black et al. 2011) and falls incidents. Collectively these findings suggest the importance of having optimum vision for safer navigation and falls reduction; however, it is interesting that, to date, the impact of a purely visual attention training program aimed to improve balance and/or mobility has not been studied. Visual attention is defined as the cognitive ability to select relevant information and filter out irrelevant information in a cluttered visual environment (Binder et al. 2009). The current study was designed to fill the gap in the scientific literature. Specifically, we were interested in visual attention training as a modality to improve balance and/or mobility in older adults with the goal of reducing falls. Reduced visual processing speed (for example, as measured with visual attention tests) is a part of ageing and older adults require more time than younger adults to process visual information, particularly in the presence of visual clutter (Sekuler ans Ball 1986; Sekuler et al. 2000). Additionally, reduced visual attention is associated with balance and mobility (Leat and Lovie-Kitchin 2008; Owsley and McGwin 2004; Broman et al. 2004). Specifically, for community-dwelling adults, Owsley and McGwin (2004) found that visual attention as measured by the useful field of view was a good predictor of mobility performance (balance and gait). Broman et al. found that the useful field of view score was associated with mobility errors in community-dwelling adults while controlling for other aspects of vision, while for participants with visual impairment, Leat and Lovie-Kitchin (2008) found that the useful field of view was the best predictor of errors round a mobility course and walking speed than other aspects of vision. Stalvey et al. (1999) used the life space questionnaire, which evaluates the extent to which older persons move in their typical life space; a restrictive life space was associated with altered performance in the useful field of view. Additionally, we know that visual attention is trainable (Sekuler and Ball 1986; Willis et al. 2006). Therefore, we hypothesize that training older adults with a structured visual attention task will result in improved balance and mobility in community-dwelling older adults. The study design was a randomised control trial, participants being randomised to either a visual attention training group or a control group who did not change any of their behaviours, but continued to undertake their normal daily activities.

Methods

Participants

The study included participants who were healthy community-dwelling adults of 70 years or older, of either gender and with visual acuity of 6/12 or better in both eyes. Participants were excluded from participation if they were unable to speak English, diagnosed with cognitive impairment or cognitive delay or not able to walk independently without a walker or a cane. The first method of recruitment was from a previous study conducted in the same laboratory (Althomali and Leat 2017). Participants were chosen based on their falls rate (more than two falls in the previous 6 months), balance status (scored low on the balance and mobility tasks) and visual attention scores (33% or greater error rate in the

overall test). We chose those with poorer balance, reduced mobility and low visual attention, so that there was room for improvement. Another source of recruitment was through the Primary Care clinic at the School of Optometry and Vision Science at the University of Waterloo. This study was reviewed and received clearance through a University of Waterloo Research Ethics Committee. The study is registered with ClinicalTrials.gov, number NCT02030743.

There are no previous data of the effect of visual attention training with the UFV or AFOV on mobility and balance on which to base a sample size calculation. So sample size was based on studies, which showed a significant improvement of visual attention with training. The studies of Richards et al. (2006), Ball et al. (1988) and Sekuler and Ball (1986) showed a significant improvement of visual attention with the useful field of view training with 8, 9 and 8 participants, respectively. The most similar data to the visual attention training that we were planning were that of Richards et al. (2006). We estimated the mean pre- and post-difference and standard deviation from the data of older participants in the focused attention task. For a two sample *t* test with 80% power and a significance level of 5%, a sample size of 12 participants per group was calculated. We increased the sample size to 15 participants in each group to be sure not to be underpowered.

Baseline measures

All testing and training took place at the School of Optometry and Vision Science (see Fig. 1 for the protocol). At baseline demographic information, such as sex, age, general health and number of medications were collected. Binocular distance visual acuity was measured with the habitual spectacles using a Bailey–Lovie logMAR acuity chart and using by-letter scoring (Bailey and Lovie 1976) at a distance of 3 m.

Visual attention

Visual attention was measured with a useful field of view test (UFV) (Ball et al. 1988; Leat and Lovie-Kitchin 2008; Sekuler and Ball 1986) including two subtests (UFV1 and UFV2) and the attended field of view (AFOV) (Coeckelbergh et al. 2004).

In all the visual attention tests, the white targets and distracters (when included) were presented on a computer monitor with grey background and having 50% contrast (Weber's contrast) measured with a Minolta cs-100 photometer. The viewing distance was 50 cm and the UFV target, which was a triangle, had a total angular subtense of 1.37° × 1.2 ° (82 min of arc × 72 min of arc) and the width of the line

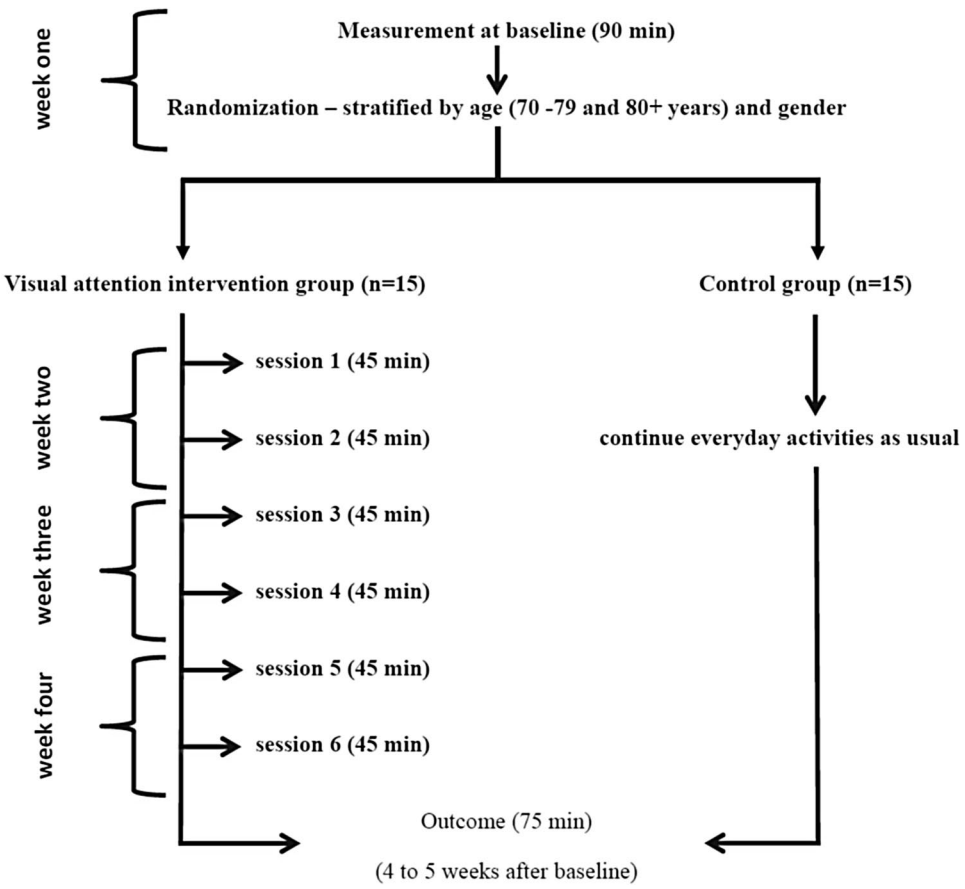

Fig. 1 Study protocol

was 0.23 ° (13.8 min of arc, equivalent to 6/83 m Snellen acuity). The circular distractors subtended 1.39° (83 min of arc) as did the Landolt C targets in the AFOV and the width of the line was 0.34° (20.6 min of arc, equivalent to 6/124 m Snellen acuity). The gap of the Landolt C target used in the AFOV was 0.23°. Testing was conducted under binocular viewing conditions and participants were provided with their best near spectacle prescription required for that working distance in a trial frame.

For the UFV1 (Fig. 2a) participants were asked to identify the location of a white triangle. The target was presented for 200 ms to preclude any eye movement during the target presentation, and was followed by a visual mask. There were 24 potential locations of the target, located on three possible eccentricities 4°, 8° and 12° and eight possible radii oriented at 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°. The order of presentation of the target location was randomised. For the UFV2, the same triangle target as UFV1 was used, but it was placed amongst 23 circles, which acted as distractors (Fig. 2b). Participants were asked to point to the location of the triangle on the screen and to guess if they were unsure. Their responses were recorded so that errors could be calculated in terms of exact location being correct (direction and eccentricity) or the direction only being correct (ignoring the eccentricity). An arcsine transformation was performed on all the UFV data as in previous studies (Sekuler et al. 2000; Ball et al. 1988; Leat and Lovie-Kitchin 2008).

The AFOV test was designed according to Coeckelbergh and colleagues' (2004) design (Fig. 2c). In this test participants were asked to locate a Landolt C amongst 23 circles. The gap of the Landolt C was randomly oriented up, right, left, and down. To shorten the test and not to fatigue the participants, targets were only presented in nine out of the 24 possible locations as described for the UFV (Fig. 2d). The participants were not informed that only nine locations were to be tested, and were not aware of this afterwards. During the test the duration of the stimulus was varied to determine a threshold in milliseconds with an interleaved "one up and one down" staircase method for the presentation time for each of the nine locations. Each location's staircase was independent of the others and the order of presentation of the nine locations was randomised. The presentation time started at a full second, hence allowing eye and head movements and the step size was 0.1 log unit. The number of trials at each location was 30, so that the total number of trials was 270. These values were chosen after pilot testing with a young adult population, which showed that a threshold was approached after this number of trials and starting from this duration. The final threshold was determined by plotting trial duration against time and taking the average of the reversals of the last section of the plot. The values included in this averaging were based on the following criteria a) at least eight reversals, b) the minimum slope for the regression line.

Balance and mobility

For the balance and mobility assessment the participants removed their shoes and wore their habitual spectacle glasses throughout.

Of the balance and mobility tests, the timed Sit to Stand test (STST) was performed first. An armless standard height chair (44.5 cm) with 1 cm of padding was used.

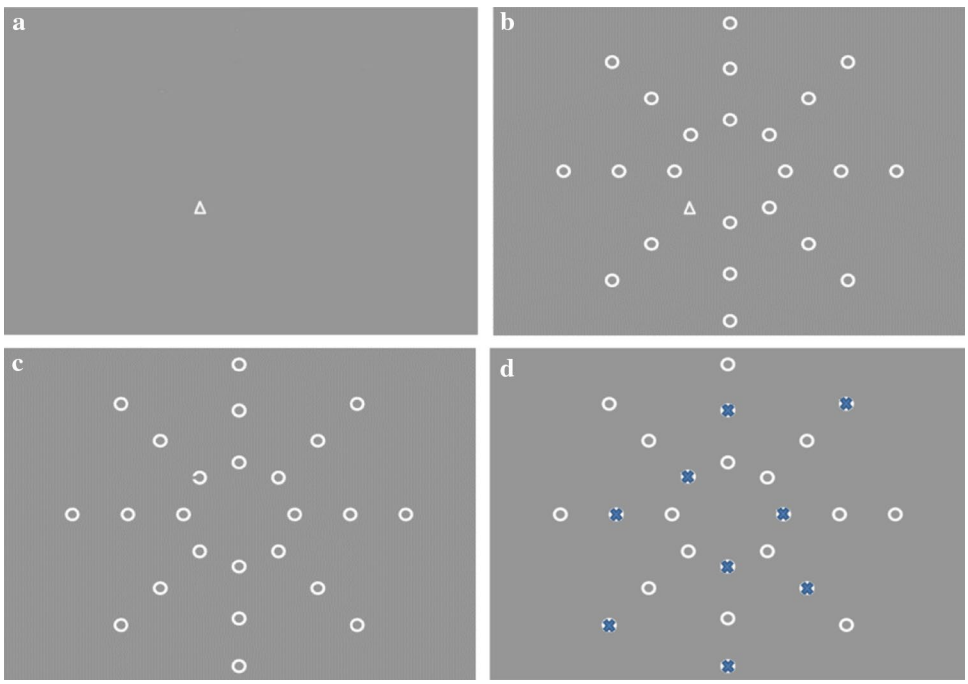

Fig. 2 The visual attention tests. **a** UFV1: target presented with no distractors. **b** UFV2: target presented with distractors. **c** AFOV: target presented with distractors. **d** AFOV: locations where the targets were presented are marked in crosses

The participants were asked to start the test in the seated position with their arms next to their body and their back against the chair's backrest. They were instructed to "Put your arms next to your body and to stand up and sit down 5 times as fast as you can, as long as you feel comfortable and safe". They were asked to keep looking straight ahead and not to use their arms to push up from the chair. They were timed with a stopwatch from when the examiner gave the "Go" signal and stopped at the fifth repetition when the participant first touched the chair seat. The final outcome was the time taken to complete the task.

The timed One-Legged Stance test (OLST) was performed next. Participants were asked to decide which leg they prefer to stand on and the test was performed on a smooth hard floor. Participants were instructed to stand on both feet in a relaxed stance and then to "Lift one leg, it doesn't matter which leg, up in front of you with your arms next to your body". Participants were asked to fixate a target in front of them and to maintain their balance for up to 30 s. The duration they were able to maintain their balance was then recorded for one timed trial per participant.

The Mini-Balance Evaluation System's Test (Franchignoni et al. 2010) is a composite test and was included as it is a clinical balance assessment tool that measures the integrity of four different balance control systems in the body. This tool was developed to improve and shorten the lengthy BESTest (Horak et al. 2009). It was chosen as it has a high inter-rater reliability and test–retest reliability and is an accurate tool for identifying fallers (Duncan et al. 2013; Godi et al. 2013; Leddy et al. 2011). It has also been shown to have less of a ceiling effect when compared to the older and well-known Berg Balance Scale (Godi et al. 2013) which, arguably, makes it a better choice for studies involving community-dwelling older adults. It consists of 14 short balance tests divided under four domains of balance control; (1) anticipatory body control, (2) reactive postural control, (3) sensory orientation and (4) balance during dynamic gait. The first part includes a scored version of the Sit to Stand test, Stand on One Leg test and Rise to Toes test. The third part included the following: stance with feet and arms together on a firm surface with eyes open and closed for 30 s and stance while standing on an inclined ramp with the participants' toes toward the top of the ramp with their eyes closed for 30 s. Finally, balance during dynamic gait was assessed by checking gait with changing speeds, with head and pivot turns, while stepping over obstacles and Timed up and Go test (with and without dual tasking). These tests are rated using a three-level scale, where "0" means severe impairment, "1" indicates moderate impairment and "2" is normal function. The final score for the Mini-BESTest was the sum of the subtest scores, which results in a maximum score of 28.

As a part of the MiniBEST assessment, a Timed Up and Go test (TUG) was conducted under two conditions; the TUG alone and the TUG with a cognitive task (TUGco). In the TUGco participant*s* counted backwards from 100 by threes until the TUG was completed. The final measure recorded for both TUG test versions was the duration they were able to complete the test.

In the 5 Meter Walking test (5MWT), participants were asked to walk an 8 m distance but only the middle 5 m distance was timed to measure the participant's performance. The first and last 1.5 m were to allow for acceleration and deceleration. The walking course was straight with no obstacles and was on a hard floor. The participant was instructed to "Walk as fast as you feel comfortable and safe for 5 m. I will tell you when to start and when to stop". The examiner followed the participant along the course and timed the start when the leading foot crossed the first tape, which marked the beginning of the 5 metres and stopped as soon as the leading foot crossed the end of the 5 m, although participants continued to walk to the end of the 8 metres. The time taken to complete this task was the outcome measure of interest.

These tests of balance and mobility were administered by a naive experimenter, who did not know to which group the participant was assigned.

Postural sway

Postural sway was the primary outcome measure and was measured using the portable AMTI AccuGAIT force plate (200 Hz) to record ground reaction forces and moments as participants stood in quiet stance, while barefoot, on the force plate. To ensure the consistency of the base of support throughout all the sessions and trials, each participant's preferred foot position was traced on paper that covered the surface of the plate; this foot tracing was reused at the outcome visit to ensure that the participant was standing in the same position at baseline and outcome visits. Postural sway was recorded for two test conditions; eyes open and eyes closed. In the eyes open measurement condition, participants were asked to stand on the force plate with eyes open and arms next to their body. Participants were instructed to look straight ahead at a fixation target placed 1 m away in front of them, while wearing their habitual glasses. When the test started they were asked to maintain their balance for 60 s, which was repeated for five trials. In the eyes closed condition, participants were asked to stand, to cross their arms across their chest and keep their head straight. During the stance participants were instructed to try to control their balance for 30 s, and this was repeated for three trials, if possible. The first five and last 5 s of the data were removed, and then a 6 Hz low pass (dual pass) Butterworth filter was used to remove any noise in the data. From the force and moment values center of pressure (CoP) was calculated

(Winter 1995). The outcome measures were the standard deviation of the medial lateral (ML) and anterior–posterior (AP) center of pressure, ML and AP CoP maximum sway, ML and AP CoP range in each direction (range = maximum excursion – minimum excursion) and the cumulative path length in centimetres. Any trial that was ≥ 3 standard deviations away from the mean standard deviation of the five trials in the eyes open condition and the three trials in the eyes closed condition was excluded from these postural analyses.

For all the balance and mobility tasks in this study, a safety spotter stood next to the participant to minimize the risk of falling and incurring an injury during test sessions. Participants were allowed to rest in between tests to reduce the effects of tiredness or fatigue.

Intervention

After the baseline assessment measures were completed, participants were randomly assigned to one of the two groups in the study. Randomisation was stratified by age (70–79 and 80 + years) and gender. Randomisation was undertaken in Excel and was conducted in blocks of four. This format was chosen to ensure balance between the numbers in the intervention and control group and also to ensure age and sex of participants were split evenly between the sub-stratification groups. The assignments were placed in numbered envelopes prior to the study by an investigator who was not involved in data collection and the envelopes were opened in strict sequence. One group received the visual attention training while the other was asked to continue their everyday activities as usual (see Fig. 1 for the protocol). The training sessions took place at the School of Optometry and Vision Science. The training sessions were conducted twice a week for 3 weeks to a total of six sessions. Each session involved 45 min of visual attention training similar, using UFV2 and AFOV stimuli which were similar, but not the same, as at baseline and ranged in difficulty. There were seven different UFV2 targets and three different AFOV targets. The difficulty level was determined with a pilot study and the training started with the easier and moved to the harder levels. The appendix shows the different targets and conditions used in the training sessions.

Outcome visit

The outcome visit was 4–5 weeks after the baseline assessment. Participants performed the same battery of tests as at baseline, except for VA testing.

Data analyses

The primary outcome measure was balance measured with the force plate and the other measures were secondary outcomes. Two sample *t* tests were performed between the intervention and control group demographic data to determine if the groups were equal at the start of the study. In this randomised control trial, the outcome measures were sway using the force plate (standard deviation of ML and AP CoP, ML and AP CoP maximum sway, ML and AP CoP range and cumulative path length), the Mini-Balance Evaluation System's Test (Mini-BESTest), One-Legged Stance test (OLST), the 5 Meter Walking test (5MWT) the Sit to Stand test (STST), the timed up and go test (TUG) and TUG with a cognitive task (TUGco). All the outcomes were pre-planned, except for the t TUG and TUGco (these two tests are subtests of the Mini-BESTest). Although originally unplanned, these post hoc analyses allowed us to examine the relationship between all of these functional tasks and visual attention training. Statistical analyses on each dependent variable were undertaken with mixed Analysis of variance (ANOVA) (2× groups, 2× visits). For the balance tests with the force plate the ANOVA was 2x groups, 2x visits, 5x trials. Significance was set at $p < 0.05$. Data analysis was undertaken with Systat software (Systat Software, Inc. San Jose, CA, USA). For situations where an ANOVA was repeated with the same data set (e.g. for the UFV calculated with different scoring and the force plate data), a Bonferroni correction was applied to correct for multiple comparisons. Informed consent was obtained from all individual participants included in the present study.

Results

Thirty older adults aged 70 + took part in the study (mean age 80.3 years ± 6) with females being 47% of the sample. No participants were excluded after randomization. In this randomised control trial study, 15 participants were assigned to each group. Table 1 shows a comparison between the two groups at baseline. There was no significant difference between any of the parameters.

First, we considered whether the training did actually improve visual attention itself. The results of the mixed ANOVA (2x groups, 2× visits) are shown in Table 2 and the data are plotted in Fig. 3. The UFV results are shown with both the analysis using errors for exact location and correct direction of the target. There was no main effect of group for any of the measures indicating that there was no overall difference between the groups. There was a main effect of visit for all the measures, indicating that both groups performed better on the outcome visit. This remained significant after application of the Bonferroni adjustment (p for significance was changed to $0.05/2 = 0.025$). There was a significant interaction between group and visit for the AFOV ($p < 0.001$) and a borderline interaction for UFV2 correct

Table 1 Baseline comparison between the control and intervention groups

	Control group ($n=15$)	Intervention group ($n=15$)	t test (p value)
Age (years) (mean ± SD, range)	81.7 ± 6.1, 71–95	78.7 ± 5.8, 71–91	0.15
Body weight (kg)	74.2 ± 12.9	76.7 ± 16.7	0.65
Height (cm)	169 ± 6	170 ± 10.6	0.71
# Of general health conditions	4.2 ± 1.6	3.4 ± 2.3	0.27
# Of eye conditions	1.4 ± 0.83	1.9 ± 1.1	0.19
# Of medications	3.5 ± 2.6	4 ± 4.9	0.72
Visual acuity (logMAR)	0.07 ± 0.1	0.09 ± 0.09	0.55

logMAR log of the minimum angle of resolution

Table 2 Mixed ANOVA for visual attention tests before and after training

Test	Data used	Effect	F-ratio	p value
UFV1	Exact location	Group	0.68	0.42
		Visit	14.24	0.001
		Group × visit	1.76	0.19
	Correct direction	Group	0.04	0.84
		Visit	7.66	0.010
		Group × visit	0.65	0.42
UFV2	Exact location	Group	3.64	0.06
		Visit	17.78	< 0.001
		Group × visit	1.59	0.22
	Correct direction	Group	2.20	0.15
		Visit	30	< 0.001
		Group × visit	3.48	0.07
AFOV	Log average time (seconds)	Group	4.55	0.04
		Visit	37.2	< 0.001
		Group × visit	22.6	< 0.001

UFV1 useful field of view subtest 1, *UFV2* useful field of view subtest 2, *AFOV* attended field of view

direction ($p=0.07$) demonstrating that the visual training itself was effective.

For postural sway with eyes open, mixed ANOVA (2× groups, 2× visits, 5× trials) revealed no interaction effects between group and visit for all force plate data including (ML) and (AP) center of pressure (CoP) standard deviation ($p=0.87$ and $p=0.64$, respectively), ML and AP CoP max ($p=0.94$ and $p=0.42$, respectively), ML and AP CoP range ($p=0.92$ and $p=0.41$, respectively) and cumulative path length ($p=0.82$). Figure 4a demonstrates the changes over time for the cumulative path length data with eyes open. A main effect of group for any of the parameters was also not observed; medial lateral (ML) and anterior–posterior (AP) center of pressure (CoP) standard deviation ($p=0.42$ and $p=0.71$, respectively), ML and AP CoP maximum sway ($p=0.52$ and $p=0.88$, respectively), ML and AP CoP range ($p=0.54$ and $p=0.73$, respectively) and the cumulative path length ($p=0.29$). Neither was there a main effect of visit for any of these parameters; ML and AP CoP standard deviation ($p=0.33$ and $p=0.98$, respectively), ML and AP CoP maximum sway ($p=0.08$ and $p=0.99$, respectively), ML and AP CoP range ($p=0.54$ and $p=0.90$, respectively) and the cumulative path length ($p=0.14$).

For sway with the eyes closed, mixed ANOVA (2× groups, 2× visits, 3× trials) showed no significant interactions between group and visit for all the force plate data; (ML) and (AP) center of pressure (CoP) standard deviation ($p=0.95$ and $p=0.85$, respectively), ML and AP CoP max ($p=0.58$ and $p=0.53$, respectively), ML and AP CoP range ($p=0.29$ and $p=0.11$, respectively) and cumulative path length ($p=0.37$). Figure 4b demonstrates the changes over time for the cumulative path length data with eyes closed. Specifically, no main effects of group for any of the postural parameters were observed; medial lateral (ML) and anterior–posterior (AP) center of pressure (CoP) standard deviation ($p=0.81$ and $p=0.33$, respectively), ML and AP CoP maximum sway ($p=0.98$ and $p=0.67$, respectively), ML and AP CoP range ($p=0.94$ and $p=0.55$, respectively) and the cumulative path length ($p=0.5$). There was no main effect of visit; ML and AP CoP standard deviation ($p=0.18$ and $p=0.49$, respectively), ML and AP CoP max ($p=0.13$ and $p=0.78$, respectively), ML and AP CoP range ($p=0.15$ and $p=0.78$, respectively) and the cumulative path length ($p=0.55$).

For the clinical assessment tools of balance and mobility, mixed ANOVA (2× groups, 2× visits) showed no significant interactions between group and visit for all the balance and mobility tasks ($p>0.05$) (Table 3). There was neither an main effect of group ($p>0.05$), nor were there any effects of visit ($p>0.05$). Figure 5 demonstrates the changes over time for the all the balance and mobility tasks.

Discussion

Impaired visual attention has been associated with increased crash rate while driving (Ball et al. 2006), balance and mobility difficulties (Leat and Lovie-Kitchin 2008; Owsley and McGwin 2004), and increased time for completing

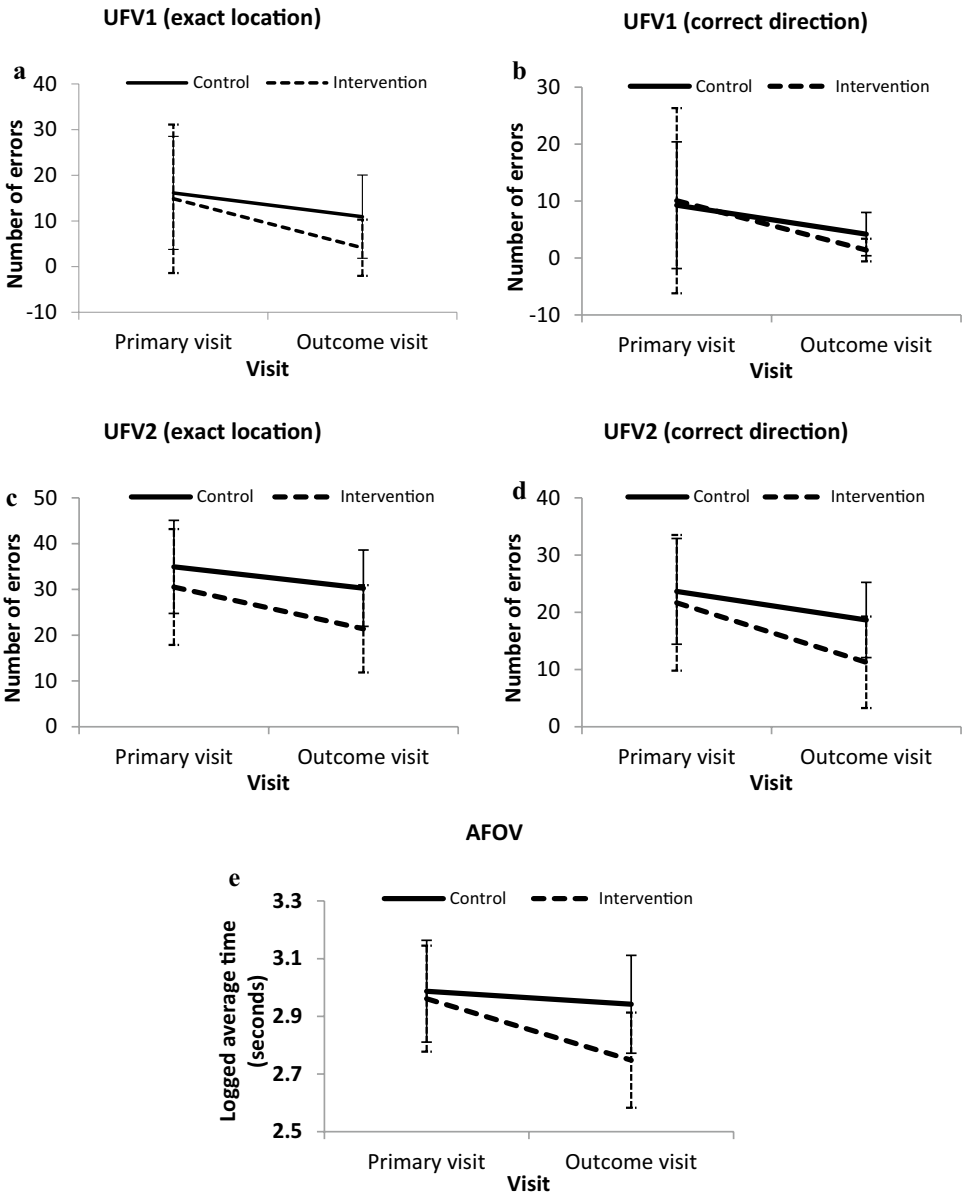

Fig. 3 The effect of visit for visual attention tests (mean ± SD). **a** UFV1 (exact location), **b** UFV1 (correct direction), **c** UFV2 (exact location), **d** UFV2 (correct direction), **e** AFOV

visual tasks (Owsley et al. 2001). Some studies have shown that visual attention training is amenable to training, which is maintained for up to 2 years (Sekuler and Ball 1986). In fact, one study suggested that the effect of training can last up to 5 years (Willis et al. 2006). In our previous study, we found that even after controlling for age, balance was significantly correlated with visual attention (Althomali and Leat 2017). Therefore, we expected that a visual intervention program, using a structured visual attention training, would improve balance and mobility and might reduce the incidence of falls in older adults.

We did demonstrate some improvement in visual attention with training in the AFOV ($p < 0.001$) and a borderline effect in UFV2 ($p = 0.07$). It is also noticeable that the intervention group was always better at the outcome visit than the control group. For UVF1, a floor effect in the visual attention training may have occurred as the number of errors was 8% before training for the exact location analysis and 7% for correct direction analysis; therefore, there was little room for improvement with training. This is illustrated in Fig. 3a, which shows that a number of participants were making zero errors at baseline.

Even though some improvement was noted in the visual attention training, there was no improvement in mobility or balance in this population. In the literature, the cut-off score in the TUG for healthy older adults to be classified as at risk for a fall is > 13.5 s (Shumway-Cook et al. 2000), while the cut-off score for the STST to show any balance dysfunction is > 14.2 (Whitney et al. 2005). In this study our sample average score for the TUG and the STST at baseline was

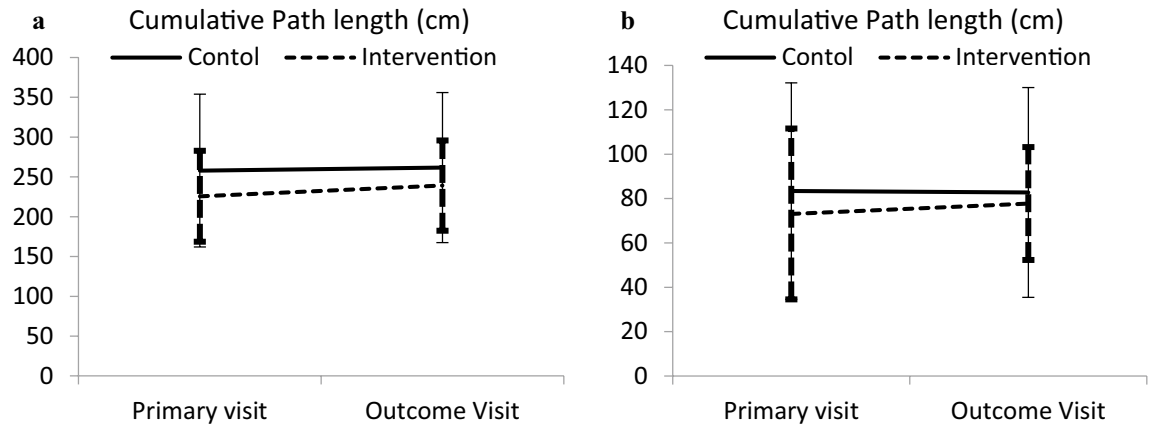

Fig. 4 Cumulative path length for both the control and intervention groups at baseline and outcome visits (mean ± SD). Higher value = more sway **a** eyes open, **b** eyes closed

Table 3 Mixed ANOVA (2× groups, 2× visits) between pre- and post-training assessment periods for the balance and mobility clinical assessments

Test	Effect	*F*-ratio	*p* value
STST	Group	0.18	0.67
	Visit	0.40	0.52
	Group × visit	1.13	0.29
OLST	Group	0.01	0.90
	Visit	0.95	0.33
	Group × visit	1.03	0.31
Mini-BESTest	Group	0.30	0.58
	Visit	3.33	0.078
	Group × visit	1.35	0.25
TUG	Group	1.11	0.3
	Visit	3.41	0.07
	Group × visit	3.13	0.08
TUGco	Group	0.39	0.53
	Visit	0.18	0.66
	Group × visit	1.63	0.21
5MWT	Group	0.78	0.38
	Visit	0.49	0.48
	Group × visit	1.20	0.28

STST Sit to Stand Test, *OLST* One-Legged Stance Test, *TUG* Timed Up and Go test, *TUGco* Timed Up and Go test with cognitive load, *5MWT* Five Metre Walking Test

11 s and 14 s, respectively for both groups. This indicates that our participants, although chosen based on their balance and falls rate, were still relatively healthy and high functioning. This means that there was less room for improvement, which may have been a reason why a significant change was not found.

The results of recent systematic reviews show that multiple-component and multi-factorial intervention programs which usually include exercise are likely effective at reducing the rate of falls (Gillespie et al. 2012; Hopewell et al. 2018). Our findings agree that visual attention training alone did not result in improved balance and mobility and may not be effective in reducing the falls rate in older adults. This does not preclude the possibility that visual training may be effective if implemented in conjunction with a physical training component, as a part of a multifactorial or multicomponent intervention. Participants chosen in the study were recruited from our previous study and were chosen for this training intervention based on their reported falls history and poor balance data. By selecting this cohort of participants we hypothesized that there would be more room for improvement and that these participants could benefit the most from the program. Unfortunately, we saw no significant improvement in our population's balance or mobility from our isolated vision attention only training. The selection of this cohort of participants may have precluded us from either extreme of the population. For example, those who were even more frail might show more improvement while those who were less frail might show more transfer of the training.

Limitations of the study

The participant pool was small but given that this was a small pilot study it is important to note (see Figs. 4 and 5) that the changes over time in the intervention group in a number of measures were not in the expected direction (e.g. cumulative path length eyes closed, TUG and TUGco). The inclusion of more participants in the future, and the inclusion of a more diverse population will increase the application of these study results to a wider group of older adults (e.g. those with mobility issues such as osteoarthritis). Second, the control group was not given any scheduled activity

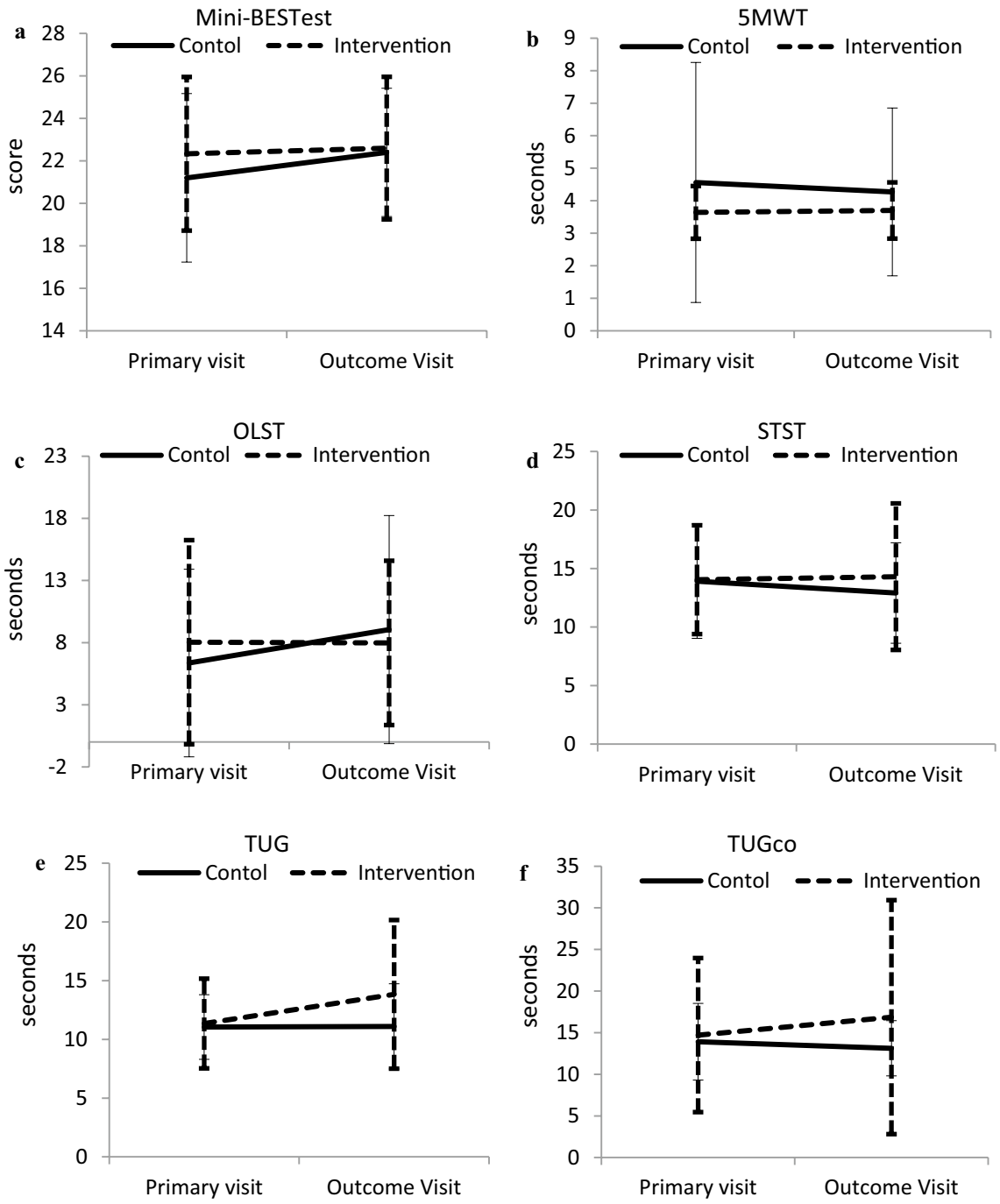

Fig. 5 The effect of visit for the balance and mobility tests (mean ± SD) **a** Mini-BESTest (maximum score of 28) (higher score = better balance), **b** 5 Meter Walking Test (higher score = poorer balance), **c** One-Legged Stance Test (higher score = better balance), **d** Sit To Stand Test (higher score = poorer balance), **e** Timed Up and Go test (higher score = poorer balance), **f** Timed Up and Go test with a cognitive task (higher score = poorer balance)

for an equivalent time to the intervention group, but had this been included, it would be expected to decrease the likelihood of finding a significant effect, and therefore, does not impact the current negative findings. Third, it is possible that a different clinical balance/mobility assessment tool may have been more sensitive to changes in balance/mobility as a result of the intervention, however, we believe that the Mini-BESTest was appropriate for the community-dwelling older adult population studied (Potter and Brandfass, 2015). Also, only two specific types of visual attention were used. It is possible that training with a wider range, or different attention tasks, e.g. including more sustained attention, may

have given positive results. Additionally, it is possible that the inclusion of more sessions, or more frequent, might have given a significant effect. However, our choice of the number of sessions and their frequency was based on other studies of Richards et al. (2006), Ball et al. (1988) and Sekuler and Ball (1986), which showed a significant improvement of visual attention with training. This effect of training was shown to transfer to other domains, such as driving, undertaking everyday visual tasks and reducing depression (Ball et al. 2007; Rebok et al. 2014; Wolinsky et al. 2009).

In conclusion, our findings indicate no improvement following visual attention training with UFV and AFOV for any of the mobility and/or balance measures chosen for study. We conclude that UFV and AFOV visual attention training alone is not effective for improving balance and mobility in this population. It is possible that a training programme that includes physical movement in combination with visual attention may be needed to obtain significant improvements in healthy older adults. Given the change in the Canadian demographics towards an older population (Statistics Canada 2015) and since a substantial portion of that population fall every year and many suffer from its debilitating effect it is imperative to still continue to develop intervention programs aimed at reducing falls in older adults and more research is needed on the effectiveness of such programmes.

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Author contribution statement MA, LV, and SL conceived and designed research. MA was responsible for data acquisition, analysis and write up. LV and SL provided critical feedback and helped shape the research, analysis, and manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All study procedures involving human participants were in accordance with the ethical standards of a University of Waterloo Research Ethics Committee and with the 1964 Declaration of Helsinki and its later amendments.

Informed consent Informed consent was obtained from all individual participants included in the present study.

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