The Journal of Physical Therapy Science

S P T S

Original Article

Relationship of visual dependence to age, balance, attention, and vertigo

Shu-Chun Lee, PhD[1]

[1] Department of Physical Therapy, Shu-Zen College of Medicine and Management: 5F, No.452, Huanqiu Rd. Luzhu Dist., Kaohsiung City 82144, Taiwan

Abstract. [Purpose] The aim of this study was to investigate the relationship of increased visual dependence to age, balance, attention, and vertigo. [Subjects and Methods] Twelve younger, 12 visually independent (VI) older and 12 visually dependent (VD) older adults were assessed for levels of visual dependence using Subjective Visual Vertical (SVV) tilt values, balance ability using the Clinical Test of Sensory Integration for Balance (CTSIB), and attentional requirements through the dual-task paradigm and experience of vertigo by completing the Situational Vertigo Questionnaire (SVQ). [Results] VD older adults had higher SVV tilt values, greater postural sway in a scenario where visual and proprioceptive inputs were simultaneously altered, similar dual-task cost and lower SVQ scores compared with younger and VI older adults. No difference was observed between the latter two. [Conclusion] Visual dependence may not necessarily increase with age but affect balance in a sensory condition involving visual-proprioceptive conflict. There is a non-significant trend for elevated visual dependence with increased attentional demands. Greater visual dependence is not accompanied by more frequent symptoms of vertigo in visually complex environments.
Key words: Attention, Balance, Visual dependence

INTRODUCTION

Effective orientation and balance requires the integration of proprioceptive, vestibular and visual sensory systems[1]. Some people rely too heavily on visual input, as opposed to proprioceptive and vestibular inputs, for spatial orientation and postural control. Several studies have reported that older people have significantly greater errors in their Subjective Visual Vertical test (SVV)[2, 3] and more postural sway following a visual disturbance compared with younger adults[4, 5]. These results suggest that older people may have higher levels of visual dependence on orientation and balance. However, a greater inter-individual variability in levels of visual dependence was observed in older people[4–6]. Additionally, visual dependence could affect postural control[5], increase attentional demands[7] and relate to vertigo and dizziness[8], but inconsistent results have been found in previous studies. Therefore, the aim of the study was to investigate the relationship of visual dependence to age, balance, attention, and vertigo.

SUBJECTS AND METHODS

Twelve healthy younger (20–50 yrs) and 24 older (>60 yrs) adults, including 12 visually independent (VI) and 12 visually dependent (VD) older adults with the highest and lowest SVV tilt values respectively measured by the Rod and Disc Test (RDT)[9], were recruited from neighboring communities. All participants were screened for exclusion criteria including: (1) a medical history of neurological, vestibular, and proprioceptive impairments; (2) uncorrected visual impairment or binocular
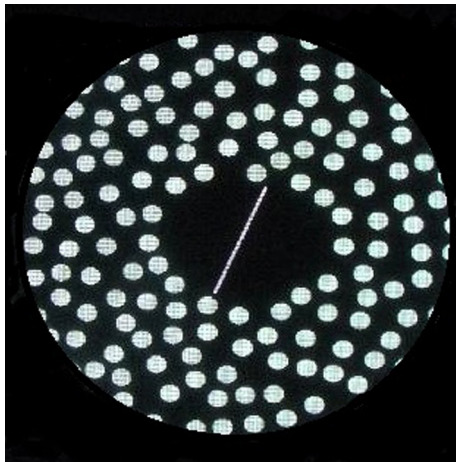
Fig. 1. The rod and disk test

Table 1. Balance ability was assessed in six sensory conditions with three visual and two supporting conditions

		Visual conditions		
		EO	EC	Visual disturbance
Supporting conditions	Firm surface	C1	C2	C3
	Foam surface	C4	C5	C6

EO: Eyes open, subjects stood looking at the static RDT image; EC: Eyes closed, subjects stood quietly with both eyes closed; Visual disturbance: subjects stood while looking at the RDT image with discs rotating; subjects stood on firm and foam (Airex Elite Non-slip Foam Balance Pad, USA) surfaces.

visual acuity (with corrective lenses) of worse than 20/40; and (3) more than one fall in the past year. They gave written informed consent to participate in the study, which was approved by the Human Research Ethics Committee at National Cheng Kung University (NCKU HREC-E-105-133-2). All participants were assessed for degrees of visual dependence, balance ability, dual-task performance and experience of situational vertigo in a randomized order.

Levels of visual dependence were determined by SVV tilt values as measured by the RDT[9] (Fig. 1). Participants were asked to set a small tilted rod on a computer screen to their perceived vertical, with florescent discs static and rotating around the center of the visual field. The RDT evokes deviation of the SVV in the direction of rotation. Greater SVV tilt represents a higher level of visual dependence. Balance ability was assessed by Clinical Test of Sensory Interaction for Balance (CTSIB)[10]. All participants stood with their hands at their sides, feet together, and completed 6 sensory scenarios with various visual and supporting conditions (Table 1). Visual disturbance was provided by the rotating RDT image without a central rod. Balance was evaluated by postural sway acceleration (m/s^2), which was measured using a smartphone device (Apple iPhone 4s, Apple Computer Inc., USA) loaded with the SPARKvue Application software (v2.5.0, PASCO Scientific, USA). Sway acceleration was recorded for 20 seconds with a sample frequency of 100 Hz and the median 10 seconds were analyzed. Mean sway acceleration in each condition was normalized to baseline. Greater sway acceleration reflected poorer balance ability. Participants were asked to perform the Timed Up and Go Test (TUG)[11] as a single task, and then implement it again with a cognitive task (subtracting 3 from 100) as a dual task. The TUG test requires a participant to stand up from a chair, walk three meters, turn around, and walk back to the chair sit down. The amount of time needed to complete either single or dual tasks were recorded and calculated as dual-task cost. Dual-task cost=|(single task-dual task)|/single task. The Situational Vertigo Questionnaire (SVQ)[8] consists of 19 questions with a score from 0 to 4. It measures how frequently symptoms of disorientation, dizziness, or vertigo are provoked in visually intense environments. Higher mean score represents more frequent symptoms.

All data are presented as mean ± standard deviation (SD). SPSS (Version 19.0. Armonk, NY, IBM Corp.) was used for all statistical analysis with the significance assumed at p<0.05. Kruskal-Wallis test with post hoc Mann-Whitney U Test was performed to examine age, SVV tilt values, dual-task cost, SVQ score, C3 and C4 in CTSIB while analysis of variance (ANOVA) with post hoc Bonferroni test was used for the C2, C5 and C6 in CTSIB among younger adults, VI older and VD older adults.

RESULTS

The participants' characteristics and results of assessment are presented in Table 2: (1) the VD older adults had significantly greater SVV tilt values than the VI older (p<0.001) and younger (p<0.001) adults; however, there was no difference between the younger adults and the VI older adults; (2) the VI (p<0.001) or VD older (p<0.001) adults were older than younger adults but no difference in age was found between VI and VD older adults; (3) the only significant difference was observed in C5 (p=0.04) and C6 (p=0.001) of the CTSIB with greater sway acceleration in VD compared with younger adults. Greater sway acceleration was also noted in VD compared to VI older adults in C6 (p=0.009); (4) dual-task cost did not differ between groups; (5) there was a significantly lower SVQ score for VD older than for younger adults (p=0.004).

Table 2. Participant characteristics

	Younger adults (n=12)	LVD older adults (n=12)	HVD older adults (n=12)
Gender			
Male, n (%)	5 (42)	4 (33)	1 (8)
Female, n (%)	7 (58)	8 (67)	11 (92)
Age (years)			
Mean (SD), range	34 (10), 20–49	66 (5), 61–76*	64 (2), 60–68*
SVV tilt (degrees)			
Mean (SD), range	2.5 (2.4), 0.7–9.3	2.7 (1.0), 0.9–4	6.6 (3.4), 4.1−16.2*‡
CTISB, Mean (SD)			
C2	1.1 (0.2)	1.2 (0.3)	1.3 (0.2)
C3	1.1 (0.3)	1.2 (0.4)	1.2 (0.2)
C4	1.3 (0.4)	1.4 (0.4)	1.7 (0.5)
C5	2.5 (0.7)	2.8 (1.3)	3.6 (1.1)*
C6	1.8 (0.5)	2.1 (0.9)	3.0 (0.6)*‡
Dual-task cost			
Mean (SD), range	0.1 (0.1), 0.0–0.2	0.2 (0.2), 0.0–0.8	0.2 (0.4), 0.0–1.4
SVQ score			
Mean (SD), range	0.3 (0.2), 0.0–0.8	0.2 (0.2), 0.0–0.8	0.1 (0.1), 0.0–0.2*

*Significantly different to younger adults ($p<0.05$).
‡Significantly different to LVD older adults ($p<0.05$).

DISCUSSION

The study aims to investigate the relationship of visual dependence to age, balance, attention and vertigo in younger adults, VI older and VD older adults. The finding was VD older adults had significantly greater SVV tilt values than both younger and VI older adults; however, there was no difference between the latter two. Either VI or VD older adults were older than younger adults but similar age was found between VI and VD older adults. VD older adults had significantly greater sway acceleration in C5 and C6 of CTSIB than younger adults as well as in C6 compared VI older adults. Dual-task cost was similar between groups but SVQ score was significantly lower in VD older adults compared to younger adults.

The study found that some of the older adults had higher levels of visual dependence while the others had similar or even lower visual dependence than younger adults. Also, VD older adults were not significantly older than VI older adults. This indicates that levels of visual dependence may not necessarily be higher in older adults, which is in contrast with previous studies that found that levels of visual dependence increase with age[2, 3]. Higher visual dependence is thought to be a response to vestibular or proprioceptive impairments[12]. However, the mechanism of increased visual dependence in older people is still unclear. It could be due to age-related decline in the function of vestibular or proprioceptive systems[13]. In this study, all participants were healthy without a medical history of sensory impairments. Some of them however, possibly VD older adults, may have sub-clinical or undiagnosed peripheral sensory dysfunctions[1, 3, 14]. Therefore, increased visual dependence in older adults could primarily result from age-related impairments rather than age *per se,* suggesting that impairments may have more influence than chronological age[15].

VD older adults showed greater statistically significant instability than younger adults in C5 and C6 of CTISB and even had significant imbalance compared to age-matched VI older adults. However, there was no difference between younger adults and VI older adults. These findings suggest increased visual dependence may have more impact on balance ability than age. In fact, degenerated balance with age has been reported as not necessarily linear[15, 16]. Some of the older adults did not have age-related impairments so that their balance ability may not differ from younger adults. Additionally, VD older adults showed instability only in C5 and C6, where visual and proprioceptive senses are simultaneously altered and vestibular input is only available to maintain balance, indicating they may have vestibular impairments and are unable to solve a situation involving visual-proprioceptive conflict. The result was not surprising because a reduction in vestibular function has been well-documented in older people[17, 18] and recent studies report that vestibular impairments may have a greater association with elevated visual dependence than proprioceptive impairments[19] although visual dependence may be due to a compensation of either vestibular or proprioceptive dysfunctions.

Visual dependence is also considered a kind of sensory reweighting deficit[20]. Older adults with increased visual dependence might have difficulty adapting to different sensory environments or when potentially conflicting information is arriving from different sensory systems[21] such as C5 and C6. This might be due to slower central processing of sensory information[6]

J. Phys. Ther. Sci. Vol. 29, No. 8, 2017

1320

and slower adaptive multi-sensory reweighting[22]. Consequently, they lengthen the postural adaptation process and exhibit worse balance performance in more challenging sensory conditions[23].

A trend towards increased dual-task cost was noted in older adults, particularly those with VD, but this was non-significant. Older adults may have greater cognitive demands than younger adults, and those with higher visual dependence, more so, which is in line with previous studies[6, 7]. Older adults, particularly those with impaired balance, have been reported to have greater attentional demands in either simple or challenging tasks compared with younger adults[6, 24]. VD older adults were relatively more unstable than VI older adults, and also showed poorer performance in a dual-task situation. In fact, divided attention capability was found to correlate with visual dependence[7]. People with lower visual dependence may have resistance to distraction[25], while people with higher visual dependence have an inability to ignore stimulation[26]. Therefore, the latter have poorer divided attention ability so they have difficulty in dual or multiple tasks. However, the dual task cost was not significantly different between groups. It may be due to a lack of visual interference components involved in the task such as absent, reduced, or inaccurate visual inputs[6]. There seems to be no effect on visually dependent individuals as long as tasks are performed in a stable visual environment, which is in agreement with previous findings that people with visual dependence only experience difficulty in resolving situations where visual information is complex or incorrect[8].

The interesting finding in this study was that the SVQ score was significantly lower in VD older adults than younger adults, although the mean scores obtained in all groups were between 0 and 1. It indicates all participants have experienced "not at all" or "very slight" symptoms of vertigo in visually intense environments. In previous studies, vertigo is often reported by patients with vestibular disorders. They complain of dizziness, disorientation and imbalance which is associated with increased visual dependence[8]. However, VD older adults with possible vestibular impairments in this study did not report obvious symptoms of vertigo. This was similar to previous studies that visual dependence was not necessarily associated with dizziness[27, 28]. Therefore, these findings highlight the need of for visual dependence test so that related impairments could be detected, not just those reporting vertigo.

In conclusion, the study aims to investigate the relationship of visual dependence, to age, balance, attention and vertigo in younger adults, VI older adults and VD older adults. The principal findings were that VD older adults had significantly higher visual dependence than younger adults and VI older adults, but there was no difference between the latter two, and VD older adults were not older than VI older adults. These findings suggest older adults did not necessarily have increased visual dependence, and impairments may be more influential than chronological age. Additionally, VD older adults had greater significant instability than younger adults and VI older adults in a sensory condition with altered visual and proprioceptive inputs. This implies that increased age-related visual dependence could be associated with vestibular impairments. Although all participants had similar dual task performance, VD older adults displayed difficulty in dividing their attention. Daily activities in everyday life are complicated and challenging. Multi-tasking could consume more cognitive resources and divert more attention from postural control and therefore increase imbalance and the risk of falling.

Finally, younger adults surprisingly showed more frequent symptoms of vertigo than VD older adults, but all participants experienced almost none of the symptoms in visually busy environments. This alerts us to the fact that higher visual dependence could be concealed if there was no reported vertigo and therefore risks of imbalance and even falling due to visual dependence may be increased.

REFERENCES

1) Peterka RJ: Sensorimotor integration in human postural control. J Neurophysiol, 2002, 88: 1097–1118. [Medline]

2) Lord SR, Webster IW: Visual field dependence in elderly fallers and non-fallers. Int J Aging Hum Dev, 1990, 31: 267–277. [Medline] [CrossRef]

3) Kobayashi H, Hayashi Y, Higashino K, et al.: Dynamic and static subjective visual vertical with aging. Auris Nasus Larynx, 2002, 29: 325–328. [Medline] [CrossRef]

4) Sundermier L, Woollacott MH, Jensen JL, et al.: Postural sensitivity to visual flow in aging adults with and without balance problems. J Gerontol A Biol Sci Med Sci, 1996, 51: M45–M52. [Medline] [CrossRef]

5) Borger LL, Whitney SL, Redfern MS, et al.: The influence of dynamic visual environments on postural sway in the elderly. J Vestib Res, 1999, 9: 197–205. [Medline]

6) Teasdale N, Stelmach GE, Breunig A: Postural sway characteristics of the elderly under normal and altered visual and support surface conditions. J Gerontol, 1991, 46: B238–B244. [Medline] [CrossRef]

7) Agathos CP, Bernardin D, Huchet D, et al.: Sensorimotor and cognitive factors associated with the age-related increase of visual field dependence: a cross-sectional study. Age (Dordr), 2015, 37: 9805. [Medline] [CrossRef]

8) Guerraz M, Yardley L, Bertholon P, et al.: Visual vertigo: symptom assessment, spatial orientation and postural control. Brain, 2001, 124: 1646–1656. [Medline] [CrossRef]

9) Dichgans J, Held R, Young LR, et al.: Moving visual scenes influence the apparent direction of gravity. Science, 1972, 178: 1217–1219. [Medline] [CrossRef]

10) Horak FB: Clinical measurement of postural control in adults. Phys Ther, 1987, 67: 1881–1885. [Medline] [CrossRef]

11) Podsiadlo D, Richardson S: The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc, 1991, 39: 142–148. [Medline] [CrossRef]

12) Oie KS, Kiemel T, Jeka JJ: Multisensory fusion: simultaneous re-weighting of vision and touch for the control of human posture. Brain Res Cogn Brain Res, 2002, 14: 164–176. [Medline] [CrossRef]

13) Lord SR, Ward JA: Age-associated differences in sensori-motor function and balance in community dwelling women. Age Ageing, 1994, 23: 452–460. [Medline] [CrossRef]

14) Bronstein AM, Yardley L, Moore AP, et al.: Visually and posturally mediated tilt illusion in Parkinson's disease and in labyrinthine defective subjects. Neurology, 1996, 47: 651–656. [Medline] [CrossRef]

15) Lazarus NR, Harridge SD: Exercise, physiological function, and the selection of participants for aging research. J Gerontol A Biol Sci Med Sci, 2010, 65: 854–857. [Medline] [CrossRef]

16) Kinsella-Shaw JM, Harrison SJ, Colon-Semenza C, et al.: Effects of visual environment on quiet standing by young and old adults. J Mot Behav, 2006, 38: 251–264. [Medline] [CrossRef]

17) Richter E: Quantitative study of human Scarpa's ganglion and vestibular sensory epithelia. Acta Otolaryngol, 1980, 90: 199–208. [Medline] [CrossRef]

18) Jacobson GP, McCaslin DL, Grantham SL, et al.: Significant vestibular system impairment is common in a cohort of elderly patients referred for assessment of falls risk. J Am Acad Audiol, 2008, 19: 799–807. [Medline] [CrossRef]

19) Abdul Razzak R, Hussein W: Postural visual dependence in asymptomatic type 2 diabetic patients without peripheral neuropathy during a postural challenging task. J Diabetes Complications, 2016, 30: 501–506. [Medline] [CrossRef]

20) Allison LK, Kiemel T, Jeka JJ: Multisensory reweighting of vision and touch is intact in healthy and fall-prone older adults. Exp Brain Res, 2006, 175: 342–352. [Medline] [CrossRef]

21) Wrisley DM, Stephens MJ, Mosley S, et al.: Learning effects of repetitive administrations of the sensory organization test in healthy young adults. Arch Phys Med Rehabil, 2007, 88: 1049–1054. [Medline] [CrossRef]

22) Peterka RJ, Loughlin PJ: Dynamic regulation of sensorimotor integration in human postural control. J Neurophysiol, 2004, 91: 410–423. [Medline] [CrossRef]

23) Jeka J, Allison L, Saffer M, et al.: Sensory reweighting with translational visual stimuli in young and elderly adults: the role of state-dependent noise. Exp Brain Res, 2006, 174: 517–527. [Medline] [CrossRef]

24) Shumway-Cook A, Woollacott M: Attentional demands and postural control: the effect of sensory context. J Gerontol A Biol Sci Med Sci, 2000, 55: M10–M16. [Medline] [CrossRef]

25) Bednarek H, Orzechowski J: Cognitive and temperamental predictors of field dependence-independence. Pol Psychol Bull, 2008, 39: 54–65.

26) Owsley C, Ball K, Sloane ME, et al.: Visual/cognitive correlates of vehicle accidents in older drivers. Psychol Aging, 1991, 6: 403–415. [Medline] [CrossRef]

27) Liston MB, Bamiou DE, Martin F, et al.: Peripheral vestibular dysfunction is prevalent in older adults experiencing multiple non-syncopal falls versus age-matched non-fallers: a pilot study. Age Ageing, 2014, 43: 38–43. [Medline] [CrossRef]

28) Agrawal Y, Carey JP, Della Santina CC, et al.: Disorders of balance and vestibular function in US adults: data from the National Health and Nutrition Examination Survey, 2001–2004. Arch Intern Med, 2009, 169: 938–944. [Medline] [CrossRef]