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Original Research Article

PERCEPTUAL-POSTURAL CORRELATION OF VISUAL DEPENDENCE IN HEALTHY ADULTS ACROSS AGE GROUPS

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ABSTRACT

Background: Visual dependence is a term to describe over reliance on vision than other sensory systems on orientation and balance. Perceptual and postural visual dependence have been reported in many articles but usually discussed in separate studies and focused on certain age groups.

Objective: The aims of this study are twofold. The first investigates the correlation of perceptual and postural visual dependence in healthy adults across age groups. The second examines the correlation between age and visual dependence at perceptual and postural levels respectively.

Methods: Forty healthy adults were recruited and assessed for levels of perceptual and postural visual dependence. The former was distinguished through subjective visual vertical (SVV) tilt by Rod and Disc test; the latter was measured by sway acceleration in six sensory conditions with various visual and proprioceptive inputs.

Results: The results showed moderate and positive correlation between the values of SVV tilt and sway acceleration with the subject standing on foam with a visual disturbance applied. A low and positive correlation was also observed between age and the value of SVV tilt and with sway acceleration, where both visual and proprioceptive inputs were altered.

Conclusion: These findings suggest perceptual visual dependence was significantly increased with postural visual dependence in healthy adults across age groups, particularly when performing a challenging balance task. Greater visual dependence at both perceptual and postural levels with increasing age was also found.

KEY WORDS: Correlation, Perception, Balance, Rod And Disc Test, Visual Dependence.

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INTRODUCTION

Effective orientation and balance control requires the integration of proprioceptive, vestibular and visual sensory systems [1].

However, some people over rely on visual input, i.e. persons who are visually dependent, for spatial orientation and postural responses. Several studies have reported that the level of visual dependence at the perceptual level increased with age, using the method of measuring errors of subjective visual vertical (SVV) induced by visual stimulation [2,3]. Increased visual dependence with age was also observed at the postural level, that older adults had significantly more postural sway in response to optic flow compared to younger adults and showed continued center of pressure oscillation even following the visual disturbance [4-6].

Investigation of visual dependence in most previous studies used younger adults as the con-

trol group in comparison with older adults [4,6], but there is lack of understanding regarding the middle-age group. In Kobayashi et al.'s study, linear regression of age and SVV tilt was analyzed from 21 to 63 years [3], it was unclear, however, whether values of SVV tilt in older adults over 65 continue increasing with age. Overall, perceptual and postural visual dependence were commonly discussed in separate articles and only focused on certain age groups. Thus, whether a correlation between the two and whether both simultaneously increase with age requires investigation. The primary aim of this study was to investigate the correlation of perceptual and postural visual dependence in healthy adults across age groups. The second was to examine the correlation between age and visual dependence at the perceptual and postural levels respectively.

MATERIALS AND METHODS

Subjects: Forty healthy adults (9 male, range 20-76 yrs.; mean 55 ± 15 SD yrs.) were recruited from neighboring communities. All subjects were screened for exclusion criteria including: (1) inability to stand independently without an assistive device; (2) a history of neurological disease including epilepsy, migraine or fainting; (3) a history of vestibular disorders; (4) clinically detectable proprioception loss; (5) uncorrected visual impairment or binocular visual acuity (with corrective lenses) of worse than 20/40; (6) more than one fall in the previous one year; (7) previous exposure to the Rod and Disc Test (RDT). They gave written informed consent to participate in the study, which was approved by the local Ethics Committee.

Protocol: All subjects were assessed for levels of visual dependence at the perceptual and postural level in a counterbalanced order.

Perceptual visual dependence: Perceptual visual dependence was distinguished through assessment of SVV tilt by the RDT [7]. A computerized RDT was displayed on an LCD TV monitor (Model TL-42S3000T, CHIMEI, Taiwan) but the image was rendered circular (53 cm diameter) by blackout material. Subjects sat upright on a padded armless chair with their eyes 50 cm from the screen while their knees were extended and their feet were dorsiflexed so that only the heels were in contact with the floor in order to diminish possible proprioceptive cues from the plantar surface of the feet. The center of the rod (14 cm length) was aligned to the subjects' eye level via adjustment of the chair height. Subjects closed their eyes whilst the rod was deviated either 20° clockwise (CW) or counter-clockwise (CCW) in a randomized order. They were then asked to open their eyes and align the rod to their SVV at their own pace with florescent discs stationary around the rod, using the wheel of a wireless computer mouse and confirm verbally when the task was completed. This process was then repeated with discs rotating at 30°/s in CW and CCW directions. Four trials each were performed for the stationary and then rotating (in both directions) disc tests. The image and subject were surrounded by blackout material ensuring complete darkness to minimize any external vertical and horizontal visual reference cues. The RDT software automatically recorded SVV tilt values taken as angular deviations from true gravitational vertical (0°). The tilt of the top of the rod to the subject's right or left was indicated as a positive or negative angle, respectively. Each subject's average SVV tilt angle with the disc stationary was subtracted from those obtained with the rotating disc. Greater SVV tilt (°, absolute value) represents a higher level of perceptual visual dependence.

Postural visual dependence: Postural visual dependence was assessed by postural sway acceleration (m/s2), 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). The iPhone device was firmly attached to the subject by means of an elastic belt around the waist over the middle part of the lower back over the L3 (3rd lumbar) vertebra process so that it was attached close to the center of gravity (COG) of the human body [8]. Several studies have indicated that accelerometric mobile devices, such as an iPhone or iPod, showed the capacity to quantify balance parameters with accuracy and reliability [9] when compared to laboratory equipment such as strain gauges and accelerometers. Therefore, the SPARKvue Application software paired with

a smartphone device can be relied on as a tool to measure postural sway through a tri-axial accelerometer [10].

Subjects stood with their hands at their sides, bare feet together, and performed 6 sensory conditions with various visual cues including Eyes open (EO): subjects stood looking at the static RDT image; Eyes closed (EC): subjects stood quietly with both eyes closed; Visual disturbance: subjects stood while looking at the RDT image with discs rotating at 30°/s in a CW direction. The subjects were also evaluated on varying supporting conditions including firm and foam (Airex Elite Non-slip Foam Balance Pad, USA) surfaces. Together, these six conditions alter the availability and accuracy of visual and proprioceptive inputs for postural control (C1-C6; Table 1). Each condition was repeated once and conducted in a randomized order. A researcher stood closely behind the subject during all trials for safety reasons. Between trials, each subject received a 10 second rest, during which subjects were able to freely move and walk around.

Postural sway was recorded for 20 seconds with a sample frequency of 100 Hz in x (medial-lateral) and y (anterior-posterior) directions under all conditions; the middle 10 second segment of each sample was analyzed in order to avoid postural adjustments and fatigue at the beginning and the end of the task. All the data were exported from the SPARKvue Application software to Microsoft Excel® (Version 2010, Windows 7) for analysis. Sway acceleration was defined as the average change of the COG velocity with respect to time in the horizontal plane and reflects postural sway. Mean sway acceleration in all conditions were normalized to baseline (C1). Greater sway acceleration in C2, C3, C5 and C6 reflect the greater influence of vision on balance, indicating higher level of postural visual dependence.

Statistical analysis: All data are presented as mean ± standard deviation (SD). SPSS (Version 19.0. Armonk, NY: IBM Corp.) was used for all statistical analysis with significance assumed at $p < 0.05$. The Shapiro-Wilk test was used to analyze all data to determine if it was normally distributed. All parameters were not normally-distributed except sway acceleration in C3 and C6 conditions. Thus, the Spearman rank correlation test was performed to examine the correlation between value of SVV tilt and sway acceleration in all conditions respectively. The same test was used again for the correlation of age and value of SVV tilt or sway acceleration in all conditions. It was assumed that the Spearman's correlation coefficient (rs) < 0.3 is very low; 0.3 – 0.5 low; 0.5 – 0.7 moderate; 0.7 – 0.9 high and > 0.9 very high [11].

RESULTS

There was an only a moderate positive correlation between the value of SVV tilt and sway acceleration in C6 ($r = 0.595$, $p < 0.001$; Fig. 1). A low positive correlation was observed on age with value of SVV tilt ($r = 0.389$, $p = 0.013$; Fig. 2) and with sway acceleration in C6 ($r = 0.372$, $p = 0.018$; Fig. 3).

Table 1: Postural visual dependence 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

EC = eyes closed; EO = eyes open.

Fig. 1: There is a positive moderate correlation ($r = 0.595$, $p < 0.001$) of the values of SVV tilt and sway acceleration in C6.

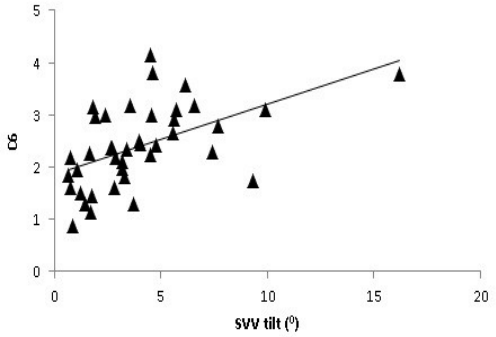


Fig. 2: Scatter graph shows a positive low correlation ($r = 0.389$, $p = 0.013$) of age and the values of SVV tilt.

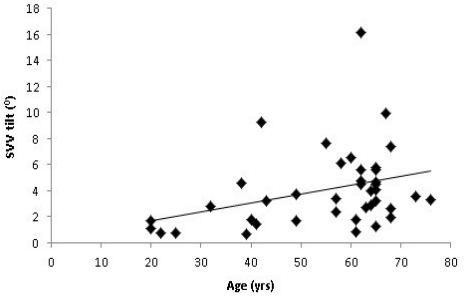
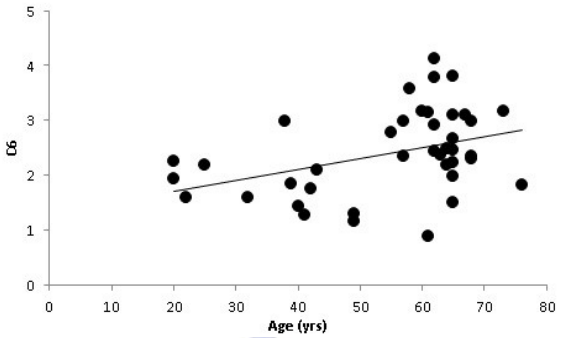


Fig. 3: It represents a positive low correlation (r = 0.372, p = 0.018) of age and the sway acceleration in C6.



DISCUSSION

The primary aim of this study was to investigate the correlation of perceptual and postural visual dependence in healthy adults across age groups. The second was to examine the correlation between age and visual dependence at the perceptual and postural levels respectively. The main finding indicates that perceptual visual dependence was significantly increased with postural visual dependence when maintaining a challenging balance task in healthy young, middle-age and older adults. Greater visual dependence at both perceptual and postural levels with increasing age was also found in the current study.

Only significantly positive correlation was found between the value of SVV tilt and sway acceleration in C6, indicating perceptual visual dependence increased with postural visual dependence in healthy adults across age groups. Similar results were found in previous studies [12–14].

Pavlou et al. found the positive correlation of the value of SVV tilt measured by the Rod and Frame test (RFT) and the score in a Sensory Organization Test in which both visual and proprioceptive inputs were altered [12]. Isableu et al. reported that visually dependent subjects, distinguished by the RFT, showed instability toward the direction in which the frame was tilted when they were looking at it and standing in the Sharpened Romberg position [12,13]. This result of correlation was not surprising since posture can be influenced by inaccurate orientation [15]. Perceptual orientation is based on the integration of visual, vestibular and proprioceptive sensory systems and postural control requires a complex interaction of musculoskeletal and sensory systems [13]. A tilted or inappropriate internal representation of verticality results in a postural alignment incongruent with respect to gravity, which can lead to imbalance [14]. Taken together, whether static (such as a tilted frame) [12–14] or dynamic (such as rotating discs) visual stimulation, it could affect spatial orientation as well as postural control; although the latter is considered to have a greater influence than the former [15].

Perceptual visual dependence may be a predictor of postural visual dependence because of moderate correlation between the two. Individuals who over-rely on visual input may experience difficulty in resolving situations where visual information is complex or inaccurate, such as crowded or busy environments [16]. This could lead to instability and falling. Through the assessment of perceptual visual dependence, there is a possibility that individuals at high risks of imbalance and even falls can be screened and identified. Evaluation of perceptual visual dependence such as the RFT or RDT is relatively simpler to perform, quicker to measure and easier to interpret compared with the postural visual dependence measured by balance tests. However, the degree of prediction ability still requires further investigation.

The correlation of perceptual and postural visual dependence was only found in C6 rather than the rest of the conditions. Generally speaking, visually dependent people tended to show imbalance in conditions in which visual cues were removed or made inaccurate [17] Sometimes standing in the presence of visual motion had an even greater destabilizing effect on balance compared to standing with eyes closed [5]. If standing in the absence of reliable proprioceptive cues, inaccurate or unreliable visual cues evoke more exaggerated disorientation and imbalance [18,19]. That could explain the only correlation being found in C6, standing in a foam with visual disturbance, rather than other conditions.

C6 compared to the rest of the conditions is a very challenging balance task. That the correlation was only found in a difficult task could be due to the fact that participants recruited in the study discussed here were healthy adults and

the majority of them had relatively low levels of perceptual visual dependence when compared to the subjects of previous studies [2,3]. Visually dependent individuals such as patients with vestibular deficits who had greater values of SVV tilt had abnormally large postural responses to a visual stimulation even though they were standing with both legs on a firm surface [16,20]. However, in healthy adults, balancing tasks such as standing with both visual and proprioceptive disturbances [12] or in a sharpened Romberg position [12,13] may be difficult enough to challenge visual dependence.

This was the first study to simultaneously investigate perceptual and postural visual dependence in one study and across age groups from 20 to 76 years of age, and the findings indicate greater visual dependence at both perceptual and postural levels with increasing age. However, the correlation was low especially when age increases. A greater inter-individual difference in older adults was observed from scatter graphs. In fact multiple studies report that balance degeneration with age is not necessarily linear [21–23]. Some older subjects had similar or even lower SVV tilt values than younger ones [5,6,24]. Although all participants were screened to identify healthy subjects, some may have sub-clinical or undiagnosed sensory impairment [1,3,25] that may affect the levels of visual dependence. All these may be the reasons of low correlation.

CONCLUSION

Levels of visual dependence were increased simultaneously on both spatial orientation and postural control in healthy adults across age groups, particularly when performing a challenging balance task. Greater visual dependence at either perceptual or postural levels with increasing age was also found in this study.

ABBREVIATIONS

CW - Clockwise
CCW - Counter-clockwise
COG - Center of gravity
EC - Eyes closed
EO - Eyes open
RDT - Rod and Disc Test
SVV - Subjective visual vertical
RFT - Rod and Frame test

Conflicts of interest: None

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