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How does the extent of central visual field loss affect adaptive gait?

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ABSTRACT

Visual impairment is one of the most important clinical risk factors associated with falls. Currently it remains unclear whether adaptive gait is progressively affected as the extent of central visual field loss (CFL) increases, or when CFL exceeds a certain size. 10 participants (aged 22 ± 3 years) negotiated a floor based obstacle in full vision (no occlusion) and wearing custom made contact lenses which simulated 10° CFL and 20° CFL. Movement kinematics assessed the period immediately prior to and during obstacle crossing. In the 20° CFL condition, participants exhibited adaptations in gait which were consistent with being more cautious and more variable during the approach to and crossing of the obstacle, when compared to both 10° CFL and full vision conditions. Specifically, in the 20° CFL condition participants placed their lead foot further from the obstacle, lifted both their lead and trail feet higher and slower over the obstacle, and took longer to negotiate the obstacle when compared to the 10° CFL and full vision conditions. Data highlights differences in adaptive gait as a function of the extent of CFL when compared to full vision. More importantly, these adaptations were only associated with loss of the central 20° of the visual field, suggesting that gait is compromised only after central visual field loss exceeds a certain level.

1. Introduction

In the United Kingdom, approximately 1 person in 30 have some form of visual impairment [1]. Visual impairment can occur due to loss in either central or peripheral visual field (the area in which objects can be seen), or both, and can be the result of damage to any part of the visual pathway. The visual field can be divided into central and peripheral regions. The central visual field extends from 5°, encompassing the macular field (the point of fixation with highest acuity) to a maximum of 30° [2]. Regions in excess of 30° are usually defined as the peripheral visual field [2]. However, visual field defects that do not encroach upon the central 5°, but which are still within 30° are also termed peripheral field defects. Previous research has shown how visual field loss and its location (e.g. central or peripheral) results in adaptations in gait compared to 'normal' full visual field e.g. [3–5].

The extent of visual field loss also affects gait, with more severe visual field loss associated with an increased risk of recurrent falls [6] and/or deterioration in mobility performance [7–9]. Whilst previous research demonstrates that mobility becomes impaired (i.e. walking speed reduces) when the extent of CFL increases [7], it remains unclear whether gait is progressively affected as the extent of CFL increases, or whether gait changes only when CFL exceeds a certain size.

The current study investigates how the extent of simulated CFL affects adaptive gait, specifically the ability to negotiate a floor-based obstacle. Previous research by our group [4,5] has investigated how adaptive gait is affected in people with varying levels of CFL and compared them to individuals with normal full vision. Rather than consider CFL as one group to be investigated, the current study extends our previous research by investigating how specific amounts of CFL affect gait. Based upon the work of Hassan et al. [7], we hypothesise that adaptive gait will be progressively affected as the extent of CFL increases.

2. Methods

2.1. Participants

Ten healthy adults, age 22 ± 3 years (mean ± SD), height 171 ± 10 cm and mass 60.0 ± 11.3 kg, with no self-reported balance, gait or vision abnormalities participated. All participants habitually

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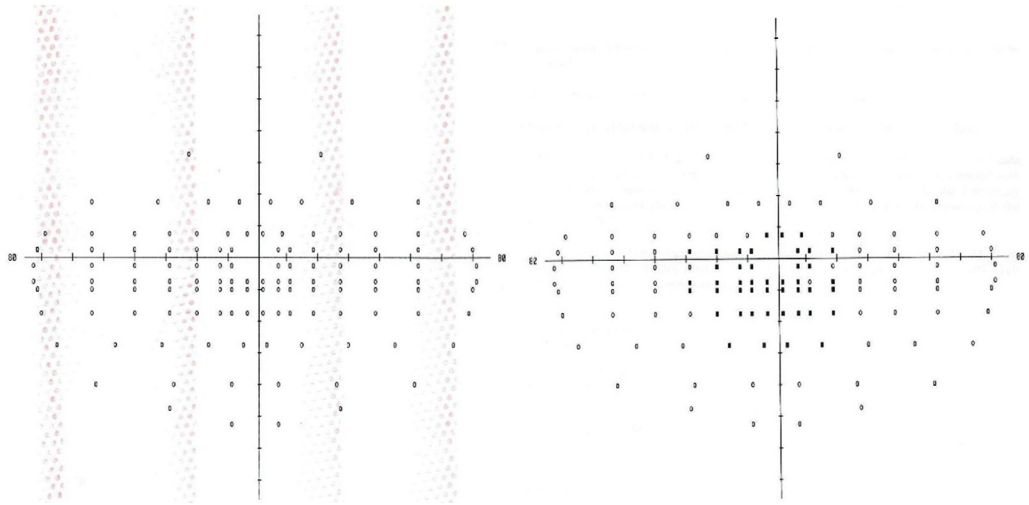

Fig. 1. Exemplar visual field plot from binocular Esterman visual field test in full (left) and 20° (right) conditions. The unfilled circles represent seen points in the test and filled circles, unseen points.

wore contact lenses. The tenets of the Declaration of Helsinki were observed and the experiment was approved by Anglia Ruskin University's Ethics Committee. Written informed consent was obtained from each participant prior to participation.

2.2. Contact lens design

Custom made contact lenses (Prima 67; soft hydrogel lens) were designed. Base curves ranged from 8.30 mm to 9.10 mm on a 14.50 mm diameter lens to occlude specific part of the central visual field. Participants wore the contact lenses in both eyes. Based on an axial length of 24 mm for the human eye [10], 10° and 20° CFL resulted in a 4 mm and 8.5 mm opaque central lens, respectively. Since the contact lenses contained no correction, participants wore their own spectacles during testing.

2.3. Visual assessments

Participants were assessed on their ability to discriminate fine detail (visual acuity – VA), perceive depth (stereopsis) and discriminate detail at low contrast levels (contrast sensitivity – CS). The mean binocular VA scores were -0.12 ± 0.1 (full), 0.16 ± 0.14 (10° CFL) and 0.82 ± 0.25 (20° CFL) logMAR. CS scores for full, 10° and 20° CFL were 1.91 ± 0.07, 1.47 ± 0.20 and 0.75[1] ± 0.69 log, respectively. Stereoacuity scores for full and 10° CFL were 24 ± 9, 56 ± 30 seconds of arc respectively. There were no recordable stereoacuity scores for 20° CFL.

To confirm the extent of visual field loss, a binocular Esterman visual field test was completed using a Humphrey Field Analyzer (Carl Zeiss Meditec, Inc., Dublin, CA) on each participant in each vision condition (for exemplar visual field plot see Fig. 1).

2.4. Protocol

Participants were required to negotiate a floor based obstacle in full, 10° or 20° CFL conditions. Whilst the order of vision condition was randomised, all trials from one vision condition were completed before progressing onto the next vision condition. Prior to collecting data, we ensured participants had adjusted to their contact lenses. Familiarisation occurred by initially asking participants to walk along a corridor ~10 m in length (obstacle free) whilst moving their head/eyes around the environment to identify features such as doors, windows and posters on the wall. Once participants exhibited a more natural gait, they walked into a waiting area containing chairs and tables. Participants were asked to walk around the room several times (in random directions) and avoid tripping/bumping into the obstacles; a member of the research team walked behind the participant at all times to provide assistance if required. Once participants verbally reported that they felt confident enough to detect obstacles in their travel path and step over them, they progressed to the main part of the experiment. This familiarisation period typically took around 10 minutes.

From approximately five step lengths away, participants walked up to (at a self-selected pace) and stepped over a single obstacle and continued to walk along the laboratory floor for at least four steps. To minimise the learning effects associated with repeatedly negotiating the same obstacle height [11], two obstacle heights were used (5 cm and 10 cm) reflecting typical heights encountered in everyday life [4]. The obstacles were constructed from medium-density-fibre-board of 1.8 cm thickness and were 50 cm in length. Obstacles were light brown in colour and were placed on the laboratory floor (navy-blue carpet). Participants also completed walking only trials, which consisted of walking across the laboratory floor with no obstacle present. Walking only trials were 'nested' within the obstacle crossing trials (presented every third trial) to avoid participants adopting a repeated motor strategy through walking up to and negotiating an obstacle. No data were collected during the walking only trials. Each obstacle height was negotiated 6 times (in a random order), thus participants completed 18 trials (12 obstacle crossing and 6 walking only trials) per vision condition and a total of 54 trials per participant.

Kinematic data were collected (at 100 Hz) using a six camera 3D motion capture system (Vicon, 460, Oxford Metrics Ltd). Data were collected during a single testing session for each participant. Participants wore shorts, t-shirt and comfortable flat-soled shoes for walking. Retro-reflective markers were attached, bilaterally, to the superior aspects of the second and fifth metatarsal heads, the most distal, superior aspect of the second toe, the lateral malleoli, the posterior aspect of the calcanei and antero-lateral and posterolateral aspects of the head. A single marker was also placed on the sternum. Two additional markers were attached to the upper front edge of the obstacle to determine the height and location of the surface's leading edge within the laboratory coordinate system. Motion data were filtered using the cross-validatory quintic spline smoothing routine with 'smoothing'

[1] Only three participants had recordable contrast sensitivity scores.