Does a peripheral "independent visual background" reduce scene-motion-induced balance disturbance in an immersive environment?

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ABSTRACT

We have demonstrated that balance disturbance induced by scene motion can be reduced using an independent visual background (IVB). It has been theorized that the human vision system can divided into two functional systems, and that the visual periphery mediates spatial orientaiton Therefore, we hypothesized that an IVB located in the peripheral field would be more effective than one located centrally. Results from 20 subjects tested in two experiments failed to support this hypothesis; rather, subjects exhibited less balance distrubance in a central field IVB condition than when the IVB was located in the periphery. Possible explanations are addressed.

1. INTRODUCTION

Motion disturbance and related sickness pose a significant problem for users of motion simulators and virtual environments (VEs) (McCauley and Sharkey, 1992). Prothero et al. (1999) developed the rest frame hypotheses and proposed that an independent visual background (IVB) could reduce simulator sickness (SS). Following Prothero's suggestion, Duh, Parker and Furness (2001) reported that balance disturbance evoked by visual scene movement was reduced when an IVB was present. Balance performance has been used in several studies to assess effects of VE exposure (see Kennedy and Stanney, 1996).

It has been suggested that human vision depends on two functionally different systems (e.g., Held, 1970; Leibowitz and Post, 1982). They proposed that focal and ambient modes of visual processing may be mediated by different retinal and brain regions. Focal mode processing in the central visual field deals with object recognition and identification and is concerned with the 'what' question. The peripheral field ambient mode processing is in charge of spatial orientation, locomotion and posture and is concerned with the 'where' question.

The IVB used by Duh and his colleagues covered the entire visual field. The two-modes model of visual processing suggests the following hypothesis. Since 'ambient' or 'peripheral' vision is thought to be in charge of spatial orientation etc., we suggest that an IVB located in the peripheral visual field would be more effective than an IVB in the central field. The present study investigated effects of location of the IVB on postural stability.

2. EXPERIMENTS

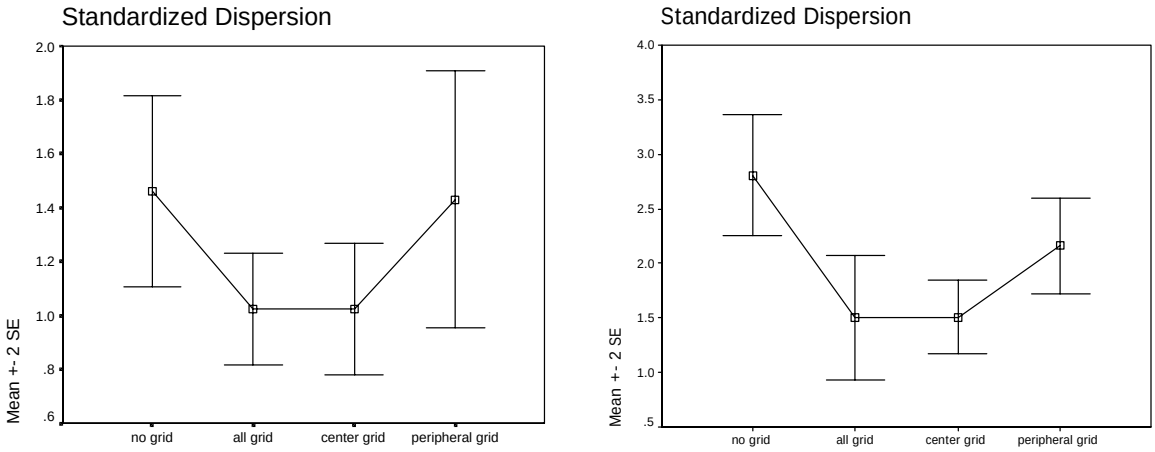
Subjects. There were 12 subjects in Experiment 1 and 8 subjects in Experiment 2. *Apparatus.* For Experiment 1, the moving scene (a cartoon) and an earth-fixed IVB (grid) were back-projected on a 3 foot coated dome. The nominal field-of-view (FOV) was 180° x 180°. Subjects stood on a Chattecx balance platform that automatically calculated dispersion around the center-of-balance. For Experiment 2, the moving scene was a simple black and white radial pattern (similar to a 6-blade propeller). *Procedure.* For both experiments, scene roll (around the nasal-occipital axis) oscillation frequency was 0.05 Hz and peak velocity was approximately 70°/s. The IVB

superimposed over the moving scene was presented over the entire scene, in the central visual field (+/-32° from the center), and in the peripheral field (>47° from the center). A no-IVB condition was included. Luminance of the peripheral IVB was increased to be perceptually equal to that of the central IVB. There were four 10-s data collection trials for each IVB condition, with the subjects in a sharpened Rhomberg stance. Baseline data, eyes closed in darkness, were collected before and after the visual stimulus trials. The order of IVB conditions was randomized across subjects. For each trial, center-of-balance dispersion was recorded and subjects rated their difficulty in maintaining balance (1-10 scale).

3. RESULTS

Subjects exhibited less center-of-balance dispersion and lower subjective difficulty ratings in total IVB and central field IVB conditions than in the no-IVB and peripheral IVB conditions. Difficulty ratings and balance dispersion scores were 'standardized' by dividing each trial score by the subject's average baseline performance. Differences in standardized dispersion as a function of IVB condition were statistically significant [Experiment 1: $F(3, 33)=5.58$, $p<0.003$;Experiment 2: $F(3, 21)=12.284$, $p<0.003$]. For Experiments 1 and 2, post hoc analysis indicated significantly less disturbance for the central IVB condition than for the peripheral IVB condition. Similar results were obtained for the rating data.

Figure 1. The left figure is dispersion data from Experiment 1; the right figure is dispersion data from Experiment 2 (means and standard errors).



4. DISCUSSION

The hypothesis, which was derived from the two visual processing modes model, was not supported. For alleviation of scene motion-induced balance disturbance, an IVB located in the visual periphery was less effective than one located in the central visual field. The failure of this experiment to confirm expectations suggests that the central visual field may be more sensitive to orientation and motion signals than is suggested by the two-modes model. Perhaps the central and peripheral fields exhibit different signal processing capabilities.

Several recent studies have challenged Dichgans and Brandt's (1978) "peripheral dominance hypothesis." Based on studies of perceived heading accuracy, Warren and Kurtz (1992) suggested that the preiphery is less sensitive to radial optical flow than the central region. Stoffregen (1985) reported that postural adjustments were evoked by either radial or parallel (lamellar) optical flow in the central visual field but only by lamellar flow in the periphery.

A possible explanation for the failure of these experiments to support the hypothesis is that, although our peripheral vision plays a special role in the perception of spatial orientation and motion, 'the rest frame' information is processed by a different pathway. Our perceptual system might seek the rest frame from the central visual field. Since our central vision is sensitive to object identification and discrimination, it is easier to identify the IVB from cues presented to the central field. Possibly the central and peripheral region differ in their ability to parse the moving scene and the static IVB. Further experiments will be required to evaluate this suggestion and to determine whether the results of the present study reveal additional differences in central and peripheral processing.

ACKNOWLEDGMENTS

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