Exp Brain Res (1986) 63: 655–658

Experimental
Brain Research

Research Note

Suppression of visually evoked postural responses

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Summary. Normal subjects standing on an earth-fixed force platform inside a movable room displaced at velocities comparable to those accompanying spontaneous body sway, exhibit a visually evoked postural response (VEPR) some 600 ms after the start of the room movement. It consists of a displacement of the centre of force of the body in the direction of the stimulus (primary component), followed shortly by a corrective displacement in the opposite (secondary component). On second presentation of the stimulus VEPR is markedly reduced, but only if full proprioceptive information from the lower limbs is available to the subjects. A patient deprived of this information showed much enhanced VEPR which he was unable to suppress, in contrast to a patient with absent vestibular function who presented normal VEPR. The results show that in the presence of conflict between different sensory clues, vision is initially dominant in sway control, although adaptive processes can quickly rearrange this hierarchy.

Key words: Vision – Posture – Motor control – Vestibular system – Proprioception

Introduction

Clear evidence of the dominant role of vision in the control of posture has been advanced in a variety of studies in which the visual stimulus was manipulated in such a manner that the information relating body movement to the environment was in conflict with that supplied by the vestibular and proprioceptive systems. These have involved the analysis of body sway in response to moving visual surrounds occupying large areas of the visual field, the assumption being that the stimulus is misinterpreted as self-displacement and thereby induces postural adjustments. In this context vision was found to prevail over other sensory inputs and a characteristics body tilt in the direction of the visual stimulus occurred (Lee and Lishman 1975; Lestienne et al. 1977; Clement et al. 1985; Hufschmidt et al. 1980). It is surprising, however, that in spite of the fact that visuo-postural responses induced experimentally by linear displacement of visual scenes are unstabilizing with respect to an earth-fixed vertical, little or no habituation or suppression of the responses has been reported (Lestienne et al. 1977; Clement et al. 1985). Since this implies a somewhat inflexible visual control of posture, the following experiments were designed by way of clarification.

Methods

The displacement of the centre of force of the body was measured by means of a force platform. The platform was placed on an earth-fixed floor and located inside a floorless room, measuring 2.50 m long, 2.20 m high and 1.80 m wide, mounted on pneumatic wheels. It could be displaced smoothly and quietly by hand. Its walls and ceiling consisted of a red and pink chequered fabric attached by its edges to the room's frame. The subject stood facing one of the lateral walls at a distance of about 38 cm so that movement of the room produced full field linear stimulation along the y axis (coronal plane). The stimuli consisted of discrete movements of the room, with a sigmoid time-course, lasting approximately 12 s, over a fixed distance of 30 cm with a peak velocity of 2 to 3 cm/s (average peak angular velocity at the level of the eye = 3.76 °/s). Three to nine stimuli were delivered regularly, from right to left and vice versa, with variable interstimuli intervals between 8 and 16 s. Room displacement was monitored with a potentiometer attached to one of the wheels. Nine normal subjects, 4 male and 5 female, aged between 18 and 54 years took part in these experiments under two conditions: first standing shoeless on the platform and then, in order to reduce lower limbs proprioceptive information, on two pieces of foam, the lower one of polystyrene, 5 cm high and the upper one of rubber 2.5 cm high. Two patients were also tested. One was a 68 year old male devoid of proprioceptive function below the knees, due to tabes dorsalis,

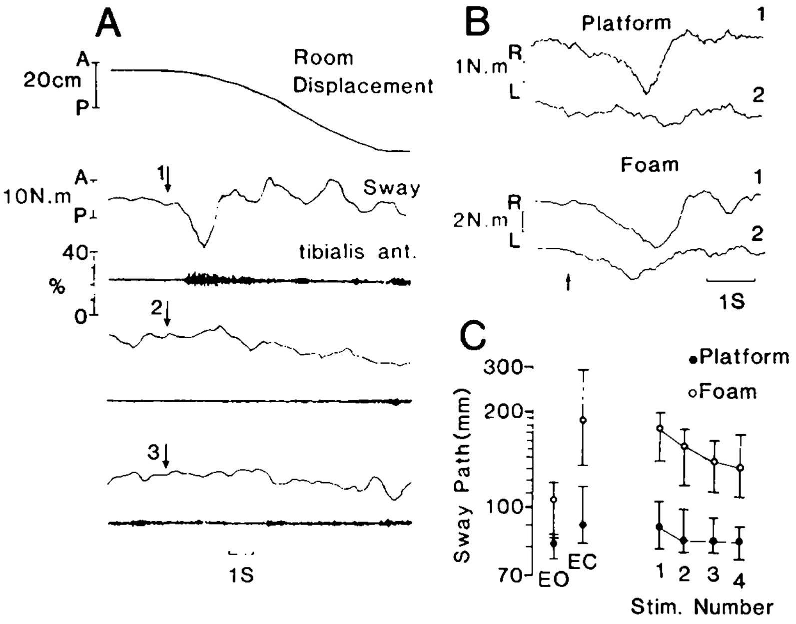

Fig. 1A–C. Habituation of visually evoked postural responses (VEPR). **A** Raw records at the start of 3 successive backward room displacements (arrows 1, 2, 3) in a normal subject. The first stimulus elicits, at a latency of 600 ms, a displacement of the centre of force in the direction of the room movement (primary component) which is absent on subsequent trials. EMG calibration refers to % of maximal voluntary contraction. Sway calibration is in Newton metres. **B** Averaged VEPR of 9 normal subjects at the start of room displacement to the left (arrow) during the 1st and 2nd trial on platform and foam. A primary component during the 2nd stimulus is present only on the foam. Note different calibrations used for platform and foam. **C** Sway path with eyes open without stimulation (EO), closed (EC) and during successive room displacements along the y axis (1–4). Each stimulus number combines room movements to the right and left. Medians and interquartile ranges for 9 normal subjects are presented

whose vestibular function, assessed clinically and by rotational tests, was within normal limits. He was not tested on the foam. The other patient was a female aged 47 years, with acquired absence of vestibular function but otherwise normal on neurological examination. Body sway in the coronal and sagittal planes plus the room displacement signal were recorded on paper with an ink jet polygraph (Elema mingograph) and on magnetic tape and thereafter subjected to further analysis as follows. Visually evoked postural responses (VEPR) were averaged with a signal processor (Solartron 1200) triggered at the start of the room displacement; a window of 6 s was set, the first 15% of which was prestimulus analysis. Since this procedure is dependent upon reproducible stimuli, the distance traversed by the room was mechanically limited to 30 cm, and the stimuli were always delivered by the same experimenter. Under these conditions the mean duration of 25 consecutive displacements was 11.80 s with a SD of 0.82 s, a variance considered adequate for the purpose of this study in the light of the long duration responses. Each individual stimulus was expanded in time (× 4) and amplitude (up to × 100) in order to check that the signal processor was actually triggered at the start of the movement; a tolerance limit of ± 35 ms was set, representing ± 5% of a typical latency of 700 ms to the beginning of the postural response (Lestienne et al. 1977). A second analysis involved measurements, in the normal subjects, of the "sway path" along the y axis over periods of 12 s, using a computer program similar to that described by others (Hufschmidt et al. 1980). In brief, the force signals from the subject standing on the platform were normalised to represent the force exerted by a 70 kg mass. During body sway the signals from the platform behave as if the force is moving across the surface of the platform. The computer program samples the momentary position of the centre of force and sums differences between successive positions to calculate the total length of the path of sway. A minimum of 4 periods with eyes open, facing the stationary room, and eyes closed were analysed and compared to the periods during which visual stimuli were applied. Experiments were also carried out with similar room displacements along the x axis (sagittal plane) by placing the platform in the centre of the room with subjects facing the front wall. Four female and one male normal subjects, aged 17 to 54 years, were tested standing shoeless on the platform. Surface EMG was recorded from soleus and tibialis anterior. In all experiments, prior to any stimulation all subjects were informed that the room, but not the platform, would move and were encouraged to keep a natural upright posture. Following the experimental session all subjects were asked to report any sensations induced by the room displacement and in particular if they experienced an illusion of movement in a direction opposite to that of the visual stimuli (linear-vection).

Results

Results from normal subjects are shown in Fig. 1. Following stimulation, the first or primary response was a postural displacement in the same direction as room movement, with a latency of some 600 ms (Fig. 1A). This was followed by a burst of EMG activity in the muscle antagonist to the primary component thus bringing about a corrective displacement in the opposite direction (secondary component). Thereafter, during the remainder of the stimulus, the tracings revealed a general non-specific instability. Strikingly, however, on repetition of the stimulus, the primary component was conspicuously absent.

Table 1. Amplitude of primary component of VEPR (N.m) during the 1st and 2nd stimuli. The responses to the first stimulus in each direction were averaged for all normal subjects. The procedure was repeated for the second stimulus

	Lateral stimuli		Backward stimuli
	platform	foam	platform
1st stimulus	1.81	4.54	7.87
2nd stimulus	0.64	3.76	2.57
%	35	82	32

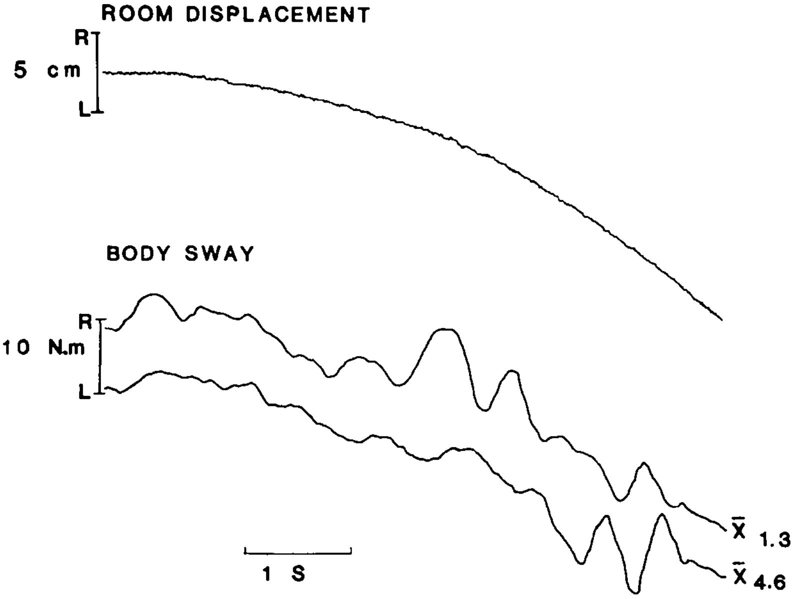

Fig. 2. Body sway induced by room movement to the left in a patient devoid of lower limbs proprioceptive information due to tabes dorsalis. The first three (1.3) and second three (4.6) averaged responses are shown

The responses to the initial room displacement both on platform and on foam were averaged and compared to those obtained during the second, in the same direction (Fig. 1B and Table 1). In respect of the platform responses, although the absolute amplitude of sway was larger in the sagittal than in the coronal plane, the attenuation of the responses referred to above was much the same in both. By contrast, on the foam, the amplitude of the primary component was considerably larger and attenuated only minimally during the second stimulus.

The aggregate sway path length to the first stimulus on the platform was comparable to that with the eyes closed, and decreased thereafter during successive trials to a level intermediate between eyes closed and open without stimulation (Fig. 1C). However, the median values of sway at the second test on the platform fell within the interquartile range of those with eyes open and the room stationary, whereas the values on the foam remained high. Concerning the sensations evoked, although slight "giddiness" or unsteadines was reported, none of the subjects experienced an illusion of self-displacement in the opposite direction to room movement (linearvection). Some subjects felt as if they moved in the direction of the stimulus but this could have reflected their actual bodily displacement.

The results from the patients with absent proprioceptive or vestibular function contrasted markedly. The maximum torque exerted in the direction of the stimulus during the first 6 s of its occurrence was measured by hand from the tracings. The mean value of the combined first stimuli to right and left was 33.15 Newton metres (N.m) for the tabetic patient, and 0.42 N.m for the labyrinthine defective patient. The range for normal subjects lay between 0 and 4.74 N.m (median: 1.60). On foam, the value for the patient without vestibular function was 14.85 N.m, the normal range being 0.8 to 24.89 N.m (median: 6.87). At the second test on the labyrinthine defective patient these values fell to 0 N.m on the platform and 6.85 N.m on the foam indicating a VEPR within normal limits and unimpaired suppression. The tabetic patient, on the other hand, swayed markedly in the direction of room movement with no effective secondary component present. As a result, he repeatedly fell off the platform and had to be caught by two observers standing to his rear. After 3 stimuli in each direction, however, he learnt to avoid falls with a conscious strategy, maintaining "if I didn't want to fall I had to move the other way as soon as the room started to move". Although useful in preventing falls, this voluntary response failed to introduce any modification within the 6 s of analysis of the VEPR (Fig. 2). Neither of the patients had significant modifications of the latency values of the VEPR.

Discussion

This study has shown that novel linear movement of a visual surround along the x or y axis initiates a postural displacement in the direction of the stimulus (primary component), followed shortly afterwards by a corrective (secondary) displacement in the opposite direction. This sequence is almost completely suppressed on subsequent stimulation. In marked contrast to this, earlier studies have reported either absence of habituation during linear visual stimulation along the x axis or its relatively slow development in the coronal plane with a disc rotating around the visual axis (Lestienne et al. 1977; Clement et al. 1985). An essential difference, however, is that the stimuli utilized here were discrete, short in duration, did not elicit vection illusions in the opposite direction and, perhaps more importantly, were within the linear velocity range of normal body sway. The VEPR, occurring during the accelerative phase of the stimulus, susceptible to rapid habituation and counteracted by a corrective component within 1 s of its initiation, seems appropriate to the execution of visuo-postural adjustments during the recurrent small changes in posture present in spontaneous body sway. The ease with which habituation occurs probably reflects the fact that, not infrequently, vestibulo-proprioceptive clues take over the normally dominant role of vision in sway control in the presence of diminished or inappropriate visual information. On the other hand, postural changes induced by rapid and long-lasting visual stimuli, associated with vection illusions, probably mediate balance adjustments to significant body displacements occurring, for instance, during locomotion or vehicular travel. It is arguable that in these situations, habituation would be undesirable since vision, once the accelerative phase of movement has ended, is the main sensory channel for body motion. The similarity in the latency values of these two types of visuo-postural responses, however, could indicate that common pathways are involved.

The studies with normal subjects on foam and with the tabetic patient indicate that, in the absence of reliable visual information, proprioceptive clues take precedence over vestibular. This is probably due to the fact that the range of frequencies and velocities present in ordinary body sway and in the stimuli applied in this study are too low to be effectively detected by the vestibular apparatus. Similarly, as shown by the impaired habituation of VEPR in the normal subjects tested on foam and in the tabetic patient, conscious efforts to "neglect" a known unstabilizing visual stimulus were not successful in the absence of an alternative source of reliable sensory information.

The rapid habituation of VEPR illustrates the remarkable plastic properties of the mechanisms detecting and correcting spontaneous body sway, and supports the concept formulated by Talbott and Brookhart (1980) of modifiable effectiveness of the visual input in the control of balance in different environmental contexts. The suggestion is that the fine sensory control of body sway is hierarchically organised; vision normally dominates over proprioceptive information from the lower limbs, but this arrangement can be quickly reversed depending upon the changing conditions in the environment. The role of volitional and vestibular activity to this end is comparatively much less effective.

Acknowledgements. The author was supported by a grant from the Brain Research Trust. My gratitude goes to Dr. J.D. Hood for having inspired and supervised this work, to Dr. M.A. Gresty for scientific and computer expertise and to Dr. D.N. Lee for critical review of an earlier manuscript.

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Received December 9, 1985 / Accepted May 13, 1986