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RESPONSE PATTERNS TO POSTURAL PERTURBATION IN DEAF CHILDREN WITH VESTIBULAR DYSFUNCTION*

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SUMMARY This study was designed to investigate the postural responses of deaf children, with and without vestibular dysfunction, to support surface induced anterior body sway. All subjects displayed a distal (gastrocnemius) to proximal (hamstring) EMG activation pattern. However, those with vestibular dysfunction produced an initial response of 170 ms, some 40 ms slower than their peers. It was proposed that this delay was due to either a visually dominated response, as opposed to a proprioceptive mediated response, or that simply more time was required to process body sway parameters in the absence of complete vestibular feedback. Either strategy would allow appropriate response amplitudes to be generated and, therefore, more efficiently normalize posture. This notion was supported by the absence of diminutive EMG responses over trials by a child with vestibular dysfunction employing a comparatively fast gastrocnemius response. This child also exhibited excessive upper body sway.

Key words: Deaf, postural response, postural displacement, equilibrium, vestibular dysfunction, long loop reflex

Introduction

The long loop reflex is thought to be the mechanism by which humans compensate for unexpected limb displacement during volitional movement. Based upon the excessive latency of the reflex response it has been proposed that this mechanism is governed by supraspinal struc-

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tures. For example, responses with latencies of approximately 6 have been found to compensate for limb disturbance in relation movement preparation (Bonnet, 1983), movement duration (Lee Tatton, 1982), and target directed movements (Capaday and Coo 1983). Of further interest is the effect of CNS lesions on long lo responses. Not only does such research provide insight into theoreti issues of motor control but, as Grimm and Nashner (1978) ha proposed, it supplies a functional analysis of a patient's movem deficits.

This latter issue has certainly been a focus of research in the study long loop responses to lower limb displacement in the freely standi subject. Such compensatory responses are not only necessary in t maintenance of upright posture but are also essential components skilled movement (Gahery and Massion, 1981). Needless to say su research has wide implications for the field of rehabilitation. Studi manipulating postural disturbance have exposed discriminating refl response characteristics between normal subjects and patients wit peroneal muscular atrophy, dorsal column lesions, and cerebellar dy function (Mauritz, *et al.* 1980), vestibular dysfunction (Brunt, *et al.* 198 Nashner, *et al.* 1982), and hemiplegia (Badke and Duncan, 1983). Certain invariant characteristics of this long loop response, also referred to as automatic postural response, have been determined based upon the premise that the response is initiated by forces acting upon the muscles and joints of the foot and lower leg (see Woollacott and Nasher, 1982 for brief comments) and further modified by visual and vestibular descending pathways. For example, in normal adults postural adjustment to induced body sway is characterized by a distal to proximal (gastrocnemius/tibialis anterior to hamstrings/quadriceps) muscle activation pattern with response latencies between 90–110 ms. Proximal muscle activation lagged behind by about 10–12 ms. This pattern was consistent with changes in speed of movement, regardless of the predictability of direction of body sway, and little variation existed when postural adjustments were superimposed with voluntary movement (Nashner and Cordo, 1981). This structure of automatic postural adjustment was present in young children although latencies were generally increased and more variable (Forssberg and Nashner, 1982).

The purpose of this report is to provide initial data on the response patterns to postural perturbations of deaf children to induced anterior body sway. Within the discipline of motor behaviour the inferior balancing abilities of deaf children have been frequently recognized (Brunt and Broadhead, 1982 and 1983). Also, as many deaf children have diagnosed vestibular dysfunction this population provides an alternative human model for the study of sensory mechanisms contributing to postural control.

METHOD

Subjects

Subjects were selected from the Elementary Campus of the Texas School for the Deaf, Austin, Texas. All children had a severe or profound hearing loss and were grouped according to the results of a postrotary nystagmus test (Ayres, 1975), positive results from which indicated an active vestibular system mediating the vestibulo-ocular reflex. This test required the subjects to sit cross-legged on a rotary board that completed one revolution per 2 sec. After 10 rotations the board was stopped and the duration of nystagmus noted. This procedure was repeated only rotating the child in the opposite direction. Based upon the nystagmus response subjects were grouped according to vestibular dysfunction (VD group, n = 4) and for comparison purposes a vestibular non-dysfunction group (VND group, n = 3). This data and further characteristics of the subjects are outlined in Table 1.

Procedures and Apparatus

An electronically driven platform provided brief posterior support surface perturbations at 4 speeds ranging from 12·25 cm/s–18 cm/s. These movements were sufficient to evoke an automatic postural response to anterior body sway without destabilizing the subjects. Subjects stood on the platform with feet bare and shoulder width apart, and arms folded. There were 8 trials with eyes open, each of which consisted of 5 support surface perturbations within an 8 sec period. Every trial began at the slowest speed with the order of presentation of the rate of translation of the remaining platform movements being counterbalanced. This procedure was repeated with eyes closed. Postural adjustment to support surface translation speeds of 13 cm/s and 18 cm/s are reported in this paper where the distance of platform movement was 2·25 cm and 4·5 cm respectively.

TABLE 1. Subject characteristics and postrotary nystagmus results

Group	*Subject*	*Sex*	*Age (Mths)*	*Etiology of deafness*	*Nystagmus scores* *Total (s)*	*SD*
VND	1	F	96	Hereditary	12	−1·0
	2	F	114	Goldenhars	10	−1·3
	3	F	123	Rubella	19	+0·2
VD	4	F	127	Meningitis	0	−3·0
	5	M	129	Hereditary	0	−3·0
	6	F	96	Meningitis	0	−3·0
	7	F	100	Meningitis	0	−3·0

Electrical activity was recorded from the gastrocnemius and hamstring muscles by centrally placed surface electrodes. The electromyographical (EMG) signals were transmitted to Tektronix AM 502 Differential Amplifiers by Harvard Apparatus Preamplifiers. Muscle activity was recorded with a Hewlett-Packard 396A instrumentation tape recorder. The analog signal was rectified and filtered and temporal data was visually determined from hard copy. An Automax 16mm driven movie camera recorded body sway (52 frames/s) from which data on ankle, knee and hip angular displacement was recorded. The data was digitized and computer processed prior to being displayed on a Hewlett Packard 72216 plotter.

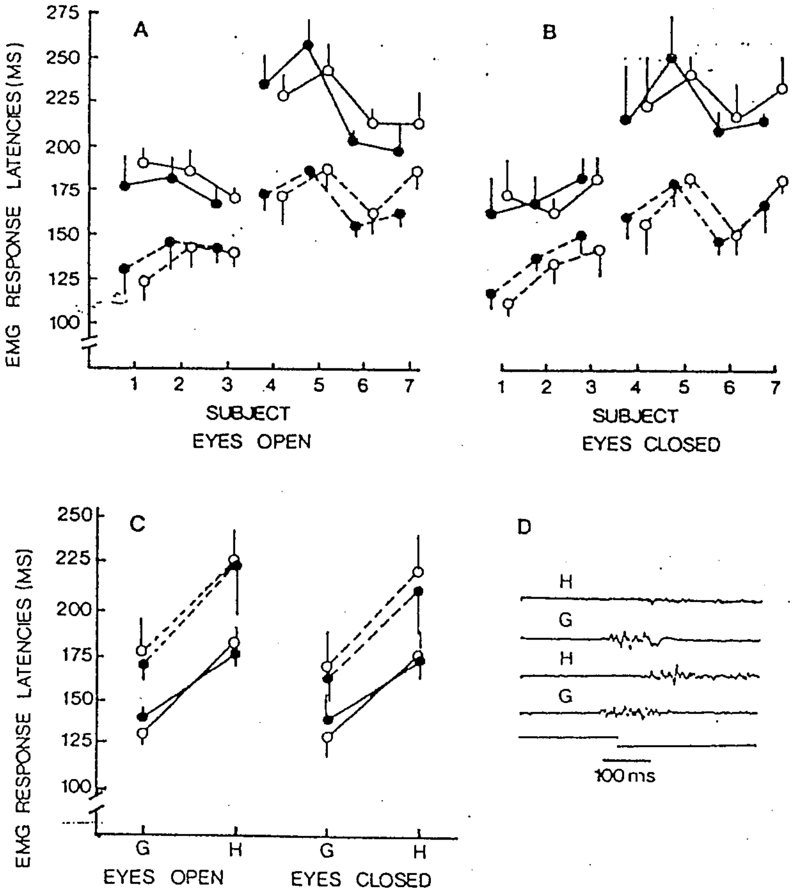

FIG. 1A–D. EMG latencies for automatic postural adjustments to anterior body sway with posterior platform displacement at 13 cm/s (solid circles) and 18 cm/s. In A and B, individual mean response latencies (±1SD) for gastrocnemius and hamstrings (solid line) muscles. In C, ensemble mean latencies (±1SD) for NVD (solid lines) and VD group for gastrocnemius (G) and hamstring muscles (H). In D, typical EMG response for subject 5 with platform speed at 18 cm/s.

RESULTS

Subjects' individual mean EMG response latencies and variability data are shown in Figure 1A–B while Figure 1C displays ensemble group mean latencies. Figure 1D is a typical EMG response for subject 5 depicting the distal to proximal muscle activation pattern with excessive response latencies. Clearly, all subjects utilize a distal to proximal muscle activation pattern. For the NVD group (eyes open condition, 13 cm/s) mean response latencies for the gastrocnemius and hamstring muscles were 136 ms and 182 ms respectively (fig. 1C). This initial response is perhaps more delayed than previously reported for children of similar age but approaches that of younger age groups (Forssberg and Nashner, 1982). Activation of the hamstrings was also comparatively delayed (46 ms as opposed to 20 ms). The VD group also displayed the same EMG sequencing characteristics but with apparent further delayed responses. For the eyes open condition at 13 cm/s, mean latencies were 170 ms and 223 ms. For both groups an increase in the speed of platform displacement or the removal of vision had minimal effect on response latencies. The variability of the response data proved to be similar for both groups. The NVD group recorded average relative variabilities of 6% for the eyes open condition (gastrocnemius and hamstring data combined) and the VD group 8·5%. For the eyes closed trials response latencies proved to be slightly more variable with respective values of 10% and 11%. Within the context of the task there appears to be certain expected characteristics of the automatic postural response exhibited by both groups with overall response latencies being the only discriminating factor.

Visual inspection of the displacement data did not reveal overiding group differencies in postural sway characteristics. However, certain subjects displayed joint displacement data that were consistent across all visual and platform speed conditions. Figure 2 depicts selected tracings of the data averaged over 4 trials per condition.

Presumably efficient processes for postural control would generate appropriate task dependent EMG activity such that the lower limb and trunk were maintained in relative alignment. This seems to be the case for subject 3 (fig. 2A) who also recorded the superior nystagmus response (table 1). However, with subject 6 (fig. 2B) the upper body is displaced well beyond the base of support and the mechanism that co-ordinates muscle activity is obviously not established. Presumably this subject would be close to the limits of stabilization. The third dominant postural strategy to emerge was that of subject 4 (fig. 2C), which indicates a precautionary response whereby the decision to allow excess ankle and knee displacement obviously limits upper body sway and maintains the center of gravity firmly within the base of support. In general, it was

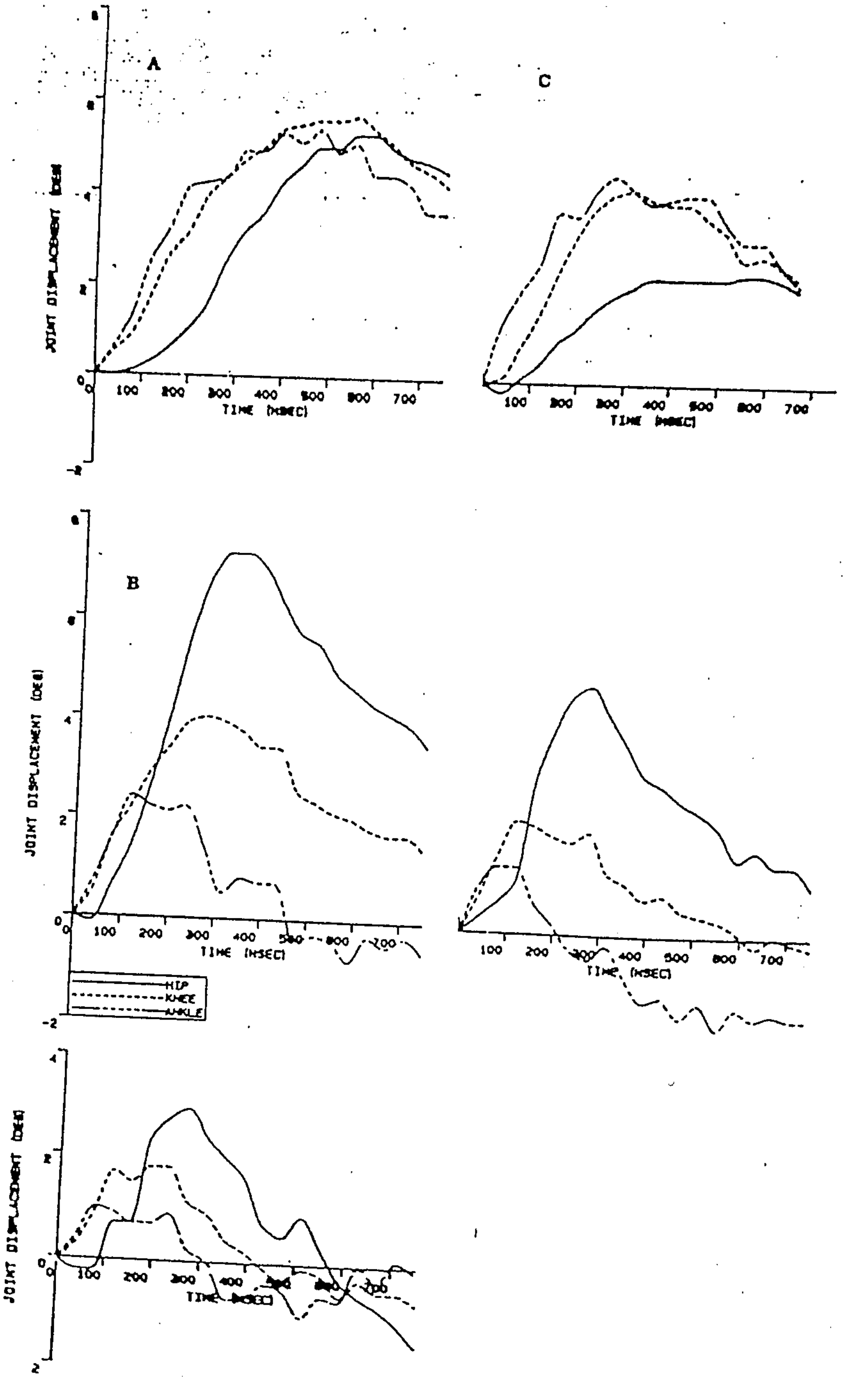

FIG. 2A–C. Ankle, knee and hip displacement data. For A, subject three, 18 cm/s (eyes closed). In B, subject six from left to right, 18 cm/s (eyes open), 13 cm/s (eyes open), and below 13 cm/s (eyes closed). In C, subject four, 18 cm/s (eyes open).

observed for all subjects that increased speed of platform displacement increased body sway, while with some subjects eyes closed conditions served to decrease overall body sway. With eyes closed it has been observed that subjects become more tense (Edwards, 1946) which could therefore contribute to an increase in stiffness and reduced joint displacement. This effect is noted in Figure 2B at the platform speed of 13 cm/s.

DISCUSSION

The initial EMG response for the NVD group approached previously observed performances of young children (Forssberg and Nashner, 1982). However, the tight synergistic hamstring linkage (about 12 ms) that helps control upper body displacement was not present. Perhaps the platform perturbations imposed limited demands on the subjects such that delayed hamstring activity (40–50 ms following the gastrocnemius response) was task appropriate to establish limb co-ordination. For example, the speed of platform translation was far less than reported in other studies and the direction of movement was obviously predictable with only one degree of freedom for platform movement (although Nashner and Cordo (1981) observed that choice displacement had little effect on response latency during faster perturbations).

Anticipation of response was also probably enhanced by the subjects becoming accustomed to rhythmical perturbations within a trial sequence. However, Shumway-Cook and Woollcott (1984) have recently reported similar synergistic delays with groups of younger normal and Downs Syndrome children. Perhaps we are therefore noting a developmental component of the postural response with optimal performance coinciding with maturation of the vestibular system. This distal-proximal temporal delay would presumably persist with a non-functioning or partial-functioning labrynthine system. The mean gastrocnemius response for the VD group (fig. 2C) is obviously delayed but the reflex response maintains a temporal synergistic relationship similar to that of the NVD group.

Reasons for the response delay are at present speculative. One simple possibility is that vestibular dysfunction creates some disturbance to the sensory processing organization that mediates, and, in this instance, is responsible for the delayed automatic postural response. A second possibility is that the VD children selected a visually dominated response strategy as opposed to sensory input from the foot and lower leg. Nashner (1976) found this to be the case with some adult subjects who employed a reflex response of about 180 ms to platform perturbation. Vision as the dominant sense in maintaining posture has received support elsewhere. For example, Lee and Lishman (1975) claimed that visual and vestibular proprioception dominate the learni of a new task until lower limb musculature is sufficiently tuned become the major stabilizing influence. Bles *et al.* (1983) also noted th the weight of vision in maintaining balance becomes considerably large in recent labyrinthless patients.

There being little change in response characteristics with eyes close obviously threatens the proposal of a visually dominated response. Eye closed trials were presented last for safety and co-operation motives prior to which subjects had already received at least 40 platform perturbations. There may therefore be a design-ordering effect as by now the subjects had established a stereotyped response and merely increasing muscle stiffness was sufficient compensation for eyes closed. This increase in stiffness may also explain the slight reduction in EMG latencies and for some subjects reduced body sway (see fig. 1 and 2B).

The speed of platform translation may have permitted some of the VD group to employ a delayed automatic reflex response. Thus, increased processing time of body sway parameters would be available resulting in more efficient response amplitudes. Task appropriate response amplitudes must be applied or a destabilizing effect will result which becomes more exaggerated with increased body sway. Perhaps this is the case with subject 6 whose response latencies were relatively short compared to other members of the VD group. From visual inspection of Figure 2B,

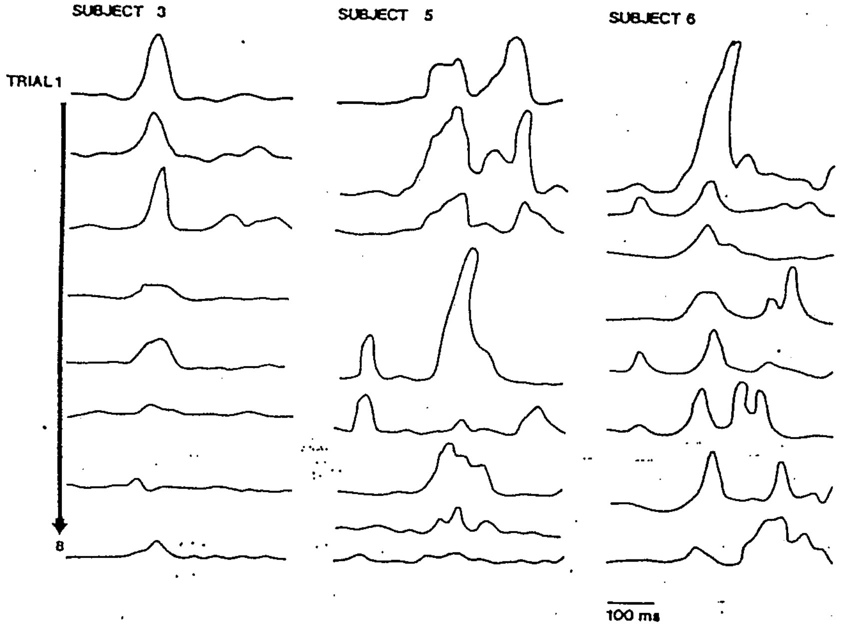

FIG. 3. Changes in gastrocnemius EMG amplitudes for eyes open condition with platform speed of 18 cm/s.

response amplitudes do not appear to be task appropriate and lower limb rotation is abruptly halted which enhances upper body sway in the absence of immediate hamstring activity. Further evidence for this notion is provided in Figure 3 which shows averaged EMG for the gastrocnemius at 18 cm/s eyes open condition. For subject 3, who displayed appropriate control over limb displacement, there seems to be a definite learning effect with response amplitudes diminishing over trials. Secondary EMG activity was not required to normalize posture. This trend is also apparent with subject 5 who had the most delayed response latencies. However, for subject 6 a diminishing effect is not apparent and a secondary (presumably voluntary) EMG burst was required to normalize posture.

It is possible therefore, that when using a typical long latency reflex response, those with vestibular dysfunction are unable to pre-tune the spinal mechanism and apply appropriate variant force characteristics to the postural response program. It is well documented that the vestibular system exerts excitatory influence upon alpha and gamma motoneurons via the lateral vestibulospinal tract (Wilson and Melvill-Jones, 1979), the destruction of which is thought to affect background EMG activity (Miller, *et al.* 1982). Further support for this notion is provided by Aiello *et al.* (1983) who reported that the degree of body tilt had minimal effect on H-reflex amplitudes in the labyrinthine defective patient although in normals body sway has an excitatory effect on the alpha motoneuron pool (Aiello *et al.* 1983; Chan and Kearney, 1982). Also, Nashner *et al.* (1982) did in fact report EMG amplitude changes with their vestibular subjects, however, they were not systematically related to context. A faster platform displacement may have enforced the use of the quicker reflex response by the VD group resulting in inappropriate response amplitudes and excessive body sway.

This paper has reported some characteristics of the automatic postural response of deaf children. The major finding was that deaf children with vestibular dysfunction exhibited excessive response delays. It was proposed that these children employed a delayed response due to either a strategy of visual dominance or the requirement for additional sensory processing time to compensate for inadequate vestibular input into detecting and controlling body sway. Either strategy may compensate for a non-functioning (or partial functioning) labyrinthine system and thereby in maintaining upright posture spinal pre-tuning and response amplitudes will be task appropriate.

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