Differences in coding provided by proprioceptive and vestibular sensory signals may contribute to lateral instability in vestibular loss subjects

JournalArticle (Originalarbeit in einer wissenschaftlichen Zeitschrift)

ID 1192538
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Year 2008
Title Differences in coding provided by proprioceptive and vestibular sensory signals may contribute to lateral instability in vestibular loss subjects
Journal Experimental brain research
Volume 184
Number 3
Pages / Article-Number 391-410
Keywords human balance control, vestibular loss, proprioception, muscle activity, leg flexion responses, stretch reflex
One of the signatures of balance deficits observed in vestibular loss subjects is the greater instability in the roll compared to pitch planes. Directional differences in the timing and strengths of vestibular and proprioceptive sensory signals between roll and pitch may lead to a greater miscalculation of roll than pitch motion of the body in space when vestibular input is absent. For this reason, we compared the timing and amplitude of vestibular information, (observable in stimulus-induced head accelerations when subjects are tilted in different directions), with that of proprioceptive information caused by stimulus induced rotations of ankle and hip joints [observable as short latency (SL) stretch responses in leg and trunk muscle EMG activity]. We attempted to link the possible mode of sensory interaction with the deficits in balance control. Six subjects with bilaterally absent vestibular function and 12 age-matched controls were perturbed, while standing, in 8 directions of pitch and roll support surface rotation in random order. Body segment movements were recorded with a motion analysis system, head accelerations with accelerometers, and muscle activity with surface EMG. Information on stimulus pitch motion was available sequentially. Pitch movements of the support surface were best coded in amplitude by ankle rotation velocity, and by head vertical linear acceleration, which started at 13 ms after the onset of ankle rotation. EMG SL reflex responses in soleus with onsets at 46 ms provided a distal proprioceptive correlate to the pitch motion. Roll information on the stimulus was available simultaneously. Hip adduction and lumbo-sacral angular velocity were represented neurally as directionally specific short latency stretch and unloading reflexes in the bilateral gluteus medius muscles and paraspinal muscles with onsets at 28 ms. Roll angular accelerations of the head coded roll amplitude and direction at the same time (31 ms). Significant differences in amplitude coding between vestibular loss subjects and controls were only observed as a weaker coding between stimulus motion and head roll and head lateral linear accelerations. The absence of vestibular inputs in vestibular loss subjects led to characteristic larger trunk in motion in roll in the direction of tilt compared to pitch with respect to controls. This was preceded by less uphill flexion and no downhill extension of the legs in vestibular loss subjects. Downhill arm abduction responses were also greater. These results suggest that in man vestibular inputs provide critical information necessary for the appropriate modulation of roll balance-correcting responses in the form of stabilising knee and arm movements. The simultaneous arrival of roll sensory information in controls may indicate that proprioceptive and vestibular signals can only be interpreted correctly when both are present. Thus, roll proprioceptive information may be interpreted inaccurately in vestibular loss subjects,

leading to an incorrect perception of body tilt and insufficient uphill knee flexion, especially as cervico-collic signals appear less reliable in these subjects as an alternative sensory input.

Publisher Springer
ISSN/ISBN 0014-4819
edoc-URL http://edoc.unibas.ch/dok/A5845483
Full Text on edoc No;
Digital Object Identifier DOI 10.1007/s00221-007-1112-z
PubMed ID http://www.ncbi.nlm.nih.gov/pubmed/17849108
ISI-Number WOS:000251642200011
Document type (ISI) Journal Article