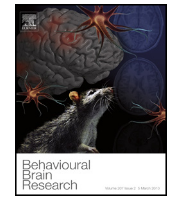
Behavioural Brain Research 272 (2014) 150–155

Contents lists available at ScienceDirect

Behavioural Brain Research

journal homepage: www.elsevier.com/locate/bbr



Research report

Illusory self-motion perception evoked by caloric vestibular stimulation in sitting versus supine body positions

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HIGHLIGHTS

- We studied self-motion illusions evoked by caloric vestibular stimulation.
- With the subject's head in an unchanged position in space, we compared 2 body positions.
- In the sitting body position illusions of self-motion in yaw predominated.
- In supine body position illusions of self-motion in roll predominated.
- The changed somatosensory input modifies vestibularly evoked ego-motion illusions.

ARTICLE INFO

Article history:
Received 10 April 2014
Received in revised form 23 June 2014
Accepted 24 June 2014
Available online 1 July 2014

Keywords:
Caloric
Vestibular
Somatosensory
Self-motion
Illusion
Perception

ABSTRACT

The purpose of this study was to determine (i) if a change in the body position that alters the somatosensory afferentation and thus the signal integrated by sensory interaction influences the illusory self-motion perception evoked by cold calorics. If yes, (ii) is the direction of the provoked nystagmus also changed?

The vestibular system in 47 healthy subjects was stimulated calorically with 20 °C water while in supine and sitting positions but with the head fixed. After each procedure the subjects were asked to describe their self-motion experience, and the provoked nystagmus was analyzed.

In 45.7% of these subjects a sensation of yaw rotation was reported while in the sitting position, whereas only 9.6% had this sensation while in the supine position. However, when in the supine position the experience of roll rotation dominated, i.e., 52.1% compared to 5.3% while in the sitting position. Pitch rotation was felt only in the sitting position by 4.3%. There was no such sensation in the supine position. The perception of a full-cycle rotation dominates in the sitting position. In the sitting position 20% of the subjects reported eccentrical head rotation along the circumference of a cone—the top of the cone was located in the neck region. Linear self-motion sensations did not differ in the two positions. The evoked nystagmus in both positions was only horizontal.

In conclusion, a change in body position with respect to the gravity vector, while head position is fixed, causes a change in the somatosensory afferentation and modifies the integrated sensory signal by sensory interaction. In turn it influences the self-motion perception evoked by calorics. A change in body position does not affect the direction of nystagmus.

1. Introduction

Self-orientation depends on the integration of information from the visual, proprioceptive, and vestibular sensory systems [24,43,47]. The vestibular system is thought particularly important, since it is organized to detect self-motion. Previous studies have applied different types of stimulation to elucidate how the system detects self-motion [6,23,28,32,55]. Rotational stimulation, caloric vestibular stimulation (CVS), galvanic vestibular stimulation (GVS), and other electrical stimulation are the major methods.

Caloric vestibular stimulation in healthy subjects causes varying illusory self-motion perceptions: angular, linear, or complex, compound movements [32]. Vestibular patients also sometimes report abnormal bodily perceptions such as depersonalization and derealization sensations [33,49]. Anatomical substrates similar to those types of illusory self-motion sensations described elsewhere [32]

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http://dx.doi.org/10.1016/j.bbr.2014.06.051
0166-4328/

are provoked by intracranial electrical stimulation via depth electrodes [28]. Stimulation of the parietal operculum elicited pitch plane illusions, stimulation of the temporal cortex caused yaw plane illusions. Translational linear illusions were more frequently elicited by stimulation of the mesial parietal cortex [28]. Wiest et al. [55] reported that the stimulation of the right paramedian precuneus induced a linear self-motion perception. Foerster [21] found that electrical cortical stimulation of the intraparietal sulcus in awake patients elicited full body rotations in space. Blanke et al. [6] also observed rotational and swaying bidirectional vestibular sensations during the stimulation of two adjacent sites at the anterior part of the intraparietal sulcus using subdural grids. Earlier studies reported sensations of “swinging, spinning”, “sinking feeling”, and “head jumping up and down” during stimulation of the superior temporal gyrus in patients who had undergone an operation for focal epilepsy [44–46]. All these data reflect the complexity of the vestibular sensations as well as the higher level of processing of vestibular information.

In contrast to the numerous studies on the effects of caloric stimulation in humans while in the conventional supine position, there are no reports on self-motion sensations evoked by caloric stimulation during the sitting position and with head inclined 60° backward thus bringing the lateral canals into the vertical plane. Caloric stimulation in this position induces the same endolymphatic current in the lateral canal as in the conventional supine position with head raised 30° above the horizontal. If only this one point is considered one may suppose that the illusory self-motion perception will not differ in the two body positions. However, there are other factors that may influence perception, for instance, a change in somatosensory input. Self-motion perception and the direction of nystagmus are generally congruent, but not when the stimulus is caloric [32]. Another factor influencing dissociation between both reactions is probably body in space position [42]. They determined that the spinning sensation stopped “almost instantaneously” when microgravity was held by a “tilt suppression” procedure, while the duration of post-rotatory nystagmus was as long as those periods of nystagmus observed pre and post flight when the head was in an erect position (no tilt suppression).

Vestibulo-somatosensory convergence in the vestibular nuclei, thalamus, and cerebral cortex has been shown in animal and human studies [7,22,41,48,56,58,60]. Functional imaging studies reveal that the vestibular cortical projections overlap with the somatosensory cortical projections [7,60]. Caloric and galvanic vestibular stimulation in experimental studies have been shown to modulate tactile perceptual thresholds [18,19]. Ferrè and co-workers also found that CVS selectively enhanced the N80 wave of somatosensory-evoked potentials (SEPs) [20]. Their source has been localized in the parietal operculum [16]. The vestibulo-somatosensory covergence is shown in clinical studies by means of CVS and GVS. The vestibular stimulation can produce transient remission of hemianaesthesia in brain-damaged patients [50,53]. All this suggests multilevel and multifocal interaction between vestibular and somatosensory signals that leads to modulation of perception.

Interestingly George and Fitzpatrick [23] found that changing head posture changes the interpretation of the galvanic vestibular signal for balance and orientation responses. All this raises the following question. Since there is a multilevel vestibular-somatosensory interaction, how does a change in body posture influence vestibularly evoked self-motion perception?

Therefore the aim of this study was to determine (i) if a change in the body position alters the somatosensory afferentation and thus the integrated signal due to sensory interaction, does it influence the illusory self-motion perception evoked by cold caloric vestibular stimulation? If yes, (ii) does the direction of the provoked nystagmus also change?

2. Material and methods

2.1. Subjects

Forty-seven healthy subjects (30 females and 17 males) took part in the study—(mean age 43.13 (SD ± 15.95), range 25–60). The volunteers from the hospital staff and responders to the public announcement were not compensated for participation. The subjects gave their written informed consent to take part in the study, which was approved by the Ethics Committee of the Medical University—Sofia in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

All subjects were examined in the Department of Neurology and Neurootology in the University Hospital “St. Naum”, Sofia. They had no history of vertigo, unsteadiness, hearing loss, or neurological disorders nor was anyone under psychiatric care or on psychotropic medications. The vestibular screening examination consisted of the head-impulse test, head-shaking test, caloric test, Dix–Hallpike testing, angular VOR evoked via rotation, and posture control measures. All values were within the normal range.

Furthermore, a short questionnaire was administered to the subjects who were asked to indicate any known history of dizziness or vertigo, back/neck problems, or cardiovascular, neurological and other physical problems. Subjects were also asked about susceptibility to motion-sickness.

2.2. Methods

Caloric irrigation of the external auditory canal was done in a darkened room. The irrigation was performed in two body positions that were randomized between the subjects. In the supine position subjects were asked to lie supine with their head oriented 30° upward to the horizontal. In this position the lateral canals were brought into the vertical plane. The caloric test (external auditory canal irrigation with 150 cm^3 water per 20 s) was administered alternatively to each ear using 20 °C cold water. In the sitting subjects were asked to sit with their head oriented 60° backward to the vertical. In this position the lateral canals were again brought into the vertical plane and the same cold caloric irrigation—with 150 cm^3 20 °C cold water per 20 s was applied alternatively to each ear. The inter stimulus interval was 10 min. The head was kept in a fixed position by straps. All participants were asked to report their self-motion experience during the two parts of the study. After each procedure they manipulated a hand-held doll in order to duplicate the sensation and give more precise data on the subject’s illusory movements. They were also intentionally asked a few questions in order to have them describe the illusory motion completely.

The eye movements were recorded and analyzed off-line using videooculography of Synapsys. The statistical analyses were performed with SPSS 16.0, and the statistical significance was set at $p < 0.05$. A descriptive statistic of demographic data was applied. The Wilcoxon signed-rank test was used to evaluate the difference between perceived self-motion in both body positions.

3. Results

3.1. Self-motion perception

Subjects reported two kinds of illusory perceptions while sitting as well as lying supine: angular (Fig. 1) and linear (Figs. 2 and 3) movement sensations.