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Vestibular System Galvanization in Man: the Effect of Stimulation Field Changes on the Angle of Body Mass Centre Displacement

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Summary

During monopolar monoaural galvanization the absolute value of body mass centre displacement angle did not depend on the stimulation electrode position. The angle value was always close either to 0° or to 180° (i.e. in the latero-lateral direction). However, some fine angle differences between different electrode positions occurred and they were statistically significant in two cases. During monoaural bipolar stimulation the body mass centre moved practically in all directions (for all four used electrode positions) and the angles formed a more or less coherent rosette in the range of 0° – 360°.

Key words

Vestibular system – Galvanization – Electrode position

Introduction

The technique of galvanic stimulation is often used for studying either the participation or the role of the vestibular system in the process of subject's orientation in his environment. This technique is used as a selective method for influencing the afferentation of the vestibular system during motor task execution. The selectivity is required because of the parallel action of other sensory systems working besides the vestibular apparatus (i.e. mainly proprioception and vision).

However, such a procedure is not without objections and reservations (Nashner and Wolfson 1974, Lund and Broberg 1983), following from vague or only hypothetical knowledge of the origin of fenomena evoked by vestibular system galvanization. It is therefore necessary, besides utilizing the galvanization procedure, also to study further its effects.

Papers utilizing vestibular system galvanization in the field of sensory-motor coordination are based mainly on the lateral displacement of body mass centre. It is the so-called "anodic fall" (Blonder and Davis 1936). Deviations in the anterior-posterior direction were considered to be statistically nonsignificant (Bizzo and Baron 1972). In more recent papers they are more and more in the centre of attention and the conditions of their appearance are being studied (Njiokiktien and Folkerts 1971, Magnusson *et al.* 1990). The geometry of the stimulation field in relation to the stimulated organ can play, besides other factors, some role in their action. Stimulation electrodes in the vicinity of the ear are often situated differently and their placement is not standardized (Gorgiladze *et al.* 1983, Hlavačka and Njiokiktien 1985, Popov *et al.* 1986). It is known that changes of the stimulation field – a change of stimulation electrode position in relation to the vestibular nerve – may substantially modify the neuronal activity at the level of the VIII's nerve (Goldberg *et al.* 1984).

It is a question whether the change of stimulation field geometry can modify the subject's motor reactions. To elucidate this, the statistical dependence of the body mass centre displacement angle on the changing stimulation field geometry was investigated during monopolar and bipolar vestibular stimulation.

Material and methods

The change of stimulation field geometry was achieved either by changing the position of the surface electrodes placed in the vicinity of the ear, or by changing the monopolar stimulation to a bipolar one.

Each change of the stimulation field represented a separate experiment:

I. Influence of the change in surface electrode position on the direction of body mass centre displacement during monopolar monoaural galvanization in standing man (see Fig. 1A).

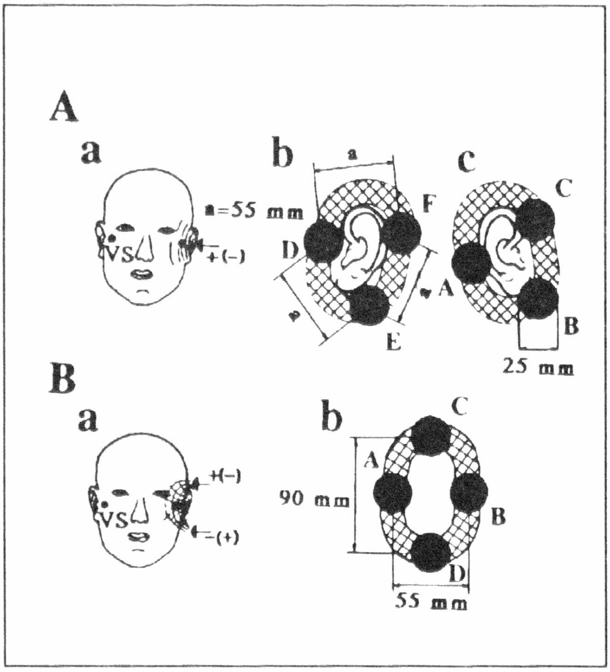

Fig. 1
A – Experiment I, B – experiment II. a – schematic chart of monopolar and bipolar stimulation. b,c – stimulation electrode locations and their dimension. VS: vestibular system.

II. Influence of change from the monopolar to bipolar monoaural vestibular stimulation, on direction of body mass centre displacement during galvanization in standing man (see Fig. 1B).

Fifteen adult persons were taken into experiment I. The subjects' average age was 30 years, S.D. = ± 9 years. Every subject was stimulated three times (in a sequence of at least 0 s) in each electrode position. The stimulating electrode was always positive. The reference electrode was fastened to the wrist of the contralateral hand. The used stimulation electrode positions are shown in Fig. 1A. The necessary number of experimental subjects was calculated for 95 % statistical reliability, for an estimated value of standard deviation $\sigma = 20^{o}$ and for the expected value of angle differences 10^{o}.

Twenty adult persons were studied in experiment II. Their average age was 31 years, S.D. = ± 8 years. Each subject was stimulated twice in each electrode position in a sequence of at least 30 s with each polarity. The used electrode positions are shown in Fig 1B.

The stimulation electrode positions or polarities were periodically changed in the stated sequence; for exp. I {+D, +E, +F} or {+A, +B, +C}, and for exp. II {+A-B, +B-A, +C-D, +D-C}.

All measurements were made in the upright position with the eyes closed. The angle between the feet was 30^{o} - heels together.

The body mass centre displacements were registered by the stabilometric method [Hlavačka and Mihalik 1986). During all measurements in one vestibular organ (either left or right) the investigated person did not change the position of his feet in relation to the surface of the stabilometric device. A constant current generator was used for the galvanization (Mihalik and Hlavačka 1985). The stimulus current intensity was 2 mA and it lasted for 4 s. The stimulation electrodes were made of stainless steel covered with cotton wool moistened with physiological saline; their shape is shown in Fig. 1. The electrodes were fixed to a frame of convenient ear phones. Neither the frame nor the electrode positions on the head were changed during the whole experiment.

The stabilometric signals were processed as follows: The body mass centre displacements were recorded in lateral (x) and anterior-posterior (y) directions. From these signals the course of body mass centre distance was calculated in respect to the position that the body mass centre acquired at the time when stimulation was started.

From the maximum distance value-M, the values corresponding to 0.1 M and 0.9 M were then calculated. The whole course of the body mass centre displacement from the start (2.5 s before galvanization) until achieving the value of 0.1 M was considered as the "starting" position. Similarly, the course of body mass centre position from the value corresponding to 0.9 M up to the end of galvanization was considered as the "achieved" position. Both these positions were named the "static" phases of body mass centre displacement. The mean values of coordinates x_i and y_i calculated for both the mentioned positions are considered as co-ordinates of the "starting" and "achieved" positions. The whole course between 0.1 M and 0.9 M is regarded as the "dynamic" phase of body mass centre displacement. The static and the dynamic phases of the displacement were separately evaluated by the following procedure. For the static phases, the angle was calculated from the coordinates of the starting and achieved positions. For the dynamic phases, the displacement angle was given by the angle of the regression line calculated for its course. The angle values thus obtained were statistically treated and the significance of their deviations were tested by Student's t-test.

Results

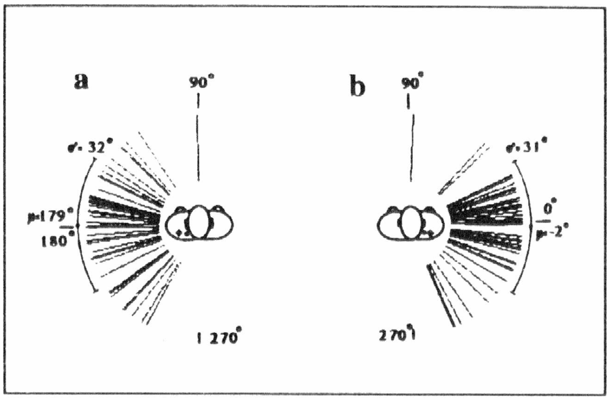

Fig. 2
Typical results for experiment I. The dynamic phases of body mass centre displacements are shown for a: electrode in position F, b: electrode in position A.

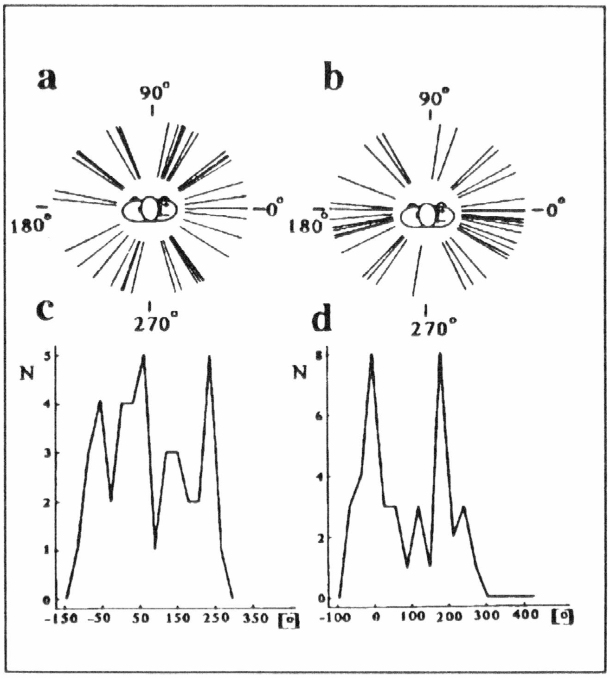

Fig. 3
Typical results for experiment II. The positions and polarities of stimulation electrodes are: +B,-A. a: results for static, b: results for dynamic phases of body mass centre displacements. c,d: show the histograms corresponding to results in a and b.

Typical results of experiment I are shown in Fig. 2. Results for all investigated electrode positions are shown in Tab. 1. There was no evidence of absolute angle value dependence on the stimulation electrode position. This applies to both the static as well as dynamic displacement phases. However, the results obtained for differences of angles (calculated for the same subjects) corresponding to different electrode positions are statistically significantly different in two cases, the corresponding electrode positions are D,E and E,F. The differences are significant at the level $p < 0.05$. Results of all calculated differences are shown in Tab. 1b.

Typical results for exp. II are shown in Fig. 3. All results obtained for monoaural bipolar stimulation show that the unambiguity in direction (concerning laterality) of the evoked body mass centre displacements which was so typical for experiment I, were no longer observed. The body mass centre moved practically in all directions and the angles obtained for the static phases created a more or less coherent rosette in the range of 0^{o} - 360^{o} . It was practically not possible to determine the most preferred angle (see Fig. 3a,c). The directions for dynamic phases are more close to the latero-lateral direction (see Fig. 3b,d) and therefore they were evaluated separately for both sides (see Tab. 2). In spite of that the results cannot be considered a simple linear combination of homolateral displacements obtained by monopolar stimulation because they still remain directionally ambiguous. Individual subjects react to a constant stimulus (unchanged electrode position and unchanged stimulus parameters) unspecifically concerning the displacement laterality.

When the number of left side movements was compared to the number of bilateral and right side movements, their proportion was 34 : 26 : 19 for the left vestibular system, and 21: 28 : 28 for the right vestibular system.

Discussion

Experiment I.

In this experiment no profound changes were expected because:
a) the situation in the case of vestibular system galvanization is complicated and this stimulus is considered from the physiological point of view only as a " reproducible error signal" (Lund and Broberg 1983),.
b) the high variance in directions of evoked body mass centre displacement during galvanization (Lund and Broberg 1983, Nashner and Wolfson 1984, Popov *et al.* 1986),
c) the constant geometry of the electrode frame used for different subjects with variable skull anatomy,
d) highly restricted stimulation field changes achieved by surface electrodes in comparison with intraauricular stimulation procedure applied in animals (Goldberg *et al.* 1984). This motivated us to analyse not only the absolute angle value but also the differences for different electrode positions. The fact that significant results occurred only in the dynamic phase of body

Table 1a
Experiment I. Body mass centre displacement angles during galvanization. Angles for static phases of movement:

Left vestibular system				Right vestibular system			
Absolute values of displacement angles							
Position	$\mu[°]$	$\sigma[°]$	t	Position	$\mu[°]$	$\sigma[°]$	t
D	182	32	0.26	A	3	38	0.32
E	183	37	0.3	B	0	42	0.03
F	182	37	0.25	C	-8	39	0.76
Displacement angle differences							
DE	0	21	0.08	AB	-9	32	1.1
DF	0	17	0.05	AC	-9	22	1.6
EF	0	22	0.02	BC	6	22	1.0

Table 1b
Experiment I. Body mass centre displacement angles during galvanization. Angles for dynamic phases of movement:

Absolute values of displacement angles							
Position	$\mu[°]$	$\sigma[°]$	t	Position	$\mu[°]$	$\sigma[°]$	t
D	189	39	0.85	A	-2	31	0.24
E	184	35	0.48	B	6	35	0.7
F	179	32	0.14	C	-5	32	0.6
Displacement angle differences							
DE	9	14	2.37*	AB	9	35	1.0
DF	-2	18	0.51	AC	6	29	0.8
EF	14	25	2.21*	BC	-5	43	0.4

Table 2

Experiment II. Body mass centre displacement angles during galvanization. Angles in the dynamic phase of movement. The values correspond to the right and left side displacements treated separately. For details see the text.

Left vestibular system				Right vestibular system			
Position	μ[°]	σ[°]	t	Position	μ[°]	σ[°]	t
AB	16	43	1.53	AB	-1	40	0.11
	175	36	0.65	189	40	0.42	
BA	-7	36	0.61	BA	1	39	0.1
	178	41	0.26	173	41	0.8	
CD	-12	36	1.37	CD	-17	34	2.18*
	169	40	1.28	181	45	0.09	
DC	-12	21	1.92*	DC	-6	36	0.86
	175	41	0.57	160	31	2.13*	

The results are significant for 1-tail t-test only.

mass centre displacement speaks for the enhanced role of galvanic stimulation just in the dynamic phases of displacement. while the maintenance of static positions is more resistant to its directional effect.

Experiment II.

According to the author's knowledge no literature has dealt with the monoaural bipolar stimulation in practice. Although the authors of two papers (Křížková 1985. Sázel 1991) mention this type of stimulation they did not use it. Therefore the presented results should be considered only as a preliminary study in this field.

The monoaural bipolar stimulation technique allowed us to apply quite a different pattern of stimulation current field in vestibular system's vicinity in comparison with monopolar stimulation techniques. The obtained results differ from those obserwed when using monopolar stimulation techniques. The main difference is in the ambiguity of direction of the evoked body mass centre displacement. The fact that the same subject under unchanged stimulation conditions reacted laterally in a non-specific manner (once left, once right) suggests that a qualitatively different stimulation pattern was extended on the VIII.'s nerve level in comparison with the monoaural monopolar stimulation. Now the question is, how this different pattern is evaluated by the CNS.

Under natural conditions of motor task performance some neurones decrease and other increase their frequency within one vestibular system (Wilson and Jones 1979). This means that there is an intralabyrinth difference of neuronal activity in one macula. It is present on both sides of the skull, in both vestibular systems symmetrically and therefore there is no interlabyrinth difference but only intralabyrinth difference under natural conditions. The situation during monoaural stimulations is different. It is known that during vestibular system galvanization the basic frequency of vestibular neurones decreases under the anode and increases under the cathode (Lowenstein 1955). These changes can be classified as interlabyrinth asymmetry caused by galvanization. Since the vestibular system is a paired organ, it is logical that any changes in body mass centre displacement are caused by the interlabyrint asymmetry, i.e. on the interlabyrinth connection (Lund and Broberg 1983, Hlavačka and Njiokiktien 1985).

In the case of monoaural bipolar stimulation only one part of the vestibular system is stimulated and both polarities act at the same region. The qualitatively different effects (concerning the movement direction) allow us to consider that during bipolar monoaural galvanization there are probably more favourable conditions for intralabyrinth than for interlabyrinth symmetry disruption.

In other words, it is probable that the bipolar monoaural stimulation does not cause significant interlabyrinth asymmetry, i.e that it does not disrupt the symmetry (Magnusson *et al.* 1990) unlike the case of monoaural monopolar stimulation. Therefore the effects on laterolateral postural coordination no longer prevail. Instead of affecting the direction, the stimulus may have some influence on other parameters of ongoing natural or partially evoked position changes.

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