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Short communication

Idiosyncratic orientation strategies influence self-controlled whole-body rotations in the dark

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Abstract

The present experiment examined the influence of spatial orientation strategies on human subjects' accuracy in a self-controlled whole-body rotation task in the dark. Subjects were seated on a robotic chair and had to perform 360° rotations with or without the presentation of a space-fixed target. Performance was compared between subjects who preferably used an ''egocentric'' or an ''allocentric'' strategy. Results suggest that orientation strategies might be tightly linked to sensory integration processes. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Vestibular perception; Spatial orientation strategies; Sensory integration processes

It is now well established that vestibular signals provide important cues about one's displacement in space. However, the collected observations depend a great deal on experimental procedures, which involve not only varying methods for self-motion estimation but also a wide range of motion dynamics. Moreover, a large inter-subject variability has often been reported but rarely discussed [3,4,7]. We believe that some cognitive aspects, namely, spatial orientation strategies, could have a significant influence on the way subjects interpret vestibular signals and, therefore, could account for some of the observed individual differences. Although the subjects remain in the dark during studies on vestibular perception, they often have a mental representation of the experimental room [9]. It is possible that subjects, while moving around without vision, have a mental image of the dynamic changes of how the world looks and that they draw from this knowledge a perception of their self-movement in environment-centered terms [6]. Another possibility is that vestibular signals are directly integrated to yield a sense of motion, a process that does not require the knowledge of the spatial environment. The purpose of this experiment was to gain insight into the possible influence of those cognitive aspects in the subjects' interpretation of vestibular signals during a simple self-controlled whole-body rotation task in the dark.

After having given their written consent, 17 healthy volunteers, with ages ranging from 23 to 31 years and with no history of vestibular disorder participated in this experiment. Subjects were seated on a mobile robotic chair that was programmed to rotate about the earth-vertical axis (see Ref. [1] for more details). Subjects controlled the chair's motion using a joystick. There were two different sets of joystick characteristics. The ''high velocity'' (resp. ''low velocity'') allowed the maximum angular velocity and angular acceleration of the chair to be 1 rad/s and 0.7 rad/s^2 (resp. 0.7 rad/s and 0.5 rad/s^2). Chair rotation was recorded to a precision of 0.1° at a sampling rate of 25 Hz by means of optically encoded odometry. Subjects wore headphones delivering wide-band noise to mask auditory spatial cues.

Subjects were asked to perform four 360°-rotations, one at a time (two joystick parameters sets × two trials), in two different conditions:

No Target Condition (NoT): subjects were simply asked to keep the eyes open and to look far ahead in front of them in the dark during rotation.

Memorized Target Condition (MT): before each rotation, subjects were shown a target on a wall in front of them; they were asked to memorize its location and to orient themselves towards it during rotation.

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NoT was always tested before MT. We measured the rotation magnitude of each trial, as well as angular velocity. After the experiment was completed, subjects were asked which condition they found easiest and were asked to describe the type of cues they had used in NoT to perform the rotation task. From subjects' comments, two different types of spatial orientation strategies stood out: an ''allocentric'' and an ''egocentric'' strategy. (This terminology was already used in a previous article [9].) Some subjects reported that they already had a mental image of the room while executing condition NoT. For them, the condition MT did not change much. These subjects were, therefore, easily categorized in the ''allocentric group.'' Others said they had ignored the environment and had accomplished the rotation using solely the starting direction as a reference. They were categorized in the ''egocentric group.'' Finally, subjects who could not precisely describe their strategy belonged to the egocentric group if they found MT more difficult than NoT or to the allocentric group otherwise. Eight subjects belonged to the egocentric group and nine to the allocentric group.

In condition NoT, mean rotation magnitudes in the egocentric and allocentric group were 268.2 ± 58.1 and $294.6 \pm 65.8°$, respectively. In condition MT, means were 295.7 ± 68.0 and $301.4 \pm 76.6°$, respectively. Whatever the group or the condition, mean response was much lower than 360° and variability was large. This result can be interpreted as the subjects' tendency to overestimate the whole-body rotation they perform. Such a result has already been reported in different experiments on self-rotation estimation [2,6,7]. These values also show that mean response was lower in the egocentric group than in the allocentric group, in both conditions. In both groups, there was a mean increase in rotation magnitude from condition NoT to condition MT, which was stronger in the egocentric group (+10.2%) than in the allocentric group (+2.3%).

A four-way ANOVA (one between-factor: strategy group, three repeated measures: condition × joystick parameters × first/second trial) was performed on rotation magnitude. A third-order interaction between the group factor, the condition and the joystick factor was exhibited [$F(1,16) = 9.1$, $p = 0.008$]. Fig. 1 tries to elucidate this combined effect of strategy and rotation velocity on performance. The largest difference between the two groups took place in condition NoT, with the high velocity joystick. The two groups did not differ significantly in the angular velocity they used (an ANOVA on this variable did not show any group specificity) but in the way they processed this velocity: allocentric group subjects improved their performance when going faster, whereas egocentric group subjects worsened it.

Previous experiments could lead us to think that the most efficient strategy to perform the task was to have a mental representation of the room. Indeed, Israël et al. [5] found that visual cues could help subjects in a similar vestibular perception experiment. Moreover, Rieser's [8] perception-representation-action model tells us that the perception of self-movement is fine-tuned in terms of flow relative to remembered features of the environment (representation) and that movement is, therefore, more precisely perceived in environment-centered than body-centered terms. However, a difference in the performance between allocentric and egocentric subjects was exhibited only at high velocities. This group-dependent effect of rotation velocity seems to show that the ''natural'' orientation strategies adopted by subjects in NoT are characterized by different integration processes of velocity signals, although this effect is difficult to be accounted for with the present data (Fig. 1A).

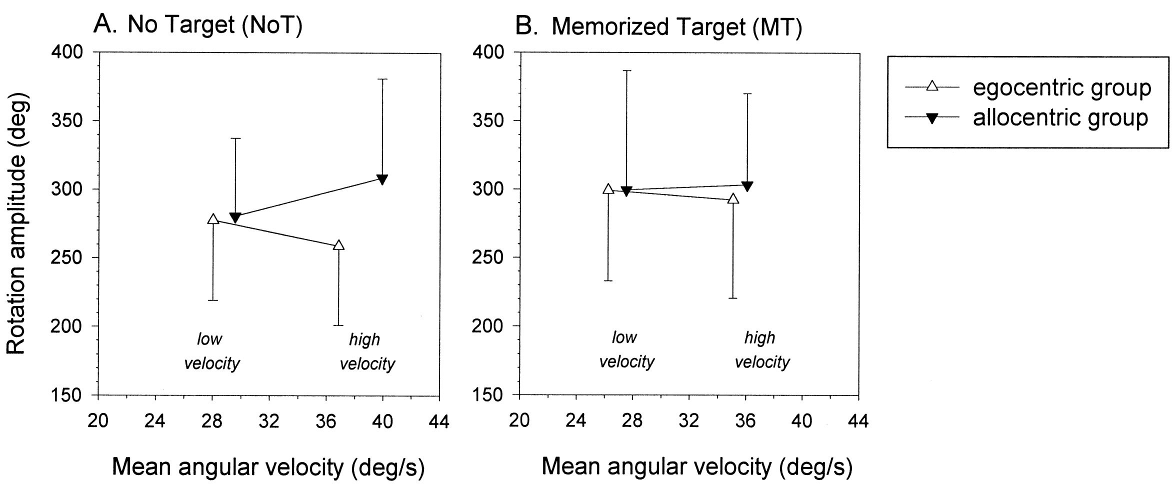

Fig. 1. Rotation amplitude in both conditions No Target (NoT) (A) and Memorized Target (MT) (B) for both the egocentric group (mean − S.D.) and the allocentric group (mean + S.D.) and with both the low velocity and high velocity joystick parameters.

Rieser's theory could, nevertheless, explain the general undershoot observed in both groups and both conditions: subjects were perhaps biased by their a priori knowledge of the relationship between the different sensory signals occurring during whole-body rotations, which usually take place in a standing position with higher velocities and accelerations than those generated when driving the robotic chair.

In conclusion, we believe that one should pay attention, not only to the experimental design, but also to individual orientation strategies when studying vestibular perception in humans. They can both be determinant in the studied phenomena. Furthermore, spatial orientation strategies do not simply result from individuals' predefined choices, but are tightly linked to sensory integration processes. However, further investigations are needed to understand the discrepant effect of angular velocity on performance among the two groups. It would also be very interesting to establish whether orientation strategies do have an influence on sensory integration modalities or conversely whether the different types of strategies are induced by idiosyncratic differences in the vestibular integration processes.

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