EVENT ABSTRACT

The somatogravic illusion during centrifugation: sex differences

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INTRODUCTION

Maintaining orientation in an environment with non-Earth gravity (1 g) is critical for an astronaut's operational performance. Such environments present a number of complexities for balance and motion. For example, when an astronaut tilts due to ascending or descending an inclined plane on the moon, the gravity vector will be tilted correctly, but the magnitude will be different from on earth. If this results in a mis-perceived tilt, then that may lead to postural and perceptual errors, such as mis-perceiving the orientation of oneself or the ground plane and corresponding errors in task judgment.

Rotation on a centrifuge offers a unique opportunity to vary the direction of the gravity vector without physical tilt, that is, without co-activation of the semicircular canals during the simulated tilt. The tilt angle simulated is the tilt of the simple vector sum of gravity and the acceleration added by the centrifuge. Perceiving acceleration as tilt is the well-known somatogravic effect [Mach1875, Clark1951]. Sustained linear acceleration together with gravity creates a single gravito-inertial force (GIF). Under normal gravity conditions, sustained linear acceleration in the transverse plane can create an illusion of tilt - the somatogravic illusion - in which the entire GIF is interpreted as corresponding to gravity. However, the magnitude of the effect, i. e. the fraction of the GIF that is interpreted as gravity,
has not been well quantified in the sagittal plane. We, therefore, varied the added acceleration to induce a somatogravic illusion and measured the perceptual effects using a haptic rod to indicate the perceived direction of gravity.

Previous experiments measuring the somatogravity illusion have used a swinging gondola, hypergravity and a visual assessment method [Tribukait1999, Tribukait2006]. Our experiments used a haptic rod outside of the participant's view, ruling out effects of eye torsion, and a fixed chair mounted so that the participant sat upright and nose-out to provide a controlled and constant direction of otolith stimulation over a physiologically valid range of acceleration forces.

METHODS AND MATERIAL

The somatogravic illusion was measured during prolonged backwards centripetal acceleration created by centrifugation simulating different pitched-forward tilts. The perception of tilt during centrifugation was compared to the perception of physical tilt generated using a motion platform (Moog).

For both setups (Moog and centrifuge), 5 male and 5 female participants, all healthy and between 20 and 45 years old, sat upright in a chair in the dark, with their head lightly restrained, and judged the orientation of a rod relative to gravity (see Figure 1). Different participant groups were used for each setup.

Each participant in the centrifugation section was selected by a medical screening done at the German Aerospace Center's Aeromedical Center. The medical examination consisted of a clinical-chemical analysis (glucose, creatinine, urea, uric acid, SGOT, SGPT, µGT, total cholesterol, HDL and LDL), hematology (blood count), urine analysis (glucose, protein, urobilinogen), resting ECG, exercise test to verify endurance capacity, standing test for orthostatic tolerance assessment and a medical history. At the time of medical examination, participants were familiarized with the conduction of the study, including the procedure of centrifugation and the associated OTL protocols. All volunteers underwent a comprehensive clinical assessment and gave a written informed consent prior to the study.

For each centrifugation, participants underwent four experiment sessions plus two control sessions on two days. Between the two experiment sessions on a single day, a 30 min break was planned.

Participants sat in a fixed-position upright chair looking outwards on a short arm centrifuge with their head lightly restrained. The head position was used to define the radius for estimation of centripetal acceleration.

A haptic rod about 20 cm in length mounted on a potentiometer was mounted so that the participant could touch it with one hand. The haptic rod was mounted on a servo-controlled motor that rotated in the parasagittal plane. The participant's hand rested on the rod throughout the experiment and so there was no issue of centrifugal forces. The rod's orientation was varied using an adaptive psychophysical staircase that honed in on the perceived direction of gravity. The participant was instructed to press a button (operated by the other hand) to indicate when the setting is satisfactory. The computer recorded the orientation and time stamp of the setting along with the rotation condition.

The GIF was swung between 0°, 22.5° or 45° (6 combinations of change in GIF) by the addition of a centripetal acceleration of between 0 g and 1 g. Participants had to make a rod setting continuously throughout the entire time they were on the centrifuge including during transitions to different rotational speeds. Once each target speed had been reached, it was maintained for 180 s.

FIGURE 1 HERE
CAPTION: Experimental setup. Participants were sitting on a centrifuge facing outwards. Their field of view was blocked by a metal hood (right). Participants manipulated a haptic rod to indicate the perceived direction of gravity.

RESULTS AND DISCUSSION

For centrifugation, all males showed a substantial somatogravic illusion with a gain (perceived tilt over simulated tilt) of 0.46, whereas 4 of 5 females did not experience it at all and continued to identify the direction of gravity correctly despite the tilt of the GIF (see Figure 2 A, B).

For physical tilt using the Moog motion platform, a similar sex asymmetry was found (gain for males: 1.2, gain for females: 0.49, see Figure 2 C, D).

FIGURE 2 HERE
CAPTION: Participants' perception of tilt compared to simulated tilt (by centrifugation, A) and physical tilt (using the Moog motion platform, C) and the corresponding linear regression slopes (B, D). It can be observed that female participants are more capable of correctly identifying the direction of gravity despite the tilt of the GIF.

The low gain observed for females suggests a restraining influence of a strong idiothetic vector acting as a prior indicating that gravity is continuously aligned with the body. Results indicate that sex should be taken into account when assessing balance or perceived orientation in situations where the direction of gravity is not aligned with the body. Examples include changes of body orientation during normal changes of posture, responding to imposed tilt (such as when bumped into while walking) or during conditions of prolonged acceleration such as when driving or piloting an aircraft.

Figure 1

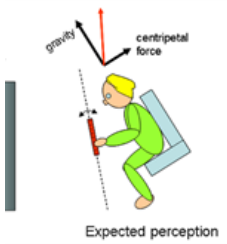
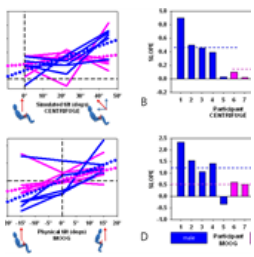


Figure 2



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