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Auditory and body perception in microgravity

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How is the conscious experience of our body impacted when information across sensory modalities are unusual, and how does it impact the localization of sound in space? Here we tested whether the absence of gravity induces an anomalous body experience and whether it interferes with spatial auditory perception, which strongly relies on a head-centered frame of reference. Participants were asked to indicate the lateralisation of auditory sources in different sensory conditions linked to vision and to gravity. The unique conditions of parabolic flight were used to ask whether gravity itself, or in combination with altered visual inputs, provides a critical cue for the emergence of distortions in body-centered frame of reference.

Methods

Auditory task

Participants were asked to indicate the lateralisation of auditory sources presented through headphones. Auditory stimuli were trains of gaussian white noise of 500 ms, pre-convolved with generic HRTFs at 20, 30, 40, -20, -30 and -40° in the azimuth and 0° in elevation in the frontal hemifield. Participants had to press a right or left key on a response pad to specify whether auditory stimuli were localized to the right or the left of their body.

Sensory conditions

The task was performed without or with vision, and with or without gravity for the Flight group (Fig. 2 and 3). Four blocks were administered, each corresponding to a different sensory condition.

When visual information was available, participants were provided with an image of their body as if they would see themselves from an "out-of body" location, i.e. without the apparent left/right reversal inherent to a mirror image (Fig. 1A & B).

The four blocks were always presented in the same order: eyes closed in normogravity (EC-1G), eyes closed in microgravity (EC-0G), eyes opened visualising their inversed mirror image in normogravity (EO-1G), eyes open visualising their inversed image in microgravity (EO-0G). For the two 1G conditions, each block was completed during the steady phases of parabolic flight. For the two 0G conditions, the task was realised during the 20s weightless phases of parabolic flights.

Participants

Twelve healthy human participants (7 female, mean age 35.00 ± 10.38) did the experiment during parabolic flights and constituted the Flight group.

A Ground group of 35 healthy human participants (15 females, mean age 33.69 ± 9.19) did the whole protocol in normogravity. For this group, only two different sensory conditions were used since gravity did not vary. The two first blocs were done with the eyes closed in 1G (EC-1G), the two following blocs were done with eyes open visualising their inversed mirror image in 1G (EO-1G).

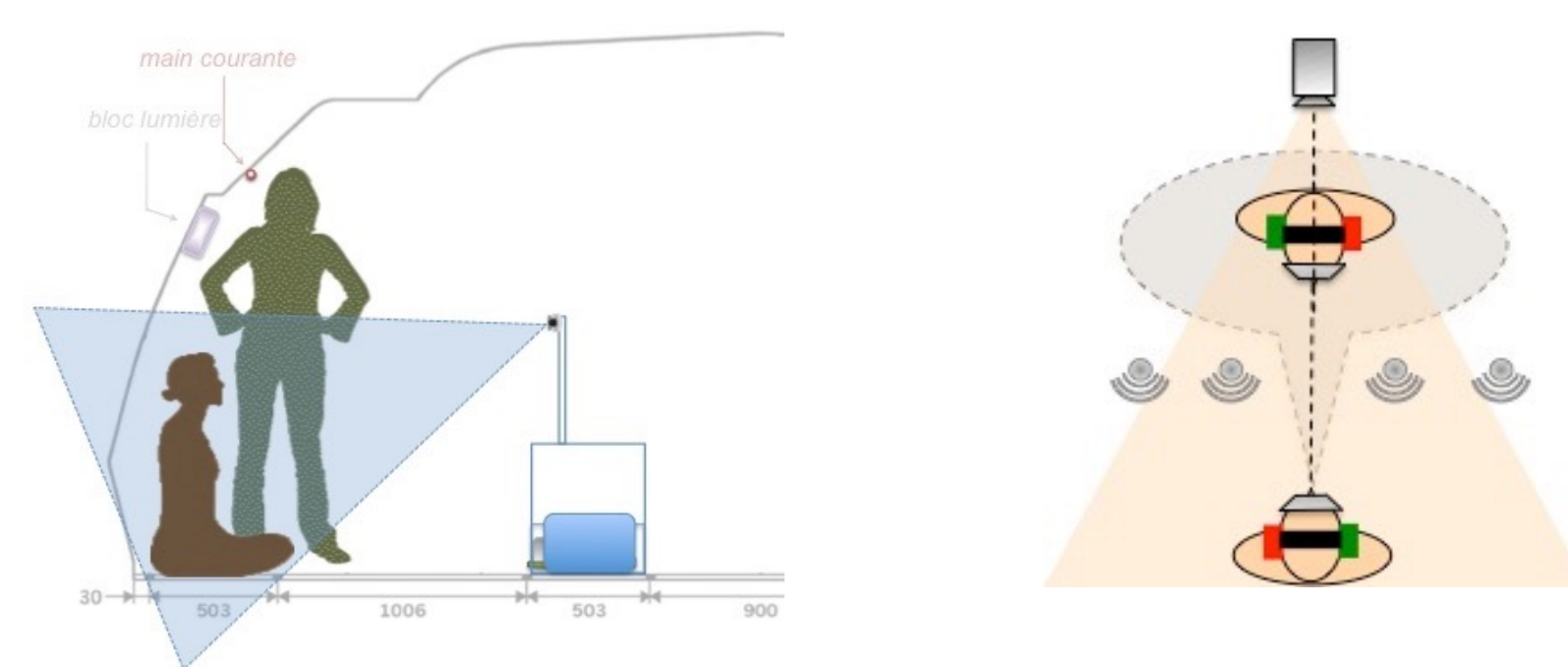


Figure 1A & B. In the eyes open conditions, a video camera captures the body of the participant from a distance of 150 cm, and this signal is sent to a software allowing to inverse the image before relaying it to the head mounted display worn by the participant.



Figure 2. Participant equipped with a response pad and headphones in the eyes closed and microgravity condition (EC-0G).

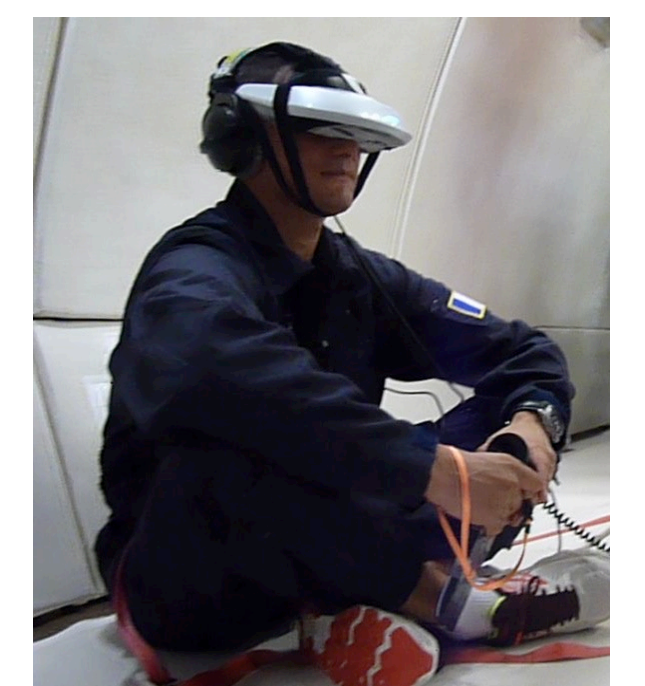


Figure 3. Participant during the eyes open and normogravity condition (EO-1G), equipped with a head mounted display in which he is visualising himself.

Questionnaire measures

The sense of embodiment was studied through pre-and post questionnaires. At the end of the eyes open blocs (EO-1G and EO-0G), the Out of Body Experience (OBE) questionnaire (adapted from Botvinick and Cohen 1998) was administered to quantify the subjective experience associated with seeing one's self. Participants were asked to rate four different statements concerning their experience using a ten-point Likert scale.

Unusual perceptual experiences linked to the experiment were studied through a comparison of pre-and post scores of an adapted version of the Perceptual Aberration Scale (PAS) (Chapman, Chapman, and Rawlin, 1978), administered before and after the end of the entire protocol.

Results

One participant of the Flight group could not complete the experiment.

Auditory task

The percentage of correct responses significantly differed according to the sensory condition in the Flight group, with the smallest percentage being found in the EO-0G condition (Fig. 6). They did not differ across conditions in the Ground group (Fig. 7).

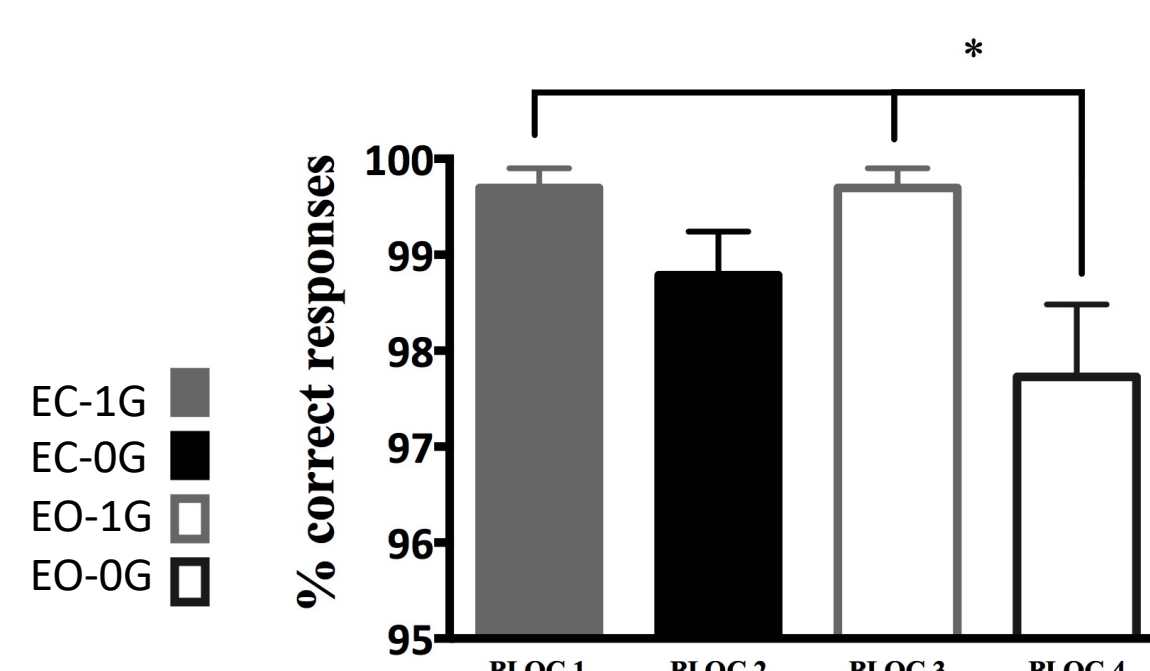


Figure 6. Percentage of correct responses in the Flight group in the four blocs (4 different sensory conditions).

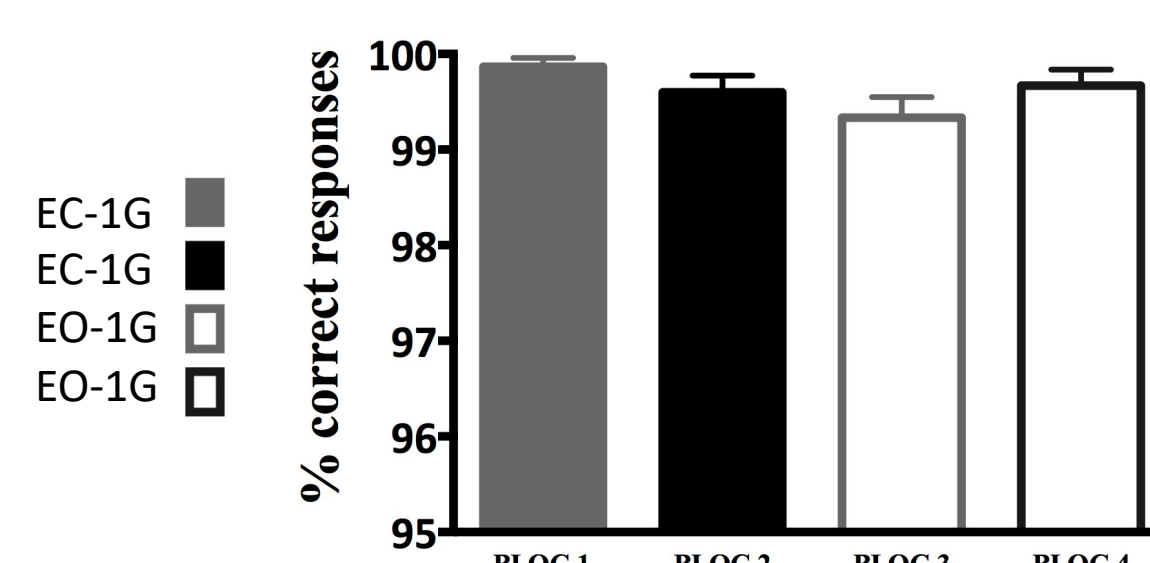


Figure 7. Percentage of correct responses in the Ground group in the four blocs (two sensory conditions).

Questionnaire measures

The OBE scores increased in the Flight group after the EO-0G bloc in comparison to the scores obtained after the EO-1G bloc, while they remained stable in the Ground group between the two EO-1G blocs (Fig. 5).

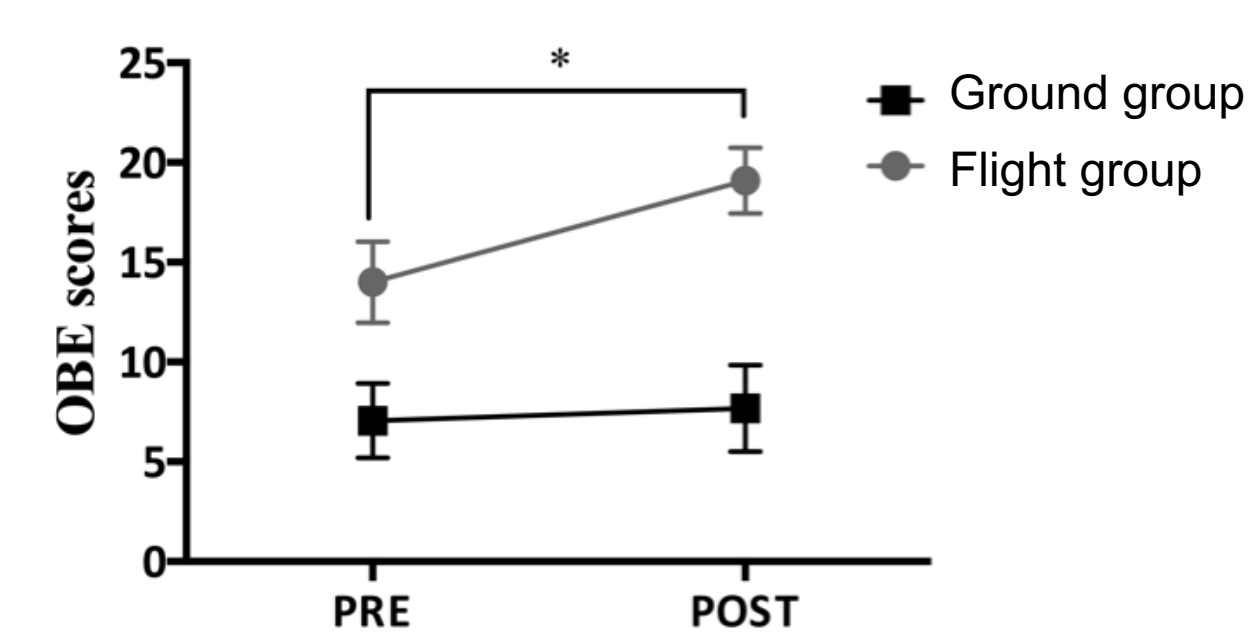


Figure 5. Out of Body Experience scores before (PRE) and after (POST) bloc 4 (EO-0G for the Flight group, corresponding to the second EO bloc for the Ground group).

The scores of the questionnaires pre- and post-experiment assessing perceptual aberrations were significantly higher after the experiment compared to before in the Flight group. They were stable in the Ground group (Fig. 4).

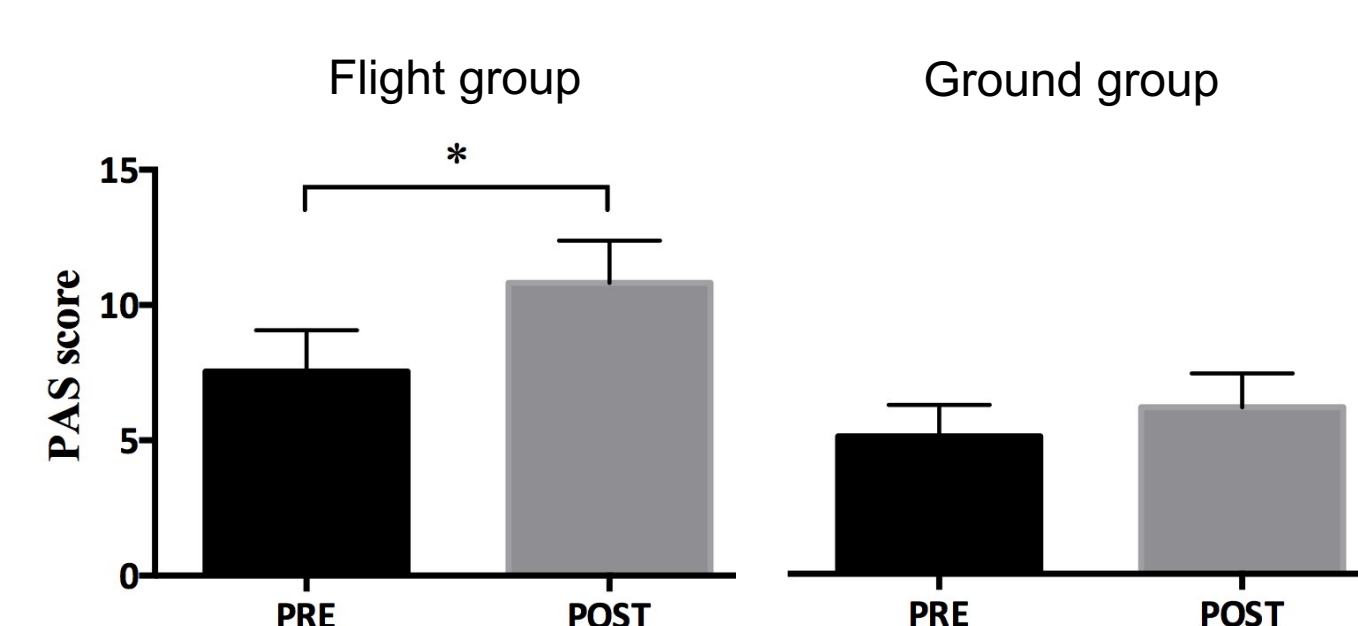


Figure 4. Perceptual Aberration Scale scores in the Flight group (left) and in the Ground group before (PRE) and after (POST) the experiment.

→ The frame of reference of auditory perception is influenced by gravity and visual perspective.

→ The sole manipulation of visual perspective linked to the body does not perturb the feeling of embodiment nor the frame of reference of auditory perception.

References

- Botvinick M, Cohen J (1998) Rubber hands 'feel' touch that eyes see. *Nature*, 391(6669):756.
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