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## Monday, June 9

## Session MP4
## Room 4
## 2:30 - 5:30 p.m.

# Cognitive Sciences

**IAA Man in Space Symposium, 1997**

# Face recognition in microgravity: is gravity direction involved in the inversion effect?

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Most objects are more difficult to recognize upside down than right side up. Face recogition is greatly impaired by inversion. The face inversion effect (Yin 1969, Diamond & Carey, 1986, Farak, Wilson, Dray & Tanaka, 1995) is a very robust effect observed under many different conditions. Moreover this effect has been used as a marker to indicate the involvement of specialized face processing mechanisms in the right cerebral hemisphere given that the normal right hemisphere advantage in face recognition vanishes when faces are presented upside down while le left hemisphere performances are not decreased by the stimulus inversion. Two possible candidates might act as a spatial references for coding faces right side up: either the direction of gravity or the retinal references. Given the great importance of visual object processing in daily life it was decided to investigate with Cognilab in the Cassiopée Mission whether visual performances in object processing might be handicapped in microgravity. Three cosmonauts were tested before and during flight in the MIR station. One set of faces (photographes of unknown people) were learned before the flight and recognition of these faces was tested both before the flight and in the spatial station. A second set of faces (photographs of other unknown faces) was learned under microgravity in the spatial station and recognition was also tested in the spatial station. During the recognition tests, the learned faces were mixed with totally new faces and the cosmonauts had to decide as fast as possible whether a presented face was a learned one or a new one. Faces were presented either upside down or right side down in the right visual field (left hemisphere) or the left visual field (right hemisphere). Error rates and reaction times were measured. The inversion effect was observed in the recognition tests of both sets of faces (those learned on the ground and those learned in the station). This effect was present on the 6th, the 10th and the 14th day of flight with no significant change with time. Therefore the inversion effect does not seem to be related to the spatial reference given by gravity direction but rather to a retinal reference. Some aspects of the information processing seems however to be sensitive to microgravity or to the flight conditions: (i) The learning and recognition performances in the station are much poorer for faces learnt in the station than for faces learnt on the ground and, (ii) for the recognition of the faces learnt in the station, the right hemisphere advantage vanishes and a left hemisphere advantage emerges. It is concluded that face recognition by the right hemisphere is handicapped either by microgravity or by another factor present during the flight.

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# MOTOR TIMING UNDER MICROGRAVITY

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Five subjects performed sequences of periodic movements by synchronizing button presses with a series of acoustic stimuli (induction phase), and by continuing to produce the movements with the same rhythm after the metronome had been switched off (continuation phase). The required inter-response intervals were 350, 410, 470, or 530 ms. Three subjects were members of the CASSIOPEE 96 spaceflight mission, two subjects were control. The stimulus-response asynchronies observed during the induction phase and the inter-response intervals of the continuation phase were analyzed in terms of mean duration, variability, and sequential dependency. These data enabled us to partition the total variability of timing into variability due to internal timekeeping processes, and variability due to motor implementation processes, in the framework of the two-level timing model originally proposed by Wing and Kristofferson. During spaceflight, the subjects tended to accelerate their tapping, that is, their reproduction of the reference interval was less precise than under the control conditions. In addition, the timing became more variable (less regular). Most of the increase in variability could be attributed to the internal timekeeping processes. The results are discussed with reference to hypothesized physiological mechanisms underlying the timing of fast serial movements.

# PERCEIVED SELF-MOTION ASSESSED BY COMPUTER-GENERATED ANIMATIONS: COMPLEXITY AND RELIABILITY

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## INTRODUCTION

Our overall goal is development of procedures to enhance assessment of spatial orientation, specifically self-orientation and self-motion perception. Our specific objective is to develop and evaluate computer-generated animations as potential tools for measuring perception. We compared perceived self-motion reports obtained using animations with those obtained using verbal reports.

## METHODS

36 subjects reported perceived self-motion following exposure to complex inertial-visual motion stimuli. 12 subjects were assigned to each of 3 perceptual reporting procedures: animation movie selection (AMS), verbal report selection (VRS), and verbal report generation (VRG). The question addressed was: do reports produced by these procedures differ with respect to complexity and reliability? Following repeated (within-day and across-day) exposures to 4 different "motion profiles"(see Appendix), subjects in the AMS group selected, from a set of movies presented on a laptop computer, the movie that corresponded most closely with their motion experience. Subjects in the VRS group selected from a set of verbal description presented in a booklet, and VRG subjects provided their own self-motion verbal descriptions. "Complexity" and reliability "scores" were calculated.

## RESULTS

Mean (and standard error of the mean) within-day reliability, across-day reliability and complexity scores for the data are presented in Table 1.

TABLE 1.
MEAN (SEM) COMPLEXITY AND RELIABILITY SCORES FOR 3 REPORTING PROCEDURES

| | COMPLEXITY | WITHIN-DAY | ACROSS-DAY |
|---|---|---|---|
| AMS | 0.546 (0.055) | 0.319 (0.075) | 0.228 (0.071) |
| VRS | 0.577 (0.051) | 0.302 (0.071) | 0.221 (0.063) |
| VRG | 0.431 (0.055) | 0.327 (0.069) | 0.295 (0.078) |

The means were essentially equivalent for movie selection and verbal report selection procedures: no statistically significant differences between reporting procedures were observed. The data suggest that reports by verbal report generation subjects were less complex than for the other conditions. The hypothesis that movie selection would be more reliable than the verbal report procedures was not supported.

Frequency of "hill" and "valley" descriptions for 2 motion profiles for each of the 3 reporting procedures are presented in Table 2.

TABLE 2.
NUMBER OF SELECTIONS BY PROFILE AND REPORT TYPE

| | PROFILE H8 | | | | PROFILE S8 | | | |
|---|---|---|---|---|---|---|---|---|
| | AMS | VRS | VRG | SUM | AMS | VRS | VRG | SUM |
| HILL DESCRIPTION | 8 | 13 | 16 | 37 | 0 | 0 | 3 | 3 |
| VALLEY DESCRIPTION | 0 | 0 | 0 | 0 | 24 | 22 | 14 | 60 |

Clearly, the H8 and S8 profiles elicited different responses (collapsed across reporting procedures, $X^2 = 85.7$; $p < 0.0001$).

## DISCUSSION AND CONCLUSIONS

There are several possible reasons for the failure of this experiment to demonstrate clearly expected advantages of animations. First, appropriate, careful training to use a standard self-motion description vocabulary may eliminate possible differences between reporting procedures. Subjects may be better able to describe motion verbally than is usually believed. Second, the motions may not have been sufficiently complex. Based on the stimulus motions, only fairly simple self-motions (2 degrees-of-freedom (DOF) translational and 1 DOF rotational) would be expected.

Third, movies/verbal descriptions depicting combined scene and self-motion perception, which almost certainly corresponded with the subjects' actual experience, were not used. Fourth, individuals probably differ with respect to how they represent motion cognitively - some may use pictorial representations, whereas others may use verbal descriptions. Finally, possible differences in self-motion experiences for VRG subjects were not easily assessed because descriptions were often relatively simple. For example, many subject-generated verbal reports were vague at best, and omitted important information (e.g., whether a "ramp back" had an upward or downward slope). For AMS and VRS subjects, selections were made from a set of precise movies / reports; consequently, it was more likely that even subtle differences in the self-motion experience elicited by repeated exposures to a particular profile would result in selection of different movies / reports.

The hypothesis that a "real-time" animation reporting procedure, which permits omission of motion vocabulary training, will produce more reliable data than verbal reports is being examined currently. Because subjects cannot readily use the animation movies selection procedure without training, Experiment 2 employs cross-coupled rotation stimuli and a new reporting procedure: animation generation. This is accomplished by having the subject manipulate a mannequin so that the mannequin's motion corresponds to the perceived self-motion. Polhemus Fastrak sensors embedded in the mannequin permit "real-time" representation of the motion on a monitor as well as recording of that motion for later analysis.

Although not the primary purpose of this research, the results indicate that different combinations of tilt with respect to gravity and translation of a visual surround with respect to the subject can yield consistently different patterns of self-motion trajectory. The hypothesis that neural signals representing visual surround velocity are additive with those representing pitch position was supported (see Harm et al., Avait. Space Environ. Med. 1993, 64, 820-26).

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## APPENDIX

### MOTION DESCRIPTIONS

Hill description. Simultaneous pitch and hill: pitch forward as translate forward over the hill; pitch rearward as translate rearward back over the hill.

Valley description. Simultaneous pitch and valley: pitch rearward as translate forward down into and up out of a valley; pitch forward as translate rearward back down into and up out of the valley.

### MOTION STIMULI

Motion stimuli were produced by the Tilt Translation Device, a 1 DOF moving base that combines pitch motion of the subject with translation of a visual surround with respect to that subject. Relationships between subject and visual surround motions can be easily manipulated. When both are sinusoidal, the visual surround may move either toward or away from the subject as they pitch forward; i.e., the phase angle between visual surround and subject motions can be controlled (see Harm et al, 1993).

TABLE 1. MOTION PROFILES

| NAME | MFP | MRP | PHASE | FREQ. - Hz |
|---|---|---|---|---|
| H8 | 10 | 13 | 20 | 0.08 |
| S8 | 5 | 9 | 180 | 0.08 |

MFP: maximum forward pitch (deg).
MRP: maximum rearward pitch (deg).
PHASE: amount by which maximum forward surround position (farthest rearward subject position in the surround) leads maximum forward pitch of the surround and subject (deg).

For profile H8, peak velocity of visual-surround-induced forward self-translation occurs during the transition from maximum forward to maximum rearward pitch; and, peak visual-surround-induced rearward self-translation velocity occurs during the transition from maximum rearward to maximum forward pitch.

For profile S8, peak visual-surround-induced forward self-translation velocity occurs during the transition from maximum rearward to maximum forward pitch; and, peak visual-surround-induced rearward self-translation velocity occurs during the transition from maximum forward to maximum rearward pitch.

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# PROLONGED WEIGHTLESSNESS, REFERENCE FRAMES AND VISUAL SYMMETRY DETECTION.

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Bilateral symmetry of form is assumed to be extracted early during visual processing in order to set an internal reference frame for the form. This internal reference frame will generally allow a coding of form invariant by rotation, prior to the form recognition (1). One of the most striking properties of bilateral symmetry detection is the spatial anisotropy in the performance of the visual system. Thus, patterns of error rates or response times (RT) as a function of symmetry axis orientation show superior performance for a vertical orientation of symmetry axis than for a horizontal one and superior performance for both of these orientations than for oblique ones, when the symmetrical shape is presented centrally. Several authors have suggested that either the anatomy or cells selectivities of the visual system could explain this anisotropy. From previous studies (2), it has been shown that meridional orientations of symmetry axis were always more salient than the oblique ones during prolonged weightlessness. However, the saliency of the vertical axis over the horizontal one, strongly evident on earth, was shown to gradually diminish over exposure to weightlessness, finally disappearing after a couple of weeks (3). From these data, it is concluded that the symmetry is detected in a retinal reference frame in which graviceptive cues are incorporated to elicit a vertical saliency.

We investigated, with three cosmonauts, during the French-Russian mission CASSIOPEE 96, whether similar reference frames are required to detect symmetry when presentation of stimulus is restricted to one visual hemifield. Indeed, the anatomy of the visual system allows one to stimulate preferentially one cerebral hemisphere when the stimulus is displayed to one side of a fixation point. The cosmonauts were maintained in COGNILAB's body restraint system, facing a computer screen where shapes were displayed. We tested two types of stimuli : closed 2D polygon and arrays of randomly positioned dots. A fixation cross was displayed in the centre of the screen, then a stimulus was presented during 100 ms either in the left or right visual field (right or left cerebral hemisphere respectively) or in the centre of the screen (both hemispheres). From trial to trial, the nature of the stimulus (symmetrical versus asymmetrical), the position of presentation and the orientation of symmetry axis (Vertical, Horizontal and 45° Oblique) were randomly varied. The subjects were asked to press the near button if shape was symmetrical or the far one if asymmetrical. We compared RTs and error rates for in-flight versus ground tests.

The results indicate that the processing of symmetry is better when both cerebral hemispheres are stimulated. In this condition, the saliency of a vertical axis of symmetry vanished during the exposure to weightlessness for the closed shapes, but increased for the random dots. This suggests that symmetry could be differently processed by the visual system as a function of type of shapes. In the case of the visual hemifield presentation, on earth as well as in weightlessness, the most salient orientation is amazingly the horizontal axis of symmetry. The saliency of the horizontal axis of symmetry (compared to the vertical axis) seems to be reduced in weightlessness but this diminution varies accordingly to the type of forms and to the stimulated cerebral hemisphere.

In conclusion, these results suggest that the processing of low level visual information integrates also non-visual information and that different symmetry detection mechanisms could exist.

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# MENTAL REPRESENTATION OF GRAVITY DURING A LOCOMOTOR TASK

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## INTRODUCTION

Droulez and Berthoz (1986) have proposed a theory which supposes that execution of complex movements and mental simulation of these movements are based on the same nervous processes. In addition, in normal gravity, several authors have reported isochrony phenomena during locomotor tasks, i.e, the time to walk mentally was similars to the time taken to actually walk (Decety et al. 1989). These results emphasize the hypothesis which suggest that mental movement and actual movement share the same cerebral mechanisms. We also think that such a simulation would play a major role in recovery after lesions or in self-adaptation to environmental modifications.

In a previous experiment (Papaxanthis et al 1997) we have demonstrated during arm pointing movement that the gravity does not only exert a local effect on muscle proprioceptors (as load or inertia) compensated for on the basis of feedback regulation, but is centrally represented in the central nervous system using the feedforward computation of gravity in the command to the muscles.

The aim of this experiment was to test wether this « on earth phenomena » still exists and is adapted to a normal 1g environment after prolonged exposure to condition of microgravity. indeed, casual report from cosmonauts have indicated that the perception of time is altered in 0g.

## METHODS

Cosmonauts performed essentially a locomotor task involving 3 main phases : two steps and stepping onto a platform (2 steps of 25 cm each) (T1) ; jumping with both feet from the 50 cm platform (T2) and after landing and ensuring good postural stabilization, walking normally for a distance of 4 m (T3). The experiment was executed using normal vision and then repeated subjects' blindfolded. In the vision condition, no instruction to fix any specific point was given. In the blindfolded condition, subjects were allowed to look for 5 s in front of them before the beginning of each trial. During the performance of these tasks, the movement was analyzed by mean of an optical automatic TV-image processor (for other kinematic studies). Immediately following the execution of the task, cosmonauts were asked to mentally repeat all the movement (T1+T2+T3). Subjects held an electronic stopwatch in their hand. They started the stopwatch when they started to walk (actually and mentally) and stop it when they completed walking. Walking time was recorded directly by the experimenter from the stopwatch. Subjects were given no information concerning their temporal errors. Ten trials were performed in each of the two conditions (with and without vision). The experiment was conducted during pre (on days L-60 and L630) and post spaceflight. The post flight tests took place on the first day (R+1), second (R+2) and sixth day of return (R+6). The experiments reported here have been performed before and after several spatial missions aboard the russian orbital station « MIR », from 1994 to 1996.

## RESULTS

Pre flight data (L-60 and L-30, see figure 1) show that in normal vision, mental time and actual time are similar, confirming the isochrony principle for the whole task. In contrast, when visual information is lacking movement times tend to be longer than in normal vision, and the mental time expressed as a percentage of the actual time (relative mental time) is greater than 1, that is to say longer than actual time.

Post flight data indicate that just after returning to earth (R+1), for the two visual conditions, movement time increased. In addition, mental time decreases with respect to the actual time (figure1). Then, on day R+2 and R+4 the relative mental time increases. On day R+6, relative mental time values become similars to those obtained during pre flight measures.

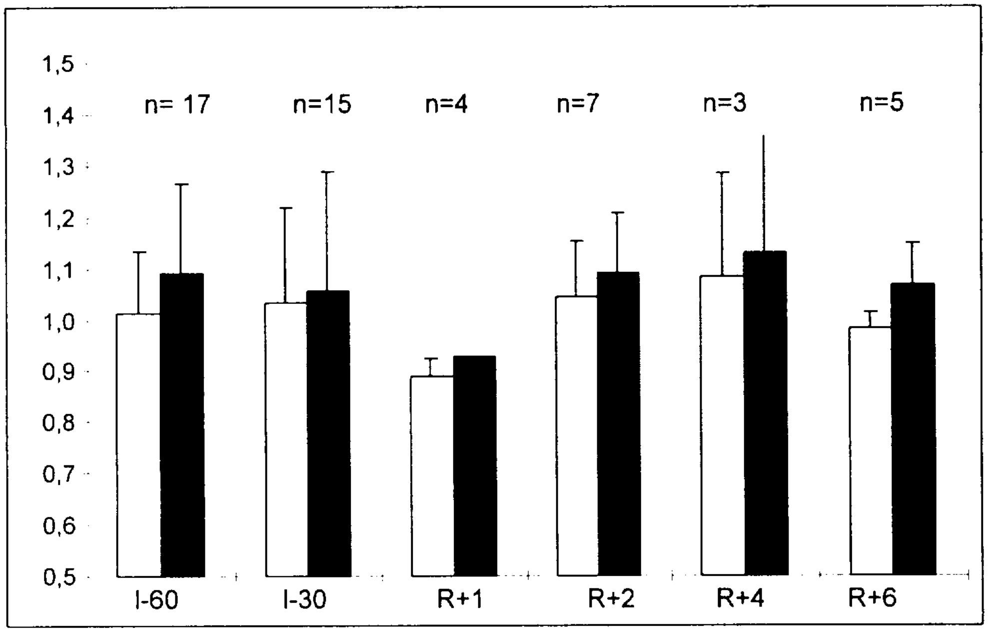

**Figure 1** : Mean mental walking time and SD for all subjects tested in normal vision (white bars) and blind-folded (shaded bars) 60 and 30 days before launch (I-60 and -30) and 1, 2, 4, 6 days after landing (R+1, 2, 4 and 6). The mean mental walking time is expressed as a percentage of the actual walking time, represented value by 1. (n indicates the number of cosmonauts tested).

## CONCLUSION

This experiment, based on a mental chronometry approach, confirms an isochrony between mental and actual time before spaceflight, suggesting that the mechanism involved during mental representation of movement is the same as the mechanism which is used to plan the actual movement. Just following return to earth (R+1) mental time was quicker than before flight. This result can be explained in the following way : after prolonged exposure to condition of microgravity, the subject continues to mentally imagine the movement using a non-Newtonian mechanic representation. After a few days of adaptation (R+2 and R+4) the mental time is adapted to real movement execution which is generated by centrally greater force production to overcome the resistance opposed by gravity. This increase in effort sensation may explain the greater values of mental time compared to actual time at R+2 and R+4.

These results suggest a central representation of gravity force. If it was not the case, similar times may have been recorded for mental and actual movements during the post flight tests.

*Acknowledgements*

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# HAPTIC PERCEPTION IN WEIGHTLESSNESS: A SENSE OF FORCE OR A SENSE OF EFFORT?

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## INTRODUCTION

In generating a mechanical force by pushing or pulling with the arm, the human motor system can perceive the level of force produced by the limb through two different mechanisms. The CNS might measure the contact force directly, via nerve endings sensitive to pressure that are found in the skin of the hand. On the other hand, the CNS might instead use information about the muscular effort that is required to produce the necessary force level. Evidence has been accumulating for this latter "sense of effort". For instance, subjects tend to over-estimate the intensity of forces produced by fatigued muscles (Jones and Hunter, 1985).

In a normal gravity environment, the total muscular effort required to oppose a given external force includes, in addition, the muscle force necessary to support the limb against gravity. To accurately estimate the intensity of an externally applied force on the basis of muscular effort, the CNS must be able to distinguish between the component of muscle force due to the external load from muscle force generated in response to the effect of gravity on the limb itself. The CNS might accomplish this task based on a priori knowledge about the every-day gravitational environment. The CNS may use an *internal model* of the effects of gravity in order to correctly translate perceived muscular effort into an accurate perception of the applied force.

If the CNS indeed uses such an approach, one would expect that in the absence of gravity the perception of externally applied force loads would be perturbed. In particular, one would expect forces exerted downward (external force upward) to be over-estimated, since more muscular effort will be required to produce the same level of opposing force. This effect would be expected to persist until the CNS has the experience necessary to update its internal model to the absence of gravitational forces. On the other hand, if the CNS relies on pressure sensors in the skin, the perception of force intensity should remain unchanged in 0G. We tested these two hypotheses by asking subjects to perform a force matching task as part of the Cognilab experiment aboard the space station Mir.

## METHODS

Subjects sat in a chair with restraining belts. A two-dimensional force-actuated joystick was attached to the right side of the chair, positioned so that the axis of the joystick projected horizontally toward the subject. With the right hand on the joystick grip and the joystick centered in its range of motion, both the joystick shaft and the forearm of the subject were oriented horizontally. The subject viewed a computer screen through an optical tunnel that thus prevented vision of the hand and joystick.

For a single experimental trial, the motors of the joystick were activated to produce a constant, downward force on the hand (the reference force). The subject was instructed to resist this force by pressing upward on the joystick so as to keep the handle in the center position. After a brief period in which the subject could sense the intensity of the applied force, he or she pressed a button to change the applied stimulus to an upward external force having a different intensity. Again, the subject resisted the external force with a downward pressure so as to hold the joystick in the center position. With a control knob, the subject was asked to adjust the intensity of the second upward force to match the intensity of the previously measured downward force. The subject could switch back and forth between the reference and the variable stimulus as often as desired, but had to finish a given trial within 1 minute. Each subject performed 7 such trials for each of 5 different reference intensities in a single session. Subjects performed 3 sessions prior to flight and 3 sessions inflight over the course of the mission.

## RESULTS

Figure 1 shows the measured force levels that were perceived as being equal for each of the 3 subjects. The measured intensities of the downward reference force and the upward response force are plotted along the X and Y axes respectively. Each point represents one trial. If the subjects were to perform perfectly this task, all points would fall along the line $x = y$. A point above the ideal line indicates that the subject required a greater intensity of upward stimulus force to match the perceived intensity of a downward force. In other words, a point above the line indicates an over-estimation of the downward external force, or equivalently, an under-estimation of an upward force. (NB: we refer here to the force produced by the joystick. In terms of the force produced by the arm, a point above the line represents an over-estimation of the upward generated force and/or an under-estimation of a downward exerted force.)

## Results

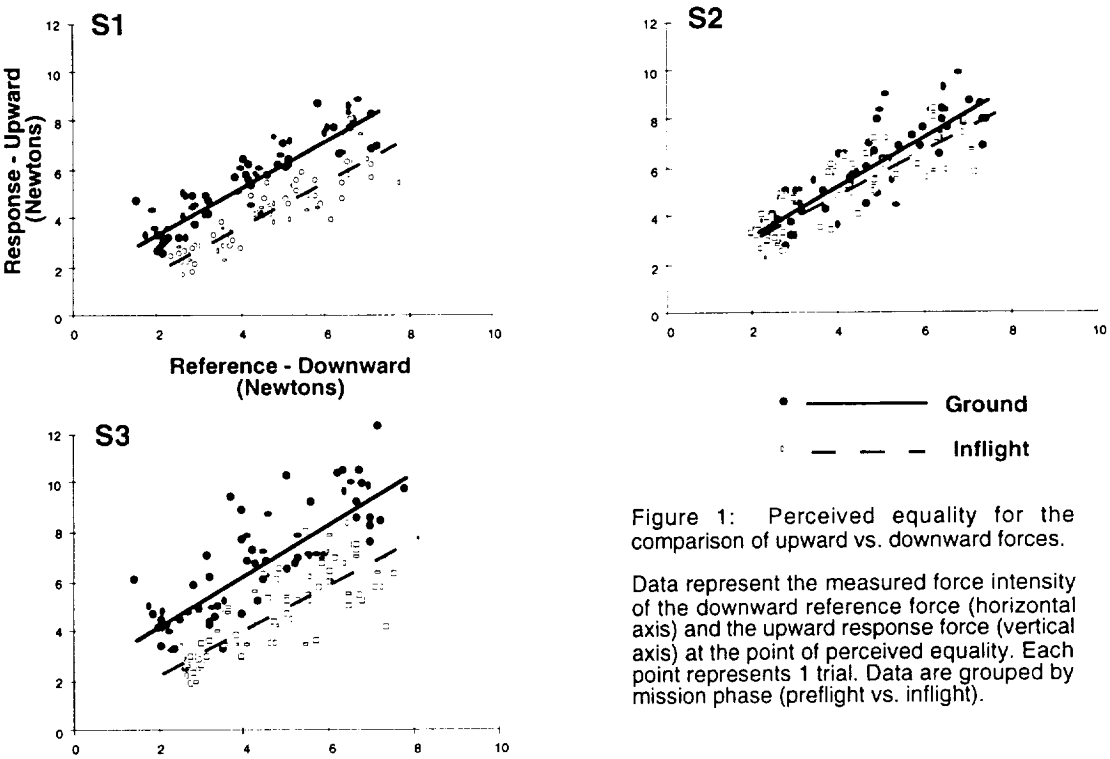

Figure 1: Perceived equality for the comparison of upward vs. downward forces.

Data represent the measured force intensity of the downward reference force (horizontal axis) and the upward response force (vertical axis) at the point of perceived equality. Each point represents 1 trial. Data are grouped by mission phase (preflight vs. inflight).

Data points are grouped by mission phase (pre-flight or inflight), and a linear regression is plotted for each group of data points. It can be seen that the best-fit regression lines shifted downward for all 3 subjects for tests carried out in weightlessness. Thus, to match the intensity of a given downward force, subjects set a level of upward stimulus that was lower inflight than on the ground. This is equivalent to saying that the perceived intensity of a downward (upward) external force is lower (greater) in orbit than on the ground.

## DISCUSSION

The data plotted above clearly shows that subjects did not base their estimations of force intensity solely on direct measures of pressure on the skin. The same magnitude of applied downward force elicits different perceptual estimates depending upon the level of gravitational acceleration. These results are consistent with the "sense of effort" hypothesis. This is not the only possible explanation, however. When the data is plotted in terms of changes in force levels (relative to the baseline level between stimuli), the difference between inflight and ground data is reduced, though not eliminated (data not shown). This latter observation is consistent with a perceptual mechanism that is tuned to changes in force levels, as opposed to measures of absolute intensity (Jami, 1990). Such a scheme would allow the CNS to adapt more readily to changes in bias forces applied to the system. Further experiments are planned to test between the "sense of effort" and the "change in force" hypotheses.

## ACKNOWLEDGEMENTS

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