

# Haptic perception in space travel

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## Introduction

Humans evolved to live on Earth, and to move around under the influence of Earth's gravitational force. The acceleration of gravity is defined as 1 g and equals 9.81 m/sec<sup>2</sup>. It is technically known as 1  $g_z$ , because the force acts through the z axis – through the head and feet for an upright human (Fig. 1). Humans (like other animals) can easily cope with the changed patterns of the various accelerative forces involved in running, jumping and swimming. Mechanised travel causes more difficulty, because it involves large variations in accelerative forces in one or more axes. Humans can adapt to these changes to some extent, but they usually show an initial impairment in motor skills, and may suffer from motion sickness.

Astronauts in orbital spaceflight live in a *microgravity* (low g) environment, which is close to zero gravity (0 g) because the acceleration of the spacecraft cancels out that of Earth's gravity. There is thus no constant accelerative force in any axis, and no gravitational 'up' or 'down'. The same effect can be produced for about 20–30 s during parabolic flight, but this is preceded and followed by about 20 s of *hypergravity* (high g) of up to 2 g (Fig. 2). Repeated parabolas offer an opportunity to examine perceptual and motor changes during both high g and low g, and compare them with performance under 1 g during straight and level flying. However, it is difficult to adapt to rapidly changing g levels, and only prolonged spaceflight allows for the study of long-term adaptation to microgravity.

Changes in g affect many aspects of human physiology, only some of which are relevant to haptic perception. Perceptual-motor performance is usually slower in orbital or parabolic flight than on the ground, and there may be several reasons for this: a floating or poorly restrained astronaut has difficulty executing manual tasks; microgravity may directly affect the control of limb movement; and the general stresses of spaceflight may affect cognitive and other functions. Current research suggests that perceptual-motor performance is impaired rather than cognitive performance [1]. This chapter concentrates on the direct effects of microgravity on hand control and haptic perception.

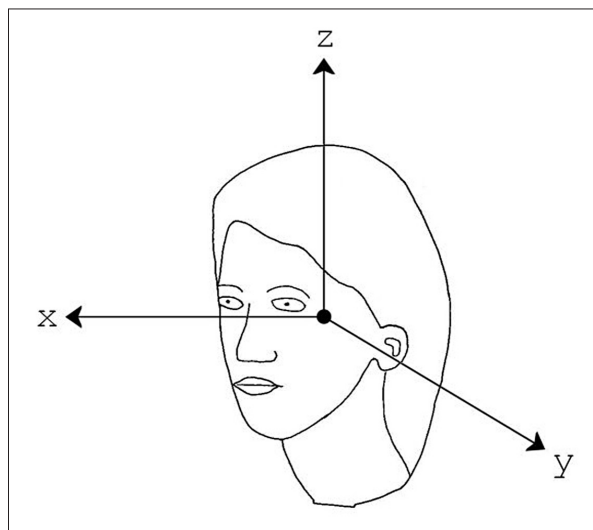
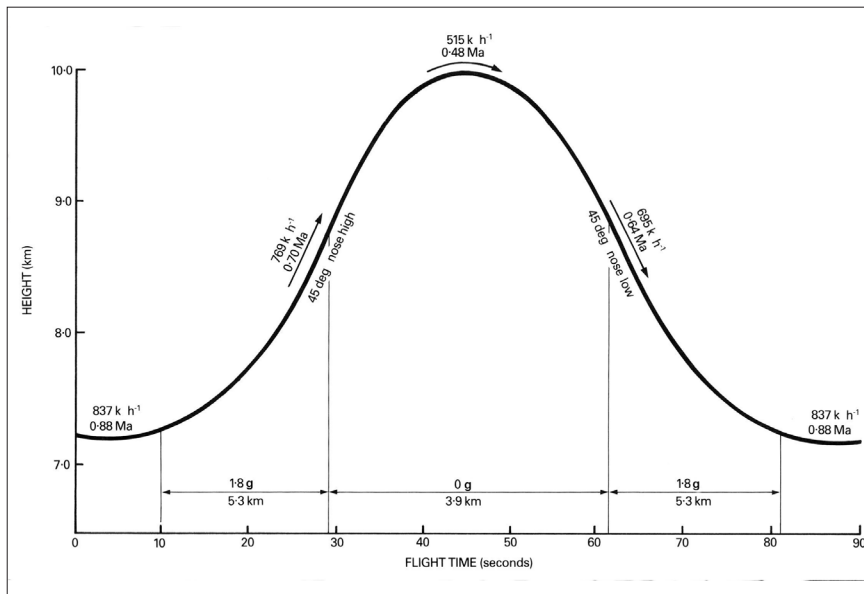


FIGURE 1.

*The principal axes in relation to an upright head. Earth's gravitational force acts through the z axis.*

**FIGURE 2.**

*Flight profile for a typical parabola in NASA's KC-135 aircraft. 20–30 s of near 0 g is preceded and followed by about 20 s of 1.8 g. (Figure courtesy of NASA)*

## Bodily orientation and the haptic system

There is a two-way relationship between the haptic system and bodily orientation: tactile information can assist knowledge of bodily orientation, and knowledge of limb position affects motor skills. The tactile contribution to orientation is discussed in this section.

The ability to perceive one's orientation with respect to gravity and to visual surrounds depends on several sources of sensory information. The vestibular system (otoliths and semicircular canals), the haptic system and the visual system all contribute. The changed situation in space travel is summarised by the Space Studies Board [2]. On Earth, the otoliths give information about static head orientation with respect to gravity; but in spaceflight they cannot do so. The semicircular canals respond normally to rotary acceleration under microgravity, but the relation between the canals and the otoliths is disturbed, leading to various visual and bodily illusions of tilt and motion. In the absence of reliable vestibular information, astronauts may take their sense of orientation from the visual orientation of the

cabin, or from the orientation of their own body [3]. The latter strategy is less likely to cause illusions and discomfort [4].

The haptic system undoubtedly contributes to the sense of orientation on Earth [5], but microgravity reduces cutaneous pressure and also reduces the loading on the joints and muscles. Thus the haptic system contributes less to orientation under microgravity than it does under 1 g [6]. A similar haptic reduction applies to divers under water, because buoyancy reduces tactile pressure [7]. Nevertheless, tactile information can make some contribution to bodily orientation under microgravity. Visually induced illusions of bodily rotation are normally enhanced in spaceflight through lack of tactile contact, but the illusions can be reduced if pressure is put on the soles of the feet by means of bungee straps [8]. Pressure on the chest or back also assists knowledge of bodily orientation during the 0 g phase of parabolic flight [9]. These findings do not demonstrate a role for the hands, but it is likely that tactile hand pressure can assist veridical perception in spaceflight. Certainly, divers under water can reduce alternobaric vertigo (a rotary illusion) by clinging to a rock or other stable structure.