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The contribution of motion, the visual frame, and visual polarity to sensations of body tilt

Ian P Howard, Laura Childerson
Human Performance in Space Laboratory, Farquharson Building, York University, North York, Ontario M3J 1P3, Canada
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Abstract. Three types of visual information contribute to the sense of self orientation with respect to gravity: visual polarity of objects with a distinct top and bottom, the principal vertical and horizontal lines of the visual environment, and visual motion. Three visual displays were designed to investigate the contribution of each visual feature to illusory self tilt: a large sphere lined with dots, a cubic room lined with dots, and a furnished room with floor and ceiling. In experiment 1 the dotted room and the furnished room were tilted to various angles about the roll axis of the erect subject who set a visual line and an unseen rod to the apparent vertical. In the dotted room, settings were made either with respect to the nearest surface to the horizontal or with respect to the nearest diagonal of the room. In the furnished room, settings were made with respect to the nearest horizontal wall but not with respect to diagonals. In experiment 2 each of the three displays was rotated at constant velocity and subjects' responses were classified into four categories: illusory self tilt at a constant angle, alternating self tilt with the body becoming erect each time a surface became horizontal, continuous head-over-heels self rotation, and a feeling that the body was supine. Almost all responses were of constant tilt in the sphere. Constant and alternating tilt were the most common responses in the dotted room. In the furnished room 60% of subjects experienced full head-over-heels self rotation.

1 Introduction

Three senses contribute to judgments of the orientation of the body with respect to gravity: vision, the otolith organs, and proprioception (see Howard 1982 for a review). Normally the information provided by these three sensory systems is concordant. However, there are many situations where the information is discordant. For instance, visual information conflicts with vestibular and proprioceptive information when we ride in a turning or accelerating vehicle, observe a wide-screen cinema, fly a flight simulator, or operate in microgravity.

There are three types of visual information that contribute to the sense of body orientation with respect to gravity. These are visual polarity, the visual frame, and visual motion. A visually polarised object is one containing an identifiable principal axis with one end distinct from the other. Most polarised objects, such as animals, plants, houses, tables, and cars have a vertical plane of radial or bilateral symmetry or near symmetry with one end designated 'top' and the other end 'bottom'. Such objects usually maintain a constant orientation with respect to gravity and, when they do not, they appear tilted or inverted. If all the polarised objects in view are inclined with respect to gravity by the same amount, observers have a compelling illusion that they themselves are tilted. Thus upright people feel a compelling illusion of self tilt about the roll or pitch axis when they view the interior of a stationary tilted room (Kleint 1936; Witkin and Asch 1948a, 1948b). The effect is due mainly to the visual displacement of the polarised features of the room, such as its ceiling-floor axis and furniture, which are normally aligned with the direction of gravity. We shall refer to this effect as polarity-induced self tilt.

The visual frame is that set of lines and surfaces that are normally vertical or horizontal. The frame used in this experiment consisted of the interior of a large cube, covered with randomly positioned dots. Other investigators have used a simple illuminated square frame set in the frontal plane. Note that a visual frame does not indicate what is 'up' and what is 'down' but only the angle of tilt with respect to vertical or horizontal. Thus an upside-down frame is indistinguishable from an erect frame. A frame tilted in the frontal plane induces strong illusions of self tilt. For example, people experience some illusory self tilt when they look at a simple tilted square in otherwise dark surroundings (Witkin and Asch 1948a; Witkin 1949). We shall refer to this effect as frame-induced self tilt. A frame inclined out of the frontal plane induces an illusion of self pitch.

Motion is the third visual feature that can affect judgments of self orientation. It has been shown that people experience self tilt about the roll axis when they observe a large circular visual display of dots rotating in the frontal plane (x axis), or an illusion of self pitch when observing a display rotating about an axis parallel to a line passing through the two ears (y axis) (Held et al 1975; Howard et al 1988). The angle of illusory self tilt or pitch in these studies rarely exceeded 20°. The rotating displays used in these studies contained no visual polarity or visual-frame features so that the effects were due wholly to visual motion. We shall therefore refer to these effects as motion-induced self tilt or pitch. In what follows, 'self tilt' refers to rotation of the erect body about the x axis, the axis parallel to the visual axes.

Witkin and Asch (1948b) measured illusory visual tilt and body tilt in subjects exposed to tilted rooms, but did not look at the contribution of motion to these illusions. A fairground device, known as the haunted swing, was built in Los Angeles towards the end of the last century (Wood 1895). Observers sat in a gondola with their heads several feet below the axis about which the room pitched, as shown in figure 1. When the room was rotated with the gondola held stationary, all observers felt as if the room were stationary and that they and the gondola had rotated about

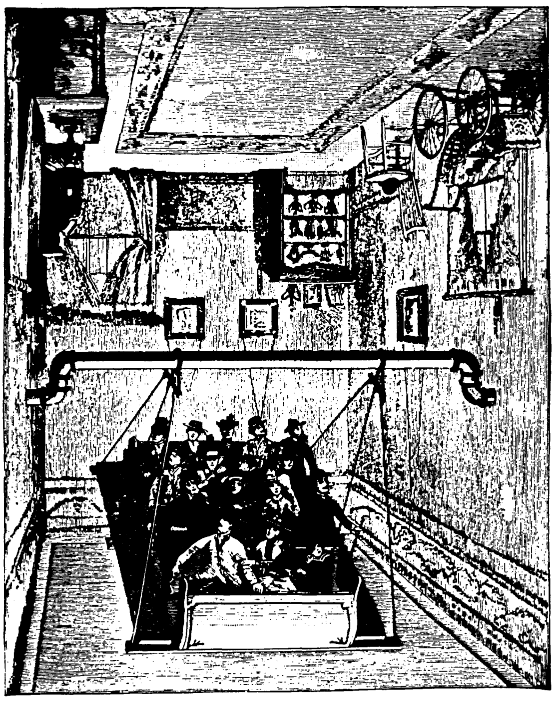

Figure 1. The haunted swing (Wood 1895). The room rotated about the stationary gondola containing the observers. Note that the heads of the observers are some feet away from the axis of rotation.

the pitch axis through 360°. This does not prove that visual factors overcame the restraining influence of inputs from the gravity sense organs (the otolith organs) because, if the gondola were to have actually rotated, the centrifugal force acting on the heads of the observers would have kept the otolith hair cells aligned with the resultant force acting along the body axis. In other words, the otolith organs would not register a real rotation of such a gondola and would therefore not provide inputs in conflict with visual inputs. Most people have played on an ordinary swing and may well have learned that otolith signals do not arise when the swing is moving at its natural frequency. The magnitude of the resultant force acting on the body would change in the haunted swing and this would affect the saccules and the proprioceptive-tactile sense organs. However, these signals would not in themselves conflict with the visual signals, since they signal a changing force acting along the body axis and are therefore not uniquely related to self rotation. During the acceleration phase there would be some conflicting signals from the semicircular canals. These were clearly not sufficient to overcome the visual signals. The extent to which visual inputs can override a full range of conflicting otolith-organ and semicircular-canal inputs can be investigated only if the head of the observer is on or near the axis of visual rotation, because it is only then that the otolith organs would respond to an actual change in body orientation relative to gravity. Kleint (1937) placed people in a furnished room that was rotated about the roll axis through 360°, with their heads on the axis of rotation. Some subjects reported sensations of total self rotation and some reported that they felt a side-to-side oscillation, but no quantitative or comparative data were presented. We therefore built a furnished room which could be rotated about a horizontal axis that passed through the head of the seated stationary subject, parallel to the visual axes (roll axis).

In previous experiments in this laboratory, subjects were placed inside a sphere of diameter 9 ft, lined with black dots and rotated about the roll axis. This produced an average illusory tilt of the body of about 25°, although some subjects experienced up to 90° of self tilt (Howard et al 1988). Some of the same subjects, however, experienced an illusion of full-body rotation when exposed to the roll or pitch motion of our rotating furnished room. In other words, the visual input totally overcame the restraining influence of the otolith organs in the rotating room, but not in the rotating sphere. The present experiments were designed to reveal the contributions of visual polarity, the visual frame, and visual motion to the illusion of self tilt. Three types of visual stimuli were used to generate various combinations of these three stimulus features: a dotted sphere, a dotted cubic room, and a furnished cubic room. They were used in the following ways: (i) the effects of the static tilt of the visual frame were measured in the tilted dotted cubic room; (ii) the effects of the static tilt of the visual frame plus visual polarity were measured in the tilted furnished room; (iii) the effects of visual motion alone were measured in the rotating dotted sphere; (iv) the effects of motion plus the visual frame were measured in the rotating dotted cubic room; and (v) the effects of motion, plus visual frame, plus visual polarity were measured in the rotating furnished room.

2 Method for experiment 1: static tilt

2.1 *Stimulus conditions*

2.1.1 *The dotted room.* The subject sat in a cubic room with sides 7 ft long, lined with black dots placed at random on a white surface. The dots were 1.3, 2.6, and 3.5 cm in diameter and covered 18% of the white surface. The room was illuminated by a 60 W bulb above and behind the subject's head. The average luminance of the wall surface at the centre of the wall was 9.8 cd m^{-2}. The subject was strapped into a seat supported on a stationary boom which protruded through one wall along the axis of rotation of the room. The subjects looked straight ahead at the centre of the wall in front of them. The fixation point lay on the axis of rotation of the room. The room was stationary and either tilted or upright. These conditions established the contribution of the visual frame provided by the edges of the room to illusory visual tilt and self tilt.

2.1.2 *The furnished room.* The subject sat in a stationary box-shaped seat with the head near the centre of a cubic wallpapered room, with sides 7 ft long, complete with baseboards, linoleum, and ceiling tiles. Furniture included a bookshelf with a cup and magazine cemented to it, and a desk with a fake sundae and a desk lamp with 40 W bulb, also cemented down. The wall to the left of the subject contained a window, and the wall to the right contained the door and had a picture hanging on it. There was also a ceiling lamp with a 40 W bulb. The average luminance of the wall surface at the centre of the wall was 8.8 cd m^{-2}. Thus, there was a rich variety of visual information about which direction was up and which direction was down. The room was stationary, either tilted or upright. These conditions established the contribution of static visual-polarity cues to illusory visual tilt and self tilt.

The angular positions of the rooms were recorded by potentiometers on their axes of rotation. The changing resistance was read every 500 ms into a Macintosh IIfx computer.

2.2 *Response measures*

2.2.1 *Illusory self tilt.* Subjects set an unseen rod to the apparent vertical, keeping the end of the rod with a knob attached to it in the 'down' position. The rod was 25 cm long and was pivoted about a roll axis between the legs of the subject. A potentiometer recording the angular position of the rod was sampled every 500 ms by the computer. A black horizontal screen hid the rod from view. The extent to which the rod was displaced from the vertical was taken as an indication of the extent to which subjects perceived their body tilted. At the same time subjects were asked to report whenever they felt that their body had turned full circle about the roll axis. A stop limited the position of the rod to between 5° and 345°.

2.2.2 *Illusory visual tilt.* In a second set of trials, subjects set a visible rod to the apparent vertical, keeping the arrowhead at one end in the 'down' position. The rod was 50 cm long and was mounted on an adjustable bracket attached to the top of the chair. The rod was placed almost at arm's length in front of the subject and was pivoted about its midpoint on a roll axis at eye level. A potentiometer recording the angular position of the rod was sampled every 500 ms by the computer. A stop limited the position of the rod to between 10° and 350°.

2.3 *Procedure*

Each of the six subjects experienced two sessions: one in the furnished room and one in the dotted room. Sessions were separated by one full day. The order of presentation of sessions was balanced, being randomly assigned to each subject so that all possible orders were presented, one to each subject. Sessions lasted from 45 min to 1 h.

Each session consisted of two main parts. Trials were carried out either with the visible rod first, and then the hidden rod, or vice versa. This order was randomised within each session.

The furnished room was set at 0°, ±40°, ±80°, and ±120° of tilt about the horizontal roll axis. These angles were with reference to the floor of the room. If we consider these same angles with reference to the side of the room nearest to the vertical they become 0°, ±40°, ±10°, and ±30°. Since the dotted room does not have a recognisable floor it is the same at 90° of tilt as in its upright position. For the dotted room therefore the angles of tilt are 0°, ±40°, ±10°, and ±30°. These angles of tilt were also presented in random order within each session.

3 Method for experiment 2: Constant velocity rotation

3.1 *Stimulus conditions*

3.1.1 *The dotted sphere.* The subject sat inside a 9 ft diameter sphere lined with black dots placed at random on a white surface, similar to those used in the dotted room. The interior of the sphere was illuminated by a 60 W tungsten lamp placed above and behind the top of the subject's head. The average luminance of the sphere surface at the centre of rotation was 9.4 cd m^{-2}. The subject was strapped by a five-point harness into a seat supported on a stationary boom which protruded through the axis of rotation of the sphere. The subject was asked to look straight ahead at the centre of rotation on the surface of the sphere. The sphere was rotated in roll about a horizontal axis at a constant velocity of $15° \ s^{-1}$. These conditions established the contribution of pure motion to illusory visual and self tilt.

3.1.2 *The dotted room.* This was as described for experiment 1, in section 2.1.1. The room was rotated in roll about a horizontal axis at a constant velocity of $15° \ s^{-1}$. These conditions established the dynamic contribution of the visual frame provided by the edges of the room to illusory visual and self tilt.

3.1.3 *The furnished room.* This was as described for experiment 1, in section 2.1.2. The room was rotated in roll about a horizontal axis at a constant velocity of $15° \ s^{-1}$. These conditions established the contribution of dynamic visual-polarity cues to illusory visual and self tilt.

3.2 *Response measures*

Rather than use the measurement devices from experiment 1, verbal responses were obtained. Preliminary trials on many other observers had revealed four different types of response to rotation of the visual field. These were: (a) Subjects felt inclined about the roll axis at a constant angle in the opposite direction to that in which the scene was rotating. This will be called 'constant tilt'. (b) Subjects felt as if they were rotating in the roll plane in antiphase to the motion of the scene to a certain limiting angle of tilt, then felt suddenly upright, then began tilting again. This will be called 'alternating tilt', or 'partial tumbling'. (c) Subjects felt they had tumbled completely through 360°. This will be called 'full tumbling'. (d) Subjects felt they were supine and looking up at the visual display which appeared to be in a frontal horizontal plane above them. This will be called the 'supine response'.

These sensations were described to the subjects before each trial. If either response 'a' or 'b' were reported, the subject was shown a dial marked every 10° and asked to indicate the maximum angle of tilt experienced.

3.3 *Procedure*

Each of the thirty subjects experienced three sessions: one in the furnished room, one in the dotted room, and one in the sphere. Sessions were separated by one full day. The order of presentation of sessions was balanced, being randomly assigned to each subject so that all possible orders were presented, with the same number of subjects receiving each. Sessions lasted approximately 10 min.

The displays were rotated continuously in roll about a horizontal axis for four full revolutions at a constant velocity of $15° \ s^{-1}$.

4 Results

4.1 *Experiment 1: Static tilt*

One purpose in the experiment was to reveal whether subjects used the floor of the furnished room or the nearest-to-horizontal side of the room as their reference. Since there is no recognisable floor in the dotted room, we assume that subjects use the nearest-to-horizontal wall. Thus when the floor of the furnished room is tilted +80°

(clockwise) the nearest-to-vertical wall is tilted $-10°$ (counterclockwise). Similarly, when the floor of the furnished room is tilted $+120°$ the nearest-to-horizontal surface is tilted $+30°$. For 40° of tilt of the floor the nearest-to-horizontal surface is also tilted by the same amount and with the same sign. There is evidence that when a square is tilted in the frontal plane at near 45°, the diagonal of the square becomes the reference for upright (Wenderoth and Beh 1977). When the rooms are tilted $+40°$ the nearest diagonal is tilted only $-5°$.

In figure 2 the accuracy (constant errors) of vertical settings of the visual rod and the unseen rod for each angle and each direction of tilt are shown, both for the dotted and for the furnished rooms. Consider each angle of tilt in turn. For the furnished room tilted plus or minus 40° both the unseen (felt) rod and the visible rod appeared displaced in the direction of the tilt of the room. For the dotted room the felt rod also seemed tilted in the direction of the floor of the room, but by a much smaller amount, and the visible rod appeared displaced in the direction of the nearest diagonal of the room. For the 80° tilt of the furnished room, and the equivalent 10° opposed tilt of the dotted room, the only significant tilts of either the visual or the felt rods were in the direction of the nearest horizontal surface. For the 120° tilts of the furnished room and the equivalent same-sign 30° tilts of the dotted room, the apparent vertical both of the visible and of the felt rods was in the direction of the nearest surface, which in this case is in the same direction as the tilt of the floor of the unfurnished room. However, if subjects had been using the floor of the furnished room as their reference the apparent vertical should have been displaced 90° more in the furnished room than in the dotted room. In fact the apparent vertical was displaced by only a few degrees more in the furnished room than in the dotted room. Overall, subjects used the nearest surface as their reference, both in the furnished and in the unfurnished rooms. The major difference between the rooms is that at a tilt angle of 40° subjects used the nearest diagonal as their reference in the dotted room whereas, in the furnished room, they used the nearest surface. Thus the visual polar features of the furnished room were not sufficient to override the lack of otolith and somatosensory signals at higher angles of tilt of the furnished room.

The errors with respect to the nearest-to-vertical wall were analysed by a repeated measures ANOVA for the two Field conditions (dotted room and furnished room),

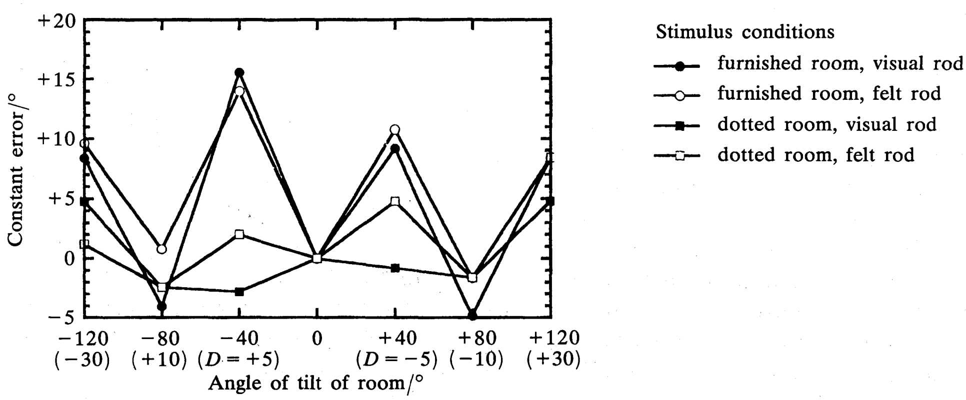

Figure 2. Experiment 1: accuracy (constant errors) of vertical settings of the visible and felt rods as a function of the angle of tilt of the furnished and of the dotted rooms. Positive errors indicate settings in the direction of the tilt of the floor. The upper scale on the horizontal axis indicates the tilt of the true floor of the furnished room, with positive values indicating clockwise tilt. The lower scale indicates the tilt of the surface of either the furnished or dotted room closest to horizontal or, for those angles marked with a *D*, the tilt relative to the closest diagonal of either room.

two Responses (visible rod and unseen rod), three Angles of Tilt of the surface nearest to horizontal (40°, −10°, and 30°), and two Directions of field tilt (clockwise and counterclockwise). There was a significant interaction effect between Field and Angle of Tilt ($F_{2,10} = 6.91$, $p < 0.05$). Main effects and other interaction effects were not significant.

Since the results for the visible rod and the felt rod and for the two directions of motion were not significantly different, the results were averaged across these two variables to yield a mean constant error of vertical settings. The mean error did not increase with the increasing tilt of the floor of the furnished room but rather with the increasing tilt of the surface nearest to horizontal and vertical, as shown in figure 3. In contrast, the mean constant error in vertical settings remained fairly level in the dotted room, increasing somewhat at 30° tilt and decreasing slightly at 40° tilt. A square frame tilted at multiples of 45° has no effect on the subjective vertical, because it is seen as an erect diamond. This would explain why subjective vertical settings were fairly accurate in the dotted room at 40° tilt. The furnished room tilted at 45° did not appear as a diamond and therefore the diagonal of the room was not used as the reference for vertical. Note that none of the subjects reported feeling tilted more than 60° in any of the tilted displays.

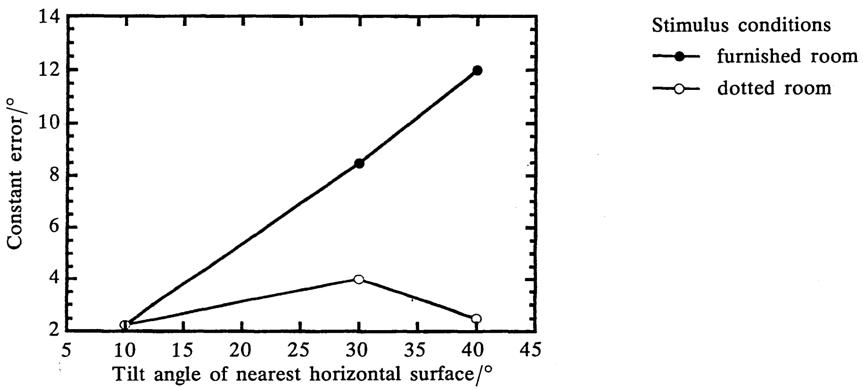

Figure 3. Experiment 1: constant errors of combined settings of the visible and felt rods as a function of the nearest horizontal surface of the furnished and dotted rooms, averaged across the two directions of tilt.

4.2 *Experiment 2: Constant velocity rotation*

Almost all the responses to constant rotation of the three types of visual display fell into one or other of the four classes of response type described in section 3.2. The percentage of subjects responding in these different ways for the sphere, dotted room, and furnished room are shown in figure 4. A Cochrane Q test was applied to these data. There were significant differences in the numbers of subjects showing constant tilt, alternating tilt, and tumbling between the stimulus conditions.

A posteriori McNemar and binomial tests revealed the following significant differences. In the sphere, twenty-two subjects (73%) felt they were constantly tilted, only four (13%) reported a sensation of tumbling through 360°, and none reported alternating tilt. In the dotted room there were significantly fewer constant-tilt responses: three subjects felt alternating tilt (a response which did not occur in either of the other conditions), and significantly more subjects (30%) felt that they had tumbled through 360°. In the furnished room there were still fewer subjects who reported constant tilt and eighteen (60%) felt that they had tumbled completely around. The four subjects who reported tumbling in the sphere also reported tumbling in the dotted and furnished rooms.

Three subjects in the dotted room, and the same three plus one more in the furnished room, felt that they were supine and rotating through 360°. If these are added to those who felt they were tumbling about the roll axis then the total of subjects reporting tumbling in the dotted room becomes 40% and in the furnished room 73%. The numbers were too small to draw conclusions about the relative incidence of the supine response but it is an interesting response. It provides the subject with a way to resolve the conflict between vision and the otolith inputs because, in the supine position, there is no changing otolith input when one rotates about a vertical roll axis. A few subjects alternated between feeling supine and tilted.

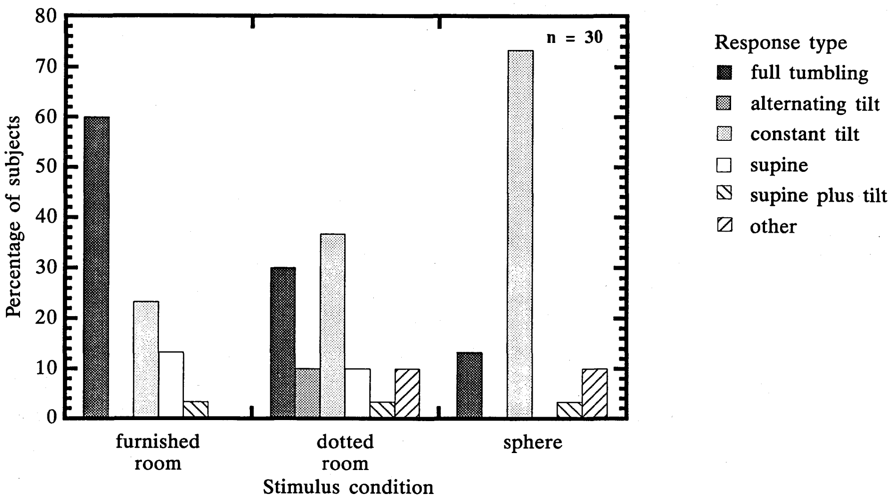

Figure 4. Experiment 2: percentages of subjects showing each type of response to constant rotation of the furnished and dotted rooms and the sphere.

5 Discussion

The most striking aspect of these results is that up to 60% of adult subjects feel that they are turning through 360° when inside a visual display rotating about a horizontal roll axis when the visual display contains a rich assortment of visual cues to the direction of gravity. In the rotating displays, the illusion of complete self rotation occurred less often when the visual cues to gravity consisted only of the main lines of a cubic space, and was relatively rare when the moving visual display contained no cues to the direction of gravity. Sensations of being upside down did not occur for static tilts of either the dotted room or the furnished room. For these stimuli, the mean illusory tilt of either the visible or the felt response rod was less than 20°, which confirms the results of earlier investigations. The sensation of total tumbling in the rotating rooms occurred in spite of the fact that the head of the subject was close to the rotation axis, in other words, when it was in a position where otolith sensations would have occurred if the subject had been actually rotating. Total tumbling also occurred in spite of conflicting information arising from pressure sensors in the skin and from proprioceptors.

The inverse of the illusion reported here is created when a person and the surrounding room are both rotated about a horizontal axis. Now the utricles are signalling that the person is rotating while vision is signalling that the person is not rotating. After a while the sensation of self rotation gives way to a sensation that the body remains erect but cycling, as in a ferris wheel (Schöne 1984).

We have produced evidence in previous reports that, when the restraining influence of the otolith organs is removed, all subjects experience a sensation of total self rotation, even in the sphere. One way to remove the otolith inputs is to test people with bilateral loss of vestibular function. We tested four patients of this type and found that they all experienced total self roll inside a sphere rotating about a horizontal axis (Cheung and Howard 1989). Another way to remove otolith-organ restraint is to test people in conditions of microgravity in NASA's KC 135 parabolic flights. These tests were done with a video film of the rotating sphere presented in a helmet-mounted system. All subjects reported total self rotation about the roll axis when in the microgravity phase of the flight parabola (Cheung et al 1990).

Another striking aspect of these results is that different people vary widely in the way they respond to visible motion of their surroundings, but tend to be consistent from condition to condition.

Finally, the rod used in experiment 1, whether visible or felt, gave the same measure of illusory tilt, leading to the conclusion that illusory body tilt and illusory visual tilt are equivalent.

In flight simulators, vection and illusory body tilt are induced by moving visual scenes which also typically contain strong visual cues to 'up' and 'down'. This experiment has teased out the contributions of motion and pictorial cues to illusory body tilt. NASA is building a preflight trainer for astronauts in which a projected picture of the inside of the space shuttle is shown rotating about the roll axis of subjects on earth. The idea is that the astronauts will get used to the experience of receiving conflicting visual and otolith-organ inputs before they are launched into space. It is hoped that this preflight training will desensitise them to this type of sensory conflict and shorten the time it takes them to adapt to conditions of weightlessness. Apart from the qualitative reports of Kleint, studies of the maximum extent to which illusory self motion can be induced by purely visual means on earth are absent in the literature. The results of the experiments reported here provide the first experimental account of the experience of full visually induced illusory tumbling of the self and of the conditions that induce this sensation. That a full illusion of body roll can be induced by visual means in a majority of adult subjects demonstrates how convincing such illusions can be when the right stimulus conditions are used.

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References

Cheung B S K, Howard I P, 1989 "Circular vection about horizontal axes in bilateral labyrinthine-defective subjects" *Acta Otolaryngologica* **108** 336–344

Cheung B S K, Howard I P, Money K E, 1990 "Visually-induced tilt during parabolic flights" *Experimental Brain Research* **81** 391–397

Held R, Dichgans J, Bauer J, 1975 "Characteristics of moving visual areas influencing spatial orientation" *Science* **141** 722–723

Howard I P, 1982 *Human Visual Orientation* (Chichester, Sussex: John Wiley)

Howard I P, Cheung B S K, Landolt J, 1988 "Influence of vection axis and body posture on visually-induced self rotation" *Advisory Group for Aerospace Research and Development* **433** 15-1 to 15-8

Kleint H, 1936 "Versuche über die Wahrnehmung. I. Richtungs Wahrnehmung" *Zeitschrift für Psychologie* **138** 1–34

Kleint H, 1937 "Versuche über die Wahrnehmung. II. Über Bewegung" *Zeitschrift für Psychologie* **141** 9–44

Schöne H, 1984 *Spatial Orientation* (Princeton, NJ: Princeton University Press) pp 122–124

Wenderoth P, Beh H, 1977 "Component analysis of orientation illusions" *Perception* **6** 57–75

Witkin H A, 1949 "Perception of body position and the position of the visual field" *Psychological Monographs* 6 (whole No 7) 1 - 63
Witkin H A, Asch S E, 1948a "Studies in space orientation: II. Perception of the upright with displaced visual fields and with body tilted" *Journal of Experimental Psychology* **38** 455 - 477
Witkin H A, Asch S E, 1948b "Studies in space orientation: IV. Further experiments on perception of the upright with displaced visual fields" *Journal of Experimental Psychology* **38** 762 - 782
Wood R W, 1895 "The haunted swing illusion" *Psychological Review* **2** 277 - 278