Fairground rides and spatial updating

Article (Published Version)

Perception, 2010, volume 39, pages 1675 – 1677

doi:10.1068/p6839

SHORT AND SWEET

Fairground rides and spatial updating

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Received 30 September 2010; in revised form 17 January 2011

Abstract. A simple experiment with a rotating office chair demonstrates that the extent of counter-rotation we experience when imposed rotation has stopped is the same as the angular inaccuracy of pointing to a previously fixated object. This suggests that our conscious percept of rotation and the updating signal for the egocentric model we use to guide motor actions are closely related.

When we turn, or point to, an object outside the current field of view, we do so on the basis of an outline model of the surroundings maintained in the parietal lobe. This is variously known as the egocentric representation (Burgess 2008), spatial image (Loomis and Philbeck 2008), or parietal window (Byrne et al 2007). I will refer to it here as the egocentric model. If we move around in the environment, this model has to be continuously updated, so that the objects that surround us retain a constant relationship with the model. In this way, location on the model continues to provide reliable directional information, independent of our current heading, which the motor system can use to direct actions such as pointing, grasping, or making saccades.

The updating input for rotation can be visual in origin (Riecke et al 2007), or it can come from the vestibular system (Ivanenko et al 1997). The roles of the semicircular canals in stabilising the eyes (VOR) and the head (VCR) are well documented, but their role in stabilising our egocentric representation has not received the same attention. It is, however, known that differential stimulation of the two labyrinths with hot and cold water does produce a feeling of rotation, and also inaccuracy when subjects are asked to point to remembered objects (Bottini et al 1994). A simpler way to achieve a similar, but more spectacular, result is to induce mild dizzyness (post-rotational vertigo) in subjects by rotating them in an office chair for a few revolutions, and then get them to point to a remembered object with their eyes shut.

The reason that fairground rides make us dizzy is that, following prolonged rotation, the fluid in the semicircular canals continues to rotate within the now stationary canals, bending the cupolae and giving a false sensation that either you or the world is rotating. A single 180° head turn will not do this, and in normal life this is not a problem; but, as ballet dancers know well, continuous head rotation in one direction results in disorientation.

I performed the following experiment on five of my colleagues, all in their thirties and competent at estimating angles (figure 1). The subject sits on the chair with feet off the ground. The chair is then rotated by hand for 3 – 5 revolutions, after which the rotation is halted with the subject facing a prominent landmark, such as a light switch, whose position he/she is instructed to note. The subject then closes his/her eyes. The subjects now have the sensation that they (and the chair) are rotating in the opposite direction to the initial imposed rotation (dashed arrow). This lasts for approximately 10 s, and, when the sensation stops, the subjects are asked to do two things: to estimate how far (to the nearest 5° or 10°) they think they have rotated from the initial direction of the landmark, and to point to the remembered landmark, in whichever order they choose.

Only after this are they asked to open their eyes. Neither of these tasks appears to be particularly difficult for most subjects. This was repeated four or six times with each subject, alternating directions. After-rotations of different extents were easy to induce by varying the vigour of the initial imposed rotation.

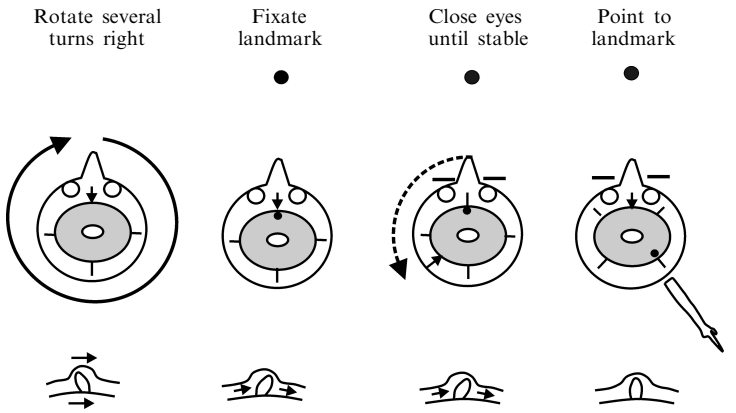

Figure 1. Scheme of the experiment. The egocentric model is represented by the grey disc and the perceived head direction by the short arrow. The position of the cupola in a semicircular canal is shown below. Further details in the text.

The results are shown in figure 2. The negative slope of the distribution means that if the subject feels they have rotated 140° left they will point 140° right, to where they believe the target still to be. However, because they have not actually rotated they now point 140° to the right of the target itself. While the eyes are closed, all subjects report that it is they that are rotating and not the world (figure 1). This is in line with what would be expected if they are responding to the (now corrupt) updating signal in the usual way, namely by assuming that they themselves have rotated, and not the egocentric model or the world. The relation between the speed and duration of the imposed rotation and the pointing error implies that the rotation of the egocentric model in the head faithfully reflects the inaccuracy of the updating signal provided by

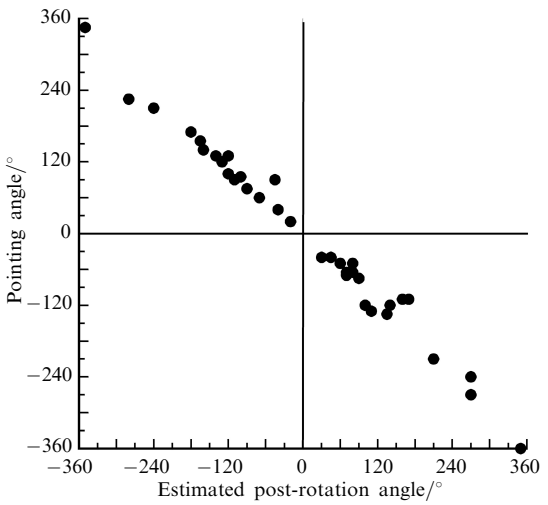

Figure 2. Relationship between the angles that five subjects estimated they had turned through in the period after the rotation of the chair had stopped, and the misalignment of the directions in which they pointed to a previously observed landmark. The slope of the best fit line is 0.929, and the correlation (r) is 0.992. Each point is a single pair of judgments.

the semicircular canals. The impressive correspondence between reported rotation and pointing error (figure 2) means that this misleading information is also available to conscious scrutiny and report, although whether this comes via the egocentric model or a separate route is not clear.

During the rotations of everyday life the seen rotation of the visual world and the vestibular rotation signal agree with each other. After prolonged rotation, however, vision and vestibular signals are in conflict, the latter indicating motion and the former not. Closing the eyes removes the visual signal, exposing the vestibular contribution, which gives a sensation of rotation. This signal is faithfully reflected in the inaccuracy of pointing because the updating of the egocentric model is itself inaccurate. Interestingly, if the eyes remain open after rotation, vision 'wins'. One can feel the conflict, and there is some visible nystagmus, but the sensation of rotation is much reduced, and pointing to the now visible landmark is not affected.

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ISSN 0301-0066 (print) ISSN 1468-4233 (electronic)

PERCEPTION
VOLUME 39 2010

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