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How robust are the deviations in haptic parallelity?

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Abstract

Several studies have shown that physically parallel bars do not feel parallel and vice versa. The most plausible cause of this deviation is the biasing influence of an egocentric reference frame. The aim of the present study was to assess the strength of this egocentric contribution. The deviations from veridicality were measured in six experiments where subjects were presented with either haptic or visual information about parallelity or their deviations. It was found that even direct error feedback (either haptically or visually) did not even nearly result in veridical performance. The improvements found were attributed to a shift in focus towards a more allocentric reference frame, possibly reflecting the same mechanisms as found in delay and noninformative vision studies. We conclude that the illusionary percept of haptic parallelity is rather robust and is indeed caused by a strong reliance on an egocentric reference frame.

PsycINFO classification: 2320

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1. Introduction

Several studies have shown that what is perceived haptically as parallel deviates far from physically parallel (e.g., Kaas & Van Mier, 2006; Kappers, 1999, 2003; Kappers & Koenderink, 1999; Newport, Rabb, & Jackson, 2002; Zuidhoek, Kappers, Van der Lubbe, & Postma, 2003). Interestingly, these deviations are not random but very systematic: in order to feel parallel, the right bar has to be rotated clockwise with respect to the left bar. The necessary rotation is subject-dependent and can be as large as 90° depending on the distance between the bars (Kappers, 2003).

Subsequent studies have focussed on finding the explanation for these large systematic deviations (for an overview, see Kappers, 2007). A key observation was that the pattern of deviations pointed towards the biasing influence of an egocentric reference frame. In this respect, it is important to note that "parallel" in an egocentric reference frame is not necessarily the same as "parallel" in an allocentric reference frame. In a hand-centered reference frame, for example, "parallel" would mean "the same orientation with respect to the hand, irrespective of the location and orientation of the hand". In a body-centered reference frame, "parallel" could mean "the same orientation with respect to concentric circles around the body midline". For all subjects in all parallelity experiments, the parallelity settings were found to lie in between "parallel" in an allocentric reference frame (that is, veridically parallel) and "parallel" in an egocentric reference frame, although the exact nature of the egocentric reference frame is still somewhat open (e.g., Kappers, 2003, 2004, 2007; Kappers & Viergever, 2006). The hypothesis is that haptically parallel is a weighted average of allocentrically parallel and egocentrically parallel.

The most likely candidates for the egocentric reference frame are hand-centered and body-centered reference frames, or even more likely, a combination of the two (Kappers, 2007). Various findings support this hypothesis. Most papers dealing with haptic parallelity show that the deviations strongly correlate with hand orientation. Most

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directly this is shown in an experiment with an extended field of bars (Kappers, 2005). Subjects were asked to make 15 bars at various locations all parallel to each other; after the experiment, their spontaneous hand orientations at the same locations were measured. The results show a strong correlation between haptic settings and hand orientations. In addition, Kappers (2007) shows that a weighted average model fits the data quite well. She also shows that a weighted average model with a body-centered egocentric reference frame likewise fits the data quite well, albeit that for most subjects the probability of a hand-centered model is larger.

Kappers and Viergever (2006) explicitly instructed subjects to orient their hands in a specific way (i.e., straight forward, divergent or convergent) while performing the parallelity task. Thus, in their experiment subjects were well aware of the orientation of their hands with respect to an outside frame of reference and thus of the misalignment of the ego- and allocentric reference frames. Even so, performance was far from veridical in the parallelity task; when their hands diverged (i.e., were rotated outwards), the deviations increased and when their hands converged (i.e., were rotated inwards), the deviations decreased. In fact, subjects more or less ignored the orientation of their hands. The weighted average model could predict how the deviations would change (either increase or decrease) with the imposed hand orientations of their subjects. Interestingly, it is not the case that subjects are not able to compensate for hand orientation, since in experimental conditions where they have to estimate or adjust clock times (Hermens, Kappers, & Gielen, 2006; Zuidhoek, Kappers, & Postma, 2005), their deviations are much smaller.

Additional evidence for the biasing influence of an egocentric reference frame is given by the reversal of the oblique-effect (e.g., Kappers, 2003; Kappers & Viergever, 2006) and the much better performance in a mirroring task as opposed to tasks adjusting parallel or perpendicular bars (Kaas & Van Mier, 2006; Kappers, 2004).

The idea that measurements can be influenced by body (part) orientation is not new. Various other authors have reported very different experiments in which also substantial deviations are found (e.g., Carrozzo & Lacquaniti, 1994; Flanders & Soechting, 1995; Paillard, 1991; Soechting & Flanders, 1992). They argue likewise that the deviations in these experiments are due to a biasing influence of an egocentric reference frame. Depending on the experimental conditions, this egocentric reference frame can have various origins, such as the arm (e.g., Flanders & Soechting, 1995) or the hand (e.g., Carrozzo & Lacquaniti, 1994).

It is an interesting and important question whether and how this egocentric bias can be influenced. Zuidhoek et al. (2003) have shown that in the parallelity experiment, a time delay in between the exploration of the reference bar and the setting of the test bar results in significantly smaller deviations. A delay supposedly induces a shift from the egocentrically biased spatial representation towards a more allocentric one (e.g., Rossetti, Gaunet, & Thinus-Blanc, 1996). Newport et al. (2002) showed that also noninformative vision (i.e., vision that is not of any relevance for the task at hand) causes a significant reduction in the size of the deviations. Later, this result was reproduced and extended by Zuidhoek and colleagues (Zuidhoek, Visser, Bredero, & Postma, 2004). The idea is that vision plays an important role in spatial cognition (e.g., Thinus-Blanc & Gaunet, 1997) and therefore might provide sensory awareness for a more allocentric representation.

The focus of the present series of experiments is to assess the strength of the egocentric contribution to the spatial representation in circumstances where subjects are confronted with either haptic or visual information about parallelity. On the basis of the effects of delay and noninformative vision, one might expect that improvements (i.e., reductions of the deviations) are certainly possible. In this respect one should realize that although the improvements reported for delay and noninformative vision are significant, they are also quite small (just a few percent of the total deviation). On the other hand, introspective reports of ourselves and numerous subjects and visitors, indicate that knowing that bars are parallel and even seeing these parallel bars, does not achieve that they also feel parallel.

Therefore, our hypothesis is that the egocentric contribution to the perception of parallelity is very strong and hard to ignore, either consciously or unconsciously. However, in conditions where subjects are asked to focus on some kind of allocentric reference frame, small improvements are likely to occur. Our aim is not to teach our subjects how to perform veridically, but to measure whether their perception changes after various training or feedback procedures. If their deviations remain substantial after training, it has to be concluded that the misperception of parallelity is an illusion strongly relying on our egocentric reference system. If, on the other hand, subjects improve after specific training or feedback, we gain information on how various factors, such as vision and error feedback may influence haptic perception and the relative dependence on different reference frames.

In a baseline condition, subjects will be tested without any training or feedback. In Experiments 2–4, subjects will receive some form of training (either haptically, visually or both), but they are not told explicitly that they make large errors. In Experiments 5 and 6 they are shown, either visually or haptically, their deviations from veridical settings. In all experiments subjects will be tested before, during, and after the training.

2. General methods

2.1. Subjects

In all experiments, eight different subjects participated. Their handedness was assessed by means of a standard questionnaire (Coren, 1993). Most of them were students