Conclusions

The smart mechanism for TTC detection proposed here has a number of interesting features. First, it is able to register tau in expanding patterns as well as in patterns that show motion parallax. Thus, it is able to explain TTC perception of objects and observers translating in any direction. Second, it allows object invariant TTC detection: any pattern with a certain tau value will be registered by (a subset of) the same array of bilocal correlators, regardless the size, shape or approach speed of the translation that depicted the flow pattern (provided that the angular size and rate of expansion of the pattern are within detection limits). Third, the idea is compatible with Gibson's notion of 'direct' perception: the mechanism is able to directly register the tau information contained in a flow pattern. Finally, it is a parsimonious mechanism, which is based on mere low-level, biologically plausible, neuronal circuitry. Disadvantages are that it would require sampling a large number of different bilocal correlator arrays, and that it cannot handle rotating approaching objects.

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Differences between Haptic and Visual Judgements of Curvature

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Abstract

Large systematic scale differences show up when subjects are asked to match the curvature of a haptically presented surface with a visually presented cross-section. Scaling factors ranging from 0.3 to 3.0 are found. Most often haptically estimated curvature is overestimated relative to visual curvature. Therefore, we conclude that is it highly unlikely that one modality calibrates the other. The results for left and right hand are not significantly different.

Introduction

It has long been thought that haptic experience is necessary for the calibration of the visual system (e.g., Locke, 1689; Berkeley, 1709). The prevailing idea was that the sense of touch provided the observer with veridical information about the shape of things in the environment. However, the experiments of, among others, Gibson (1933), Rock and Harris (1967) and Power (1980) have shown convincingly that vision dominates in situations where vision and touch provide conflicting information. Moreover, even in the absence of visual information haptic judgements are seldom veridical (e.g., Vogels, Kappers & Koenderink, 1996).

Here we are interested in the question how well observers can match visual and haptic curvature in a situation without any conflicting information. If the visual system is calibrated by input from the haptic system (or vice versa) we do not expect to find any systematic differences. If, on the other hand, the calibration processes of the two senses are more or less independent, the relationship between haptic and visual judgements of curvature cannot be predicted. Deviations from a one-to-one relationship between haptically and visually judged curvature are possible and expected in such a case.

Another motivation for this study is that in previous research we repeatedly found that performance in bimanual discrimination tasks is worse than performance of both hands separately (e.g., Kappers, Koenderink, Te Pas, 1994). Such results might possibly be explained if the hands are calibrated independent of one another. The matching task we use here, provides us with a tool to gain insight into the relative calibration of the two hands.

Methods

Subjects were asked to haptically explore a cylindrical surface which was presented to them behind a curtain so that they could not see it. Visual stimuli were presented in a folder in front of the curtain. Each page of this folder contained a possible cross-section of a cylindrical surface. Task of the subjects was to indicate which of the visually presented cross-sections corresponded best to their estimation of the curvature of the haptically presented surface. Visual and haptic stimuli were presented at about the same distance from the subject.

The haptic stimuli were 20 cm in diameter and made out of polyurethane foam impregnated with synthetic resin. The bottom of the stimuli was flat and always rested on the table; the upper surface was cylindrically curved. The base height of the stimuli was different for each stimulus so that the total height was not a cue for curvature. The following curvatures (reciprocal radius) were used: -5.7, -4, -2.8, -2, -1.4, -1, -0.7, -0.5, -0.35, 0, 0.35, 0.5, 0.7, 1, 1.4, 2, 2.8, 4, 5.7 (1/m). The set of cross-sections contained the same curvatures but in addition also -22.6, -16, -11.3, -8, 8, 11.3, 16, 22.6 (1/m) were available. Since a cross-section of a curvature of 0.35/m is almost indistinguishable from a straight line, it was not necessary to add curvatures in the lower range. Subjects were explicitly told that the curvature ranges of the haptic and visual stimuli were not necessarily identical.

Each cylindrical surface was presented 10 times to the subject in random order. Exploration time was unlimited. On average, a complete session took about 2.5 hours. Right and left hand were tested in different sessions on different days.

Three naïve subjects participated in this experiment. IV and KK were dominantly right-handed, whereas WH was dominantly left-handed according to the definitions of Coren (1993).

Results

The results for all three subjects are shown in Figure 1; the visually matched curvature is given as a function of the haptically presented curvature. The error bars show the standard deviations in the 10 repeated trials of a data point. The straight line in each of the graphs shows where measurements should lie if haptically and visually presented curvature match exactly. Clearly, for none of the subjects this is the case, although the results of subject WH come close.

We fitted straight lines through the data points, which in all cases yielded correlation coefficients above 0.9. The ratio of the slopes of these lines with the drawn line (slope of 1) gives an indication of the relative under- or overestimation of haptic curvature with respect to visual curvature. Subject IV relatively overestimates haptic curvature with a scaling factor of 2.2 for the left hand and a scaling factor as large as 3.0 for the right hand. Also subject WH shows a small overestimation of haptic curvature: 1.4 for both the right and the left hand. In her case, deviations mainly occur for the higher curvatures. Subject KK, on the other hand, underestimates haptic curvature relative to visual curvature (0.3 for the left hand, 0.6 for the right hand). Pilot studies with three more experienced subjects showed behaviour similar to that of subjects IV and WH. Their scaling factors lie between 1.4 and 2.5.

Results for the left and the right hand were always very similar. None of the subjects showed an overestimation for one hand and an underestimation for the other. The differences between the scaling factors of the right and the left hand were only small and they were largest for subject IV.

Discussion

These matching experiments reveal large differences between haptically and visually judged curvature. Most subjects overestimate the curvature of the haptically presented surface with respect to the visual cross-sections. This finding agrees with our own introspective experiences that surfaces which are first touched and then seen look much more flat than expected. For this reason it is tempting to locate the source of this mismatch somewhere in the haptic system, but there is a snag in it: if the visually presented cross-sections could have been touched they probably would appear much more curved than expected. One conclusion can be drawn with certainty, namely that at least one of the two modalities does not provide the observer with veridical information.

Our results make it highly unlikely that one of the modalities calibrates the other because in that case one would not expect the large systematic differences we find.

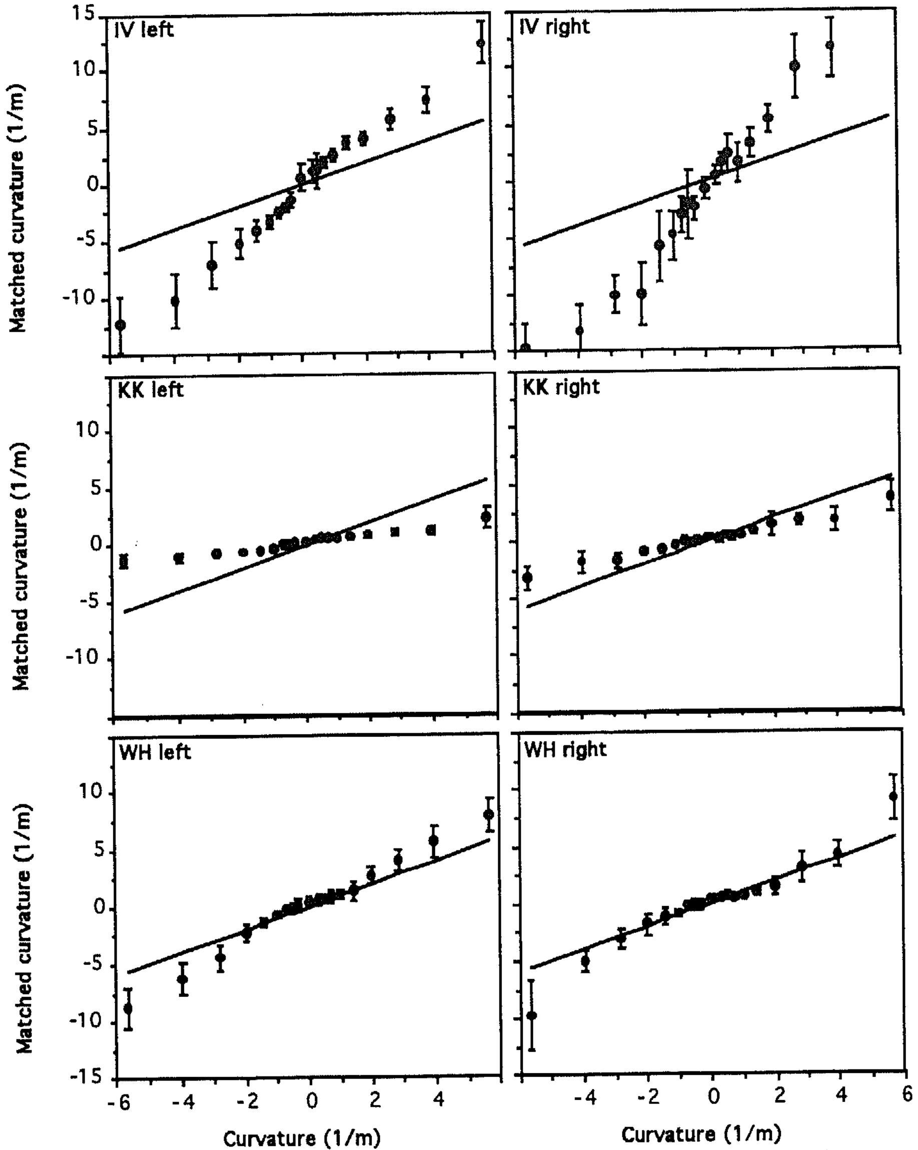

Figure 1 Visually matched curvature as a function of the haptically presented curvature. Perfect correspondences would lie on the straight lines. Error bars indicate standard deviations from the 10 trials. Left and right refer to the hand used to touch the surfaces.

However, we can neither conclude that the two modalities are completely independent, since in conflicting situations vision certainly influences haptic perception (Gibson, 1933; Rock & Harris, 1967; Power, 1980). Clearly, more research is needed to shed light on this issue.

Since for all subjects the results for the left and the right hand are very similar, we do not think that the calibration processes of the two hands can be totally independent. If that would be the case, much larger differences are to be expected. As a consequence, independent calibration processes of the two hands can be ruled out as an explanation of the relatively poor performance we found in bimanual discrimination tasks. Part of our future research will be focussed on investigating alternative explanations.

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Postural Control of Equilibrium in the First Year of Learning to Walk

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Abstract

The development of independent walking is considered here as the process of learning dynamic equilibrium. 7 children have been observed from onset of walking up to 2 years later. Locomotor parameters were recorded by a large force–plate synchronised with four video cameras. The developmental trend observed in limb kinematics is analysed within the system/task model (Newell, 1986). The child strategy at various periods of learning to walk is interpreted as a motor solution to a motor problem : the mastering of disequilibrium during the single–support phase of the step cycle.

Introduction

While almost all children are biologically prepared for bipedal locomotion – biomechanical and neural development are in place at 12 months or so – we argue here that walking itself is learned. That is, biological preparation allows the child to begin to experience the unique patterns of destabilizing forces associated with the body in such a task.

One of the main problems encountered by the young toddler at onset of walking is the control of equilibrium. To control equilibrium is to control the relative position of the centre of mass (CM) and of the centre of pressure (CP) in relation with the base of support (Winter, 1992; Bril & Brenière, 1992). During the step cycle the unipodal stance is the period of greater disequilibrium (Yang, Winter & Wells, 1990) as the projection of the centre of mass onto the ground falls outside of the base of support.

Model

Two conditions are required to insure the equilibrium of an object :

1 – The resultant of the external forces – gravitational forces and ground reaction forces – must be equal to zero.

2 – The sum of the moments of the forces with respect to the centre of mass must be equal to zero.

A corollary of these conditions is a null distance between the centre of foot pressure (CP) (that is the barycentre of the reactive forces) and the projection onto the ground of the centre of mass (CM).

In walking, during the single support phase the projection of the centre of mass falls outside the surface of support. However the walker will not loose balance owing to constant postural adjustments which stabilise the body in an upright position.