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Differential developmental trajectories for egocentric, environmental and intrinsic frames of reference in spatial memory

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Abstract

We studied the development of spatial frames of reference in children aged 3–6 years, who retrieved hidden toys from an array of identical containers bordered by landmarks under four conditions. By moving the child and/or the array between presentation and test, we varied the consistency of the hidden toy with (i) the body, and (ii) the testing room. The toy's position always remained consistent with (iii) the array and bordering landmarks. We found separate, additive performance advantages for consistency with body and room. These effects were already present at 3 years. A striking finding was that the room effect, which implies allocentric representations of the room and/or egocentric representations updated by self-motion, was much stronger in the youngest children than the body effect, which implies purely egocentric representations. Children as young as 3 years therefore had, and greatly favoured, spatial representations that were not purely egocentric. Viewpoint-independent recall based only on the array and bordering landmarks emerged at 5 years. There was no evidence that this later-developing ability, which implies object-referenced (intrinsic) representations, depended on verbal encodings. These findings indicate that core components

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of adult spatial competence, including parallel egocentric and nonegocentric representations of space, are present as early as 3 years. These are supplemented by later-developing object-referenced representations.

Keywords: Spatial cognition; Spatial representation; Navigation; Development; Allocentric; Egocentric; Viewpoint independence

1. Introduction

A well-known distinction exists between two potential frames of reference in spatial memory. Egocentric representations of location, expressing an object's relation to the self, would be simple to generate from sensory data, and could provide a direct basis for action. Allocentric representations, expressing a location with respect to an external frame of reference (e.g. one provided by visual landmarks) would be more difficult to compute, but would provide a better basis for flexible navigation and for the long term storage of complex layouts.

In the present study we trace the developmental time courses of different types of representation using a task in which children recall the locations of hidden toys. A body of developmental literature describes transitions from "egocentric" to "allocentric" responses to stimuli in early childhood (e.g. Acredolo, 1978; Bremner & Bryant, 1977; Piaget & Inhelder, 1967). Our paradigm takes as its starting point the fact, now well established in the adult and animal literature, that different frames of reference are not mutually exclusive, but ordinarily operate in parallel (Nadel & Hardt, 2004). In a factorial design, we distinguish between the contributions to performance of those frameworks for representation provided by the body, and those provided by the environment. In this way we are able to provide answers to some questions about the development of viewpoint independence raised, but inconclusively answered, in earlier perspective-taking studies (e.g. Huttenlocher & Presson, 1973; Piaget & Inhelder, 1967).

Recent studies of adult spatial memory by Simons & Wang (1998); Wang & Simons (1999) have provided an elegant demonstration of the parallel effects of frames of reference defined by (i) the body, and (ii) the surrounding environment. Participants were shown an array of five objects and subsequently asked to say which of the objects had been moved. Between presentation and test, the participant's position and the array's orientation within the room were manipulated so that the array of objects remained either consistent or inconsistent with its initial position, as judged relative to (i) the body and (ii) the room. In the baseline condition, where both frames of reference were available, participants were tested from the same place in the room and the array did not move. When they moved to a new place in the room, and therefore saw a new view of the array, the body-array relation was made inconsistent. The room-array relation was made inconsistent when participants moved to a new place, but the array was simultaneously rotated so that their view of it matched the view seen at the start. Finally, when the array was rotated but participants answered from the same place in the room, both relations were made inconsistent. Simons and Wang's results showed that the frames of reference provided by body and environment had additive effects on recall accuracy. Recall was most accurate