

The development of body, environment, and object-based frames of reference in spatial memory in normal and atypical populations

Marko Nardini • Janette Atkinson •

Oliver Braddick • Neil Burgess

Background

We devised a spatial memory task to distinguish between body- and environment-based spatial representations in typically developing 3–6-year-old children. These were compared with three clinical groups: individuals with Williams Syndrome (WS), a developmental disorder associated with severe visuo-spatial deficits; children born very prematurely, and children with perinatal events including focal lesions. Our questions were: (1) Are body- and landmark-based representations dissociable over the course of normal development? (2) Could visuo-cognitive difficulties in WS be explained by an impairment to a particular subsystem of spatial memory? (3) Do preterm children and those with perinatal brain injury show specific spatial memory impairments consistent with indications of abnormality on MRI?

Method

Participants retrieved toys from an array of identical hiding places bordered by landmarks. By walking the child and/or rotating the array, we varied whether the hiding location was consistent between presentation and test, as judged relative to (1) the body, and (2) the surrounding room. When neither of these frames of reference stayed consistent, only (3) local landmarks within the array could be used.

Results

In typically developing children (Nardini et al. 2006) there was evidence for parallel, additive use of body and environment-based frames of reference as early as three years. A striking finding was that the youngest children relied much more strongly on the environment than on the body to find the toy; i.e. they already had, and greatly favoured, spatial representations that were not purely egocentric. Recall based only on the array and surrounding landmarks, which implies object-referenced (intrinsic) representations, emerged later, at five years. Children with WS (chronological age 8–15 years) scored below the three year old level and combined body- and environment-based frames of reference in an unusual, non-additive pattern. Adults with WS matched typical four year olds in that they combined these additively but showed little use of additional object-referenced representations. Preterm and term children at risk of brain injury showed variable outcome, but global 1–2 year delays were typical. A minority also showed marked dissociations between body- and landmark-referenced representations. Some of these dissociations can be linked to brain injury evident on MRI, and to deficits on other developmental tests.

Conclusions

Our results from typically developing 3–6 year olds show distinct developmental trajectories for the use of different frames of reference in spatial memory. In WS, substantial deficits persisting to adulthood include in particular the very poor ability to reference locations to local landmarks. The other clinical groups show more variable outcome, with some preliminary indications of specific deficits consistent with structure-function relationships proposed in adult models.

M. Nardini (✉) • O. Braddick

Department of Experimental Psychology, Oxford University, UK
e-mail: marko.nardini@psy.ox.ac.uk

J. Atkinson

Department of Psychology, University College London, UK

N. Burgess

Institute of Cognitive Neuroscience and Department of Anatomy,
University College London, UK



Keywords Egocentric and allocentric • Memory • Landmarks and navigation • Williams Syndrome

Acknowledgments We thank our clinical collaborators: Drs Frances Cowan, Leigh Dyet; Professors David Edwards, Mary Rutherford. We also thank the Williams Syndrome Foundation for their help and participation. Supported by Medical Research Council

programme grant G790850.

Reference

Nardini M, Burgess N, Breckenridge K, Atkinson J (2006) Differential developmental trajectories for egocentric, environmental and intrinsic frames of reference in spatial memory. *Cognition* 101:153–172

