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How useful are landmarks when learning a route in a virtual environment? Evidence from typical development and Williams syndrome

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ABSTRACT

The ability to learn a route through a virtual environment was assessed in 19 older children and adults with Williams syndrome (WS) and 40 typically developing (TD) children aged 6–9 years. In addition to comparing route-learning ability across groups, we were interested in whether participants show an adult-like differentiation between "useful" and "less useful" landmarks when learning a route and the relative salience of landmark position versus landmark identity. Each virtual environment consisted of a brick wall maze with six junctions. There were 16 landmarks in the maze, half of which were on the correct path and half on incorrect paths. Results showed that both groups could learn each route to criterion (two successful completions of a route without error). During the learning phase, the WS group produced more errors than the TD group and took longer to reach criterion. This was predominantly due to the large number of perseverative errors (i.e., errors that were made at the same choice point on consecutive learning trials) made by the WS group relative to the TD children. We suggest that this reflects a difficulty in inhibiting erroneous responses in WS. During the test phase, the TD group showed stronger recall of landmarks adjacent to junctions (more useful landmarks) than of landmarks along path sections (less useful landmarks) independent of each individual's level of nonverbal ability. This pattern was also evident in the WS group but was related to level of nonverbal maturation; the differentiation

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between recall of junction and path landmarks increased as nonverbal ability increased across WS participants. Overall, the results demonstrate that individuals with WS can learn a route but that the development of this ability is atypical.

Introduction

Route learning (i.e., the ability to know where you are, to learn your way around a town, or to learn a route from A to B) is a crucial aspect of human development (Rissotto & Giuliani, 2006). Siegel and White (1975) proposed that route-learning abilities develop in three stages. The first stage involves knowledge of the landmarks along a route, defined as landmark knowledge. The second refers to knowledge of the sequential order of the turns and landmarks of a route, defined as route knowledge. The final stage involves the development of a cognitive map, also known as configurational knowledge, by which the spatial relationships between routes and landmarks in an area are understood. More recently, a qualitative difference between the first two stages (landmark knowledge and route knowledge) has been challenged, and many now favor a model of continuous development of route-learning ability, with the only qualitative change occurring during the integration of learned places, to form a cognitive map (Montello, 1998). Furthermore, Jansen-Osmann and colleagues (Jansen-Osmann & Fuchs, 2006; Jansen-Osmann, Schmid, & Heil, 2007) differentiated between the cognitive representations formed during the stages described above and the perceptual–motor learning required to build such representations. They defined the cognitive system of internal representations as spatial knowledge and the perceptual–motor learning as wayfinding behavior.

Route learning can also be considered in terms of spatial frames of reference. That is, landmark and route knowledge can be accomplished using an egocentric frame of reference (i.e., by encoding the location of a landmark relative to oneself [response learning]) and, hence, involve viewpoint-dependent representations. In contrast, the development of a cognitive map requires an individual to use an environment-based frame of reference (i.e., to encode the locations of objects relative to other objects or elements of the environment [place learning]) and is viewpoint independent (see Burgess, 2006). In typical development, young children rely on egocentric frames of reference for route learning, with spontaneous use of environment-based representations emerging within the school-age years (e.g., Bullens, Igloi, Berthoz, Postma, & Rondi-Reig, 2010; Nardini, Thomas, Knowland, Braddick, & Atkinson, 2009).

Learning a sequence of landmarks and turns (i.e., route knowledge) is an effective strategy for navigating a new environment, and such a sequence is one aspect of developing a more complete representation of an environment or a cognitive map (Montello, 1988). In the literature on environmental learning, most researchers have focused on the use of a cognitive map and there has been less emphasis on landmark knowledge and route knowledge (see Buchner & Jansen-Osmann, 2008). In the current study, landmark knowledge and route knowledge were assessed using virtual environments in typically developing (TD) children aged 6 to 9 years and in individuals with Williams syndrome (WS). The study focused on the use of proximal landmarks when learning a route and explored egocentric viewpoint-dependent processing. We were interested in whether participants differentiated between "useful" and "less useful" landmarks and the relative salience of landmark position versus landmark identity. Using Jansen-Osmann and colleagues' terminology (Jansen-Osmann & Fuchs, 2006; Jansen-Osmann et al., 2007), we measured wayfinding behavior by recording the number of learning trials required and the number of errors made while learning a route, and we assessed landmark knowledge (a feature of spatial knowledge) by measuring participants' recall of landmarks. This study is the first to use virtual environments with people with WS and the first to explore knowledge of landmark usefulness in TD children as young as 6 years.

Landmarks are an important feature of route learning and, more generally, are important to the development of spatial cognition. Landmarks can be defined as objects within the environment that are remembered due to their perceptual and contextual salience (see Caduff & Timpf, 2008). They