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Prematurity may negatively impact means-end problem solving across the first two years of life

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ABSTRACT

Preterm infants are at risk for delays in motor, perceptual, and cognitive development. While research has shown preterm infants may exhibit learning delays in the first months of life, these delays are commonly under-diagnosed. The purpose of this study was to longitudinally evaluate behavioral performance and learning in two means-end problem-solving tasks for 30 infants born preterm (PT) and 23 born full-term (FT). Infants were assessed at 6, 9, 12, 18, and 24 months-old in tasks that required towel pulling or turntable rotation to obtain a distant object. PT infants performed more non–goal-directed and less goal-directed behavior than FT infants throughout the study, resulting in a lower success rate among PT infants. PT infants showed delayed emergence of intentionality (prevalence of goal-directed behaviors) compared to FT infants in both tasks. Amount and variability of behavioral performance significantly correlated with task success differentially across age. The learning differences documented between PT and FT infants suggest means-end problem-solving tasks may be useful for the early detection of learning delays. The identification of behaviors associated with learning and success across age may be used to guide interventions aimed at advancing early learning for infants at risk.

What this paper adds?

Preterm infants may be delayed in performance and learning of means-end problem solving throughout the first two years. Means-end tasks might help identify early learning delays. Documenting behaviors associated with learning longitudinally in problem-solving tasks can inform us how to facilitate learning for infants at risk.

1. Introduction

Means-end problem solving entails the execution of an intentional sequence of actions performed on a means object to achieve a goal related to an end object, such as pulling a cloth or string to obtain a distant supported or connected object (Rat-Fischer, O'Regan, & Fagard, 2014; Willatts, 1984, 1999) or using a hook/rake to surround and retrieve a distant object (Fagard, Rat-Fischer, & O'Regan, 2014). Successful means-end problem solving requires not only appropriate sensorimotor abilities and motor-perceptual coupling (Case-Smith, Bigsby, & Clutter, 1998; Gibson & Pick, 2000; Lobo & Galloway, 2008; Thelen, 1990), but also cognitive abilities, such as

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differentiation between the means and end object, choosing the correct action sequence, and understanding causal relations (Bremner, 2000; Bonawitz et al., 2010; Lobo & Galloway, 2008, 2013; Piaget, 1953; Sommerville & Woodward, 2005). The development of means-end problem solving is foundational for future social, cognitive, and linguistic development (Brandone, 2015; Csibra & Gergely, 2007). It might serve as a model for understanding mechanisms of early learning (Bonawitz et al., 2010; Bremner, 2000; Gibson & Pick, 2000; Lobo & Galloway, 2008; Willatts, 1999). In addition, means-end tasks may effectively identify early and persistent learning differences, and may thus serve as convenient and effective diagnostic tools to identify learning impairments earlier than they might be identified by other tools (Clearfield, Stanger, & Jenne, 2015; Lobo & Galloway, 2013).

1.1. Development of means-end problem solving in full-term infants

Typically developing infants succeed in one-step means-end tasks at 6–8 months, in two-step tasks at 9 months, and in three-step tasks at 10 months of age (Clearfield et al., 2015; Lobo & Galloway, 2008; Willatts, 1984, 1999). For example, infants pull a cloth to retrieve a distant, supported object at 7–8 months (Willatts, 1984, 1999) and use a hook to bring a distant toy within reach at 10–12 months (Clearfield et al., 2015; Fagard et al., 2014). Means-end problem-solving development continues throughout the second year as infants learn to solve more complex tasks and transfer their knowledge across contexts (Brown, 1990; Piaget, 1953). The majority of previous research on means-end problem-solving has been cross-sectional or has covered only short age periods (e.g. 3 months). Only one recent study (Babik et al., in review) assessed means-end problem solving longitudinally in full-term (FT) infants from 6- to 24-months of age in two means-end tasks: pulling a towel or rotating a turntable to retrieve a distant supported toy. With age, infants increased their performance of goal-directed behaviors and decreased performance of non–goal-directed behaviors. Task success was associated with the performance of more goal-directed behaviors. Success rate increased with age, with earlier emergence of intentionality, defined as a prevalence of goal-directed behaviors, in the towel task compared to the more demanding turntable task (6.9 vs. 10.8 months). This study, however, comprehensively reported problem-solving development only for typically developing infants.

1.2. Development of means-end problem solving in infants born preterm

Preterm birth occurs when infants are born before 37 weeks of gestational age (“moderate to late preterm” 32–37 weeks, “very preterm” 28–32 weeks, “extremely preterm” before 28 weeks). Infants born preterm (PT) are at risk for early sensorimotor impairments related to visual tracking, fixation, and visuo-manual coordination (Atkinson & Braddick, 2007; Petkovic, Chokron, & Fagard, 2016), grasping, bimanual coordination, and object exploration (Bos, van Braeckel, Hitzert, Tanis, & Roze, 2013; Grönqvist, Strand-Brodd, & von Hofsten, 2011; Lobo, Kokkoni, Cunha, & Galloway, 2015), as well as motor coordination and postural control (de Groot, 2000; van der Fits, Flikweert, Stremmelaar, Martijn, & Hadders-Algra, 1999). As sensorimotor development is an important facilitator for early learning, PT infants are also at risk for delays in learning, problem solving, and cognitive development (Cherkes-Julkowski, 1998; Heathcock, Bhat, Lobo, & Galloway, 2004; Jongbloed-Pereboom, Janssen, Steenbberg, & Nijhuis-van der Saden, 2012; Lobo & Galloway, 2013).

Previous research has demonstrated that prematurity might negatively impact infants’ problem-solving development (Lobo & Galloway, 2013; Petkovic, Rat-Fischer, & Fagard, 2016; Sun, Mohay, & O’Callaghan, 2009). Lobo and Galloway (2013) showed that infants born before 32 weeks gestation had poorer learning at 3–4 months compared to full-term infants in an exploratory learning task involving learning to kick to move an overhead toy. These learning differences persisted through the second year of life in a means-end task involving pushing buttons to activate a distant toy. Furthermore, infants’ success rates in these learning tasks were stronger predictors of cognitive delays at 24-months than was a standardized assessment performed at the same times.

Sun et al. (2009) identified delays in means-end problem solving among 8-month olds, with high-risk PT infants showing the least, low-risk PT infants showing higher, and FT infants showing the highest level of intention. Petkovic, Rat-Fischer et al. (2016) showed that while late PT infants with typical muscle tone did not have trouble using a rake to obtain an out-of-reach object at 15–17 months, very PT infants with hypotonia were unsuccessful in this task even at 23 months. In line with dynamic systems theory, early sensorimotor exploration impairments might limit the types of behaviors infants perform with objects, restricting information gathering, and thus concatenating into means-end problem solving and overall cognitive delays for PT infants (Thelen, 2000; Thelen & Smith, 1994).

1.3. The role of amount and variability of object exploration in cognitive development

Object exploration involves sensorimotor interaction with objects and information gathering that can facilitate learning (Gibson, 1988; Rochat, 1989; Ruff, 1984). Exploratory behavior for typical infants at 5 months has been positively related to intellectual functioning at 4 and 10 years of age, as well as to academic achievement at 10 and 14 years (Bornstein, Hahn, & Suwalsky, 2013). PT infants have been shown to perform a lower amount and variability of exploration and less multimodal exploration compared to FT infants (Lobo et al., 2015). Reduced engagement in variable, multimodal exploration may result in impoverished information gathering and suboptimal learning (Bahrick, Lickliter, & Flom, 2004; Needham, Barrett, & Peterman, 2002; Wilcox, Woods, Chapa, & McCurry, 2007). For instance, very PT infants spent less time orally and manually exploring objects compared to FT infants at 6 months, with the amount of oral and manual exploration at this age positively related to language and cognition at 24 months (Zuccarini et al., 2017). Similarly, for PT infants, delayed object exploration at 7 months related to poorer cognitive outcomes at 24 months (Ruff, McCarton, Kurtzberg, & Vaughan, 1984).