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Perception–action development from infants to adults: Perceiving affordances for reaching through openings

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ABSTRACT

Perceiving possibilities for action—affordances—requires sensitivity, accuracy, and consistency. In the current study, we tested children of different ages (16-month-olds to 7-year-olds) and adults to examine the development of affordance perception for reaching through openings of various sizes. Using a psychophysical procedure, we estimated individual affordance functions to characterize participants' actual ability to fit their hand through openings and individual decision functions to characterize attempts to reach. Decisions were less accurate in younger children (16-month-olds to 5-year-olds); they were more likely to attempt impossible openings and to touch openings prior to refusing, suggesting a slow developmental trend in learning to perceive affordances for fitting through openings. However, analyses of multiple outcome measures revealed that the youngest participants were equally consistent in their decision making as the oldest ones and that every age group showed sensitivity to changes in the environment by scaling their attempts to opening size.

Introduction

Fitting objects—especially body parts—into openings is a ubiquitous behavior. Beginning during the fetal period, children stick their thumbs, fingers, and toes into their mouths. As soon as they can reach, young infants delight in putting their fingers and hands into small crevices. After they can crawl and

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walk, infants' locomotor play includes slithering into tight spaces. In fact, infants' fascination with fitting objects into openings sustains an industry of toys such as nesting cups and shape sorters. Infants' propensity for fitting body parts into dangerously small openings has resulted in national safety guidelines for toys and playground equipment (U.S. Consumer Product Safety Commission, 2008). In the current study, we investigated how children of different ages and adults cope with the problem of fitting their hand through openings of different sizes.

Affordances reflect the fit between body and environment

The problem of fitting through openings is a prime example of what Gibson (1979) termed an "affordance"—the match between the body and the environment that makes a particular action possible. Actions can succeed only if they are scaled to the properties of the body and the environment (Fajen, 2005; Franchak & Adolph, in press; Warren, 1984; Warren & Whang, 1987). For example, reaching through an opening is possible only if the hand is smaller than the opening. Even millimeter changes in opening size relative to hand size have drastic effects on whether fitting is possible (Ishak, Adolph, & Lin, 2008). Likewise, changes in the body affect affordances; with growth in hand size or decrease in flexibility, children can no longer fit their hand through the same small openings.

Across the life span, people must perceive affordances to adapt actions to the changing constraints of the body and the environment (Franchak & Adolph, in press). Perceiving affordances can be characterized by sensitivity, accuracy, and consistency. Sensitivity refers to the ability to detect the critical body–environment relations. It is demonstrated by scaling actions or judgments to the changing possibilities for action (e.g., attempting to fit through larger openings more often than smaller openings). Accuracy refers to the match between the actual affordance and participants' decisions. Accuracy is necessary to ensure that selected actions are appropriate given the properties of the body and environment. Errors in action selection, such as trying to fit through openings that are too small, can have dire consequences for safety. Accuracy can be influenced by sensitivity and by differences in response criteria such as how heavily one weights the penalty for error. Finally, affordance perception must be consistent over successive encounters. For example, attempting and refusing to fit through the same opening on successive presentations reflects a lack of consistency.

Development of affordance perception

Adults' perception of affordances for fitting through openings satisfies the demands of sensitivity, accuracy, and consistency. When walking through doorways and under barriers, adults demonstrated sensitivity to affordances by scaling judgments of passable openings to their relevant body dimensions—shoulder width or standing height (Franchak, Celano, & Adolph, 2012; Higuchi et al., 2011; Stefanucci & Geuss, 2010; Wagman & Malek, 2009; Warren & Whang, 1987). When walking though doorways, adults demonstrated accuracy by distinguishing passable openings from impossibly small ones; errors were small and occurred primarily at openings 1 to 2 cm smaller than what was possible to fit through—their threshold opening size (Franchak, van der Zalm, & Adolph, 2010). Moreover, adults' attempts to fit show exquisite consistency (Franchak et al., 2010); adults consistently refused openings that were 2 to 3 cm smaller than their thresholds, and they consistently attempted openings that were 2 to 3 cm larger than their thresholds. Decisions were inconsistent only within a small 4- to 6-cm range around their thresholds. Similarly, when deciding whether to reach through openings of different sizes, adults were sensitive, accurate, and consistent; attempt rates and exploratory behaviors were scaled to opening size, errors were typically less than 1 cm, and decisions were consistent within a 2-cm range around their thresholds (Ishak et al., 2008).

Infants and children must learn to perceive affordances accurately. When they first acquire new skills, infants' decisions about possible and impossible actions are rife with errors, but over weeks of experience practicing their new skills, decisions become increasingly accurate. For example, novice walkers attempted to descend impossibly steep slopes and cliffs (requiring rescue from an experimenter to prevent injury). Over weeks of walking, decisions gradually geared in to infants' actual abilities. Experienced walkers made accurate decisions by refusing to descend or by switching to an alternative sliding or backing position (Adolph, 1997; Kretch & Adolph, 2013a, 2013b).