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Concurrent anticipation of two object dimensions during grasping in 10-month-old infants: A quantitative analysis

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ABSTRACT

The anticipation of more than one object dimension while grasping for objects has been rarely investigated in infancy. The few existing studies by Newell et al. and Schum et al. have revealed mixed results probably mainly due to methodological limitations. Therefore, the present experiments tested concurrent anticipatory grasping for two object dimensions, namely, object size and object orientation using a quantitative motion capture system (Vicon), in 10-month-old infants and adults. We presented objects varying in size (small vs. large) and orientation (horizontally vs. vertically) and analyzed participants' anticipatory hand configurations. As with adults, we observed that infants rotated their wrists, thumbs, and index fingers as a function of object orientation and adjusted their maximum grip apertures and their grip apertures shortly before they touched the objects as a function of object size. Analyses on an individual level showed that infants like adults anticipated both dimensions when the maximal values of aperture and angle were used but not when the measures shortly before touch were considered. Thus, the ability to anticipate more than one object dimension can already be observed at 10 months of age but seems to improve considerably over the first year of life.

1. Introduction

Objects are an important part of infants' everyday lives. Infants are confronted with them in many different ways, for example, when they interact with toys or articles of their daily use. To be successful in their interaction with objects, infants must learn to anticipate the characteristics of objects because such anticipation enables them to adjust their actions appropriately to different aspects of the objects. Accordingly, when adults grasp for an object, they adjust their grips prior to contacting the object (e.g., Jeannerod, 1984). They are not only able to consider one object dimension in advance but can also anticipate multiple object dimensions. When objects vary, for example, in their size and orientation, adults adjust their hand shape and the orientation of their hand before touching the objects (Cuijpers, Smeets, & Brenner, 2004). This makes sense, as nearly all objects vary along multiple physical dimensions such as size, shape, texture and orientation. So far, it has been shown than infants are able to anticipate one object dimension, such as the orientation of an object or the size of an object (e.g., Lockman, Ashmead, & Bushnell, 1984; Von Hofsten & Rönnqvist, 1988). However, the anticipation of more than one object dimension while grasping for objects has rarely been

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investigated at that age. The few existing studies by Newell, Scully, McDonald, & Baillargeon (1989) and Schum, Jovanovic, & Schwarzer (2011) have revealed mixed results probably mainly due to methodological limitations. Therefore, this study aimed at further investigating infants' consideration of two object dimensions while grasping for objects by analyzing task-relevant kinematics using a quantitative 3D motion capture system. In particular, we studied 10-month-old infants compared to adults and analyzed their anticipatory grasping for two object dimensions, namely, size and orientation.

According to Von Hofsten (2004) infants' actions are prospective and goal-directed from the very beginning of life but their visual and manual anticipations become increasingly organized within the first year of life. This can be seen in studies on infants' ability to anticipate a single object dimension, that is, to adjust the hand shape before touching the object, when they grasp for it. Some studies, for example, have investigated infants' anticipation of object orientation. Lockman et al. (1984) found that 5-month-olds made grip adjustments for object orientation only after they had made contact with an object, whereas 9-month-olds anticipated a horizontal or vertical orientation prior to any haptic feedback. On trials on which the object was oriented vertically, the backs of the infants' hands were oriented sideways, and on trials in which the object was oriented horizontally, the backs of the infants' hands were oriented upward. Witherington (2005) adapted the same measuring method as Lockman et al. (1984) and showed that the qualitative change, from haptically to visually controlled grasping for object orientation, occurs between five and seven months of age. This finding was confirmed in a study by McCarty, Clifton, Ashmead, Lee, & Goubet (2001), who found anticipatory hand orientation for horizontally and vertically oriented rods in 7- and 9-month-olds but not in 5-month-olds.

In addition to these qualitative measures, studies applying more quantitative kinematic measuring methods find evidence of anticipatory adjustment to different object dimensions slightly earlier. As an example, Von Hofsten and Fazel-Zandy (1984) showed early evidence of object orientation anticipation even in 4.5-month-olds when measuring the position of the base joints of the index and little finger in 3D space. In addition, McCarty and Ashmead (1999) measured the adjustment to object orientation in 5-, 7- and 9-month-old infants by attaching infrared-emitting markers on the back of their hands. The results showed that even 5-month-olds adjust the back of their hands to object orientation. Such kinematic measuring methods seem to be more sensitive for changes in infants' hand movements and, therefore, are able to detect even small differences between hand positions.

This also applies to studies that have examined infants' anticipatory grasping for the size of an object. Von Hofsten and Rönnqvist (1988), for example, found anticipatory grip adjustments for object size in 9- and 13-month-olds, but not in 5- to 6-month-olds, by analyzing the distance between the thumb and index finger. In contrast, Fagard (2000) demonstrated anticipatory adaptation in infants aged seven and eight months by analyzing qualitatively different types of grasping: the infants used only one hand when reaching for small objects and two hands when reaching for large objects. Siddiqui (1995) and Newell, McDonald, & Baillargeon (1993) further observed that even 5-month-olds anticipated an object's size. These authors showed that the infants tend to use more digits with increasing object size.

Not only the anticipation of one object dimension like size or orientation is of great practical relevance, but also the anticipation of two or more object dimensions as most objects vary simultaneously in more than one dimension. Such a complex anticipation requires visual coding and processing of the varying dimensions of the objects. Literature on the pure visual processing of multiple object dimensions in infants points to a general pattern of transition from a predominantly single-dimension processing to an integration of several, at least two object dimensions (for a summary see Cohen, 1998). Overall, a general principle seems to be that infants' propensity to integrate multiple object dimensions depends on their age and the perceptual complexity of the stimulus, such as the number of dimensions that have to be integrated. While the lines of simple angles are integrated very early, Younger and Cohen (1986) have demonstrated that a corresponding mode of processing is reached only by 7 months when the stimulus consists of a complex line-drawn animal that is composed of three varying dimensions. Jovanovic, Duemmler, & Schwarzer (2008), for example, found the pure visual integration of object dimensions like size, shape, and texture only in 8-month-olds. Thus, the mere visual processing of multiple object dimensions is developed only in the second half of the first year.

Only a few studies have investigated whether a corresponding processing of more than one object dimension occurs in action as well, when, for example, infants grasp for an object. The first evidence for the anticipation of two object dimensions in infants was found in a study of 8-month-olds by Newell et al. (1989). The authors tested infants aged four and eight months when they reached for objects varying in size and shape. Toy cups of three different diameters and two different shapes (open mode = cup opening face up and closed mode = cup opening face down) were presented as stimuli. The findings revealed that 4-month-olds used different hand configurations for the different cups, but, in agreement with other studies (e.g., Lockman et al., 1984; Witherington, 2005), only after contact with the objects. In contrast, 8-month-olds adjusted the number of digits used to grasp the objects as a function of object size and shape prior to contact, but only for large cups. This finding shows that the prospective hand configurations of 8-month-olds can be affected by more than one object dimension. However, Newell et al. (1989) could not conduct inferential analyses because they had only limited data per subject, and thus, we do not know whether their observations in fact would have reached statistical significance.

A study by Schum et al. (2011) tested the anticipation of two object dimensions in 10- and 12-month-olds. The authors presented objects that varied in size (small vs. large) and orientation (horizontally vs. vertically) and measured infants' one-handed grips. It was found that 12-month-olds properly anticipated both object dimensions: they used qualitatively different grips to adjust for object size, namely, a precision grip (i.e., thumb-index finger opposition) for small objects and a palmar grip (i.e., whole hand grasp) for large objects, and they adjusted the back of their hands sideways for vertically oriented objects and upwards for horizontally oriented objects. In contrast, most of the 10-month-olds were found to properly anticipate object orientation but to fail to anticipate object size in their grips. In a control condition, the authors showed that 10-month-olds were, in principle, able to form a precision or palmar grip as a function of object size, if additional object dimensions did not vary. Thus, it seems that 10-month-olds were unable to cope with the anticipation of two object dimensions.