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Spontaneous object and movement representations in 4-month-old human infants and albino Swiss mice

Alan Langus [a,*], Amanda Saksida [a], Daniela Braida [b], Roberta Martucci [b], Mariaelvina Sala [b,c], Marina Nespor [a]

[a] Language, Cognition and Development Laboratory, SISSA – International School for Advanced Studies, Via Bonomea 265, 34136 Trieste, Italy
[b] Dipartimento di Biotecnologie Mediche e Medicina Traslazionale, Università degli Studi di Milano, Italy
[c] CNR, Institute of Neuroscience, Via Vanvitelli 32, Milan, Italy

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ABSTRACT

Can young infants decompose visual events into independent representations of objects and movements? Previous studies suggest that human infants may be born with the notion of objects but there is little evidence for movement representations during the first months of life. We devised a novel Rapid Visual Recognition Procedure to test whether the nervous system is innately disposed for the conceptual decomposition of visual events. We show that 4-month-old infants can spontaneously build object and movement representations and recognize these in partially matching test events. Also albino Swiss mice that were tested on a comparable procedure could spontaneously build detailed mental representations of moving objects. Our results dissociate the ability to conceptually decompose physical events into objects and spatio-temporal relations from various types of human and non-human specific experience, and suggest that the nervous system is genetically predisposed to anticipate the representation of objects and movements in both humans and non-human species.

1. Introduction

In order to make sense of the world we have to understand the objects that inhabit it, and how they behave. There is considerable evidence that during the first months of life human infants perceive objects as bound physical entities that move as wholes on continuous paths and continue to exist even when they disappear from sight (Aguiar & Baillargeon, 1999; Leslie & Keeble, 1987; Spelke, 1990). Adherence to some of these principles is observed also in newborn human infants (Valenza, Leo, Gava, & Simion, 2006), primates (Call, 2000; Hall-Haro, Johnson, Price, Vance, & Kiorpes, 2008; Natale, Antinucci, Spinozzi, & Poti, 1986; Santos, 2004) and chicks (Regolin & Vallortigara, 1995). In human infants the notion of objects does therefore not appear to require visual, physical or even human specific experience with actual objects to emerge (Baillargeon, 2002; Spelke, Breinlinger, Macomber, & Jacobson, 1992). It has therefore been suggested that a concept of objects may form part of our innate cognitive repertoire (Carey, 2011).

Could young infants' conceptually decompose physical events into constituents that go beyond simple object representations? There is some evidence that during the first year of life infants are sensitive to the spatial arrangement of objects (e.g. depth, distance, containment and support) and how this changes over time (cf. Baillargeon, 2004). Motion in particular is interesting because in many situations, it signals to infants the presence of events better than space does (Kellman, Spelke, & Short, 1986; Werker,

* Corresponding author.
E-mail address: langus@sissa.it (A. Langus).

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Cohen, Lloyd, Casasola, & Stager, 1998): it determines whether objects are animate or inanimate, and may be the basis for understanding the causality of events (Golinkoff, Harding, Carlson-Luden, & Sexton, 1984; Kotovsky & Baillargeon, 2000; Mandler, 2004; Wang, Kaufman, & Baillargeon, 2003). It has therefore been suggested that – at least in theory – the concept of motion and space may also belong to the pre-linguistic conceptual primitives from which infants construct their understanding of how objects in the physical world relate to each other (Jackendoff, 1983; Mandler, 2004). However, there are several gaps in experimental evidence to support the idea that during the first months of life infants conceptually decompose physical events into object and movement representations.

Young infants are clearly sensitive to object motion. However, because movement is so central to young infants' perception of objects, it has primarily been used as a tool for studying object properties (see Baillargeon, 2004). Movement thus facilitates object perception during the first months of life (Kellman et al., 1986; Smith, Johnson, & Spelke, 2003; Werker et al., 1998): young infants fail to perceive objects both if these are stationary (Kellman & Spelke, 1983), and if the infants themselves are moving relatively to a stationary object (Kellman, Gleitman, & Spelke, 1987). This suggests that object movement, and not any motion in general, may be necessary for young infants to perceive objects. Young infants could thus primarily use the information about where an object is and how its location is changing over time for guiding attention to – and keeping track of – objects in the visual field (Leslie, Xu, Tremoulet, & Scholl, 1998). Evidence from young infants cannot therefore rule out the possibility that they may not conceptually decompose physical events into independent object and movement representations, but instead represent physical events holistically (Carey, 2011; Pulverman, Hirsh-Pasek, Golinkoff, Pruden, & Salkind, 2006).

Conceptual decomposition of physical events has only been studied in older infants. For example, 14- to 17-month old infants familiarized with a motion event of a star moving in relation to a ball, can discriminate change in the star's path (e.g. over vs. under) and manner of movement (jumping vs. spinning) (Pulverman, Sootsman, Golinkoff, & Hirsh-Pasek, 2003), an ability that has also been observed in 7-month-old infants (Pulverman & Golinkoff, 2004). However, in these discrimination tasks infants could also simply recognize overall changes in the motion event without building independent representations of event parts. Borrowing an example from color perception, the color PRUPLE is a made of the basic colors RED and BLUE and the color GREEN of the basic colors YELLOW and BLUE. When humans see a change from PURPLE to GREEN they perceive a holistic change in the composite colors and are incapable of seeing a change in the basic color constituents RED to YELLOW. Similarly, young infants could thus detect an overall change in motion events without being aware of which constituent (e.g. object, motion path or manner) has changed (for a discussion see Pulverman et al., 2006). Because only 14- to 17-month olds have been shown to represent the manner and path of motion independently, it is not clear whether also younger infants perceive motion events as consisting of individual constituents. Furthermore, dissociating manner and path of motion does not directly answer the more fundamental question of whether infants also represent objects and movements independently.

These gaps in our knowledge about when young infants begin to see physical events as consisting of objects, movements and space make it difficult to determine how this ability emerges from the interplay of nature and nurture. For example, because evidence for object representations pre-dates movement representations by several months, it may be suggested that infants are born with the notion of object, but that independent movement representations emerge later in cognitive development. In fact, several studies suggest that experience could facilitate infants' abilities to represent different aspects of physical events. Visual training with occlusion events can thus strengthen infants' understanding that objects continue to exist even when they move behind an occluder and help them to predict when the object should emerge from occlusion (Johnson, Amso, & Slemmer, 2003). In addition, also physical experience with objects can facilitate infants' ability to segregate objects (Needham, 2000) as well as to understand the goal of actions (Sommerville, Woodward, & Needham, 2005). Finally, learning the names of objects can help infants to categorize them (Gliga, Volein, & Csibra, 2010; Xu, 2002). Young infants begin to grasp objects with agility around 5-months of age (Carey, 2009; Von Hofsten, 1991), and they appear to know some common words from 6-months of age onwards (Bergelson & Swingley, 2012) – a developmental timeframe which roughly coincides with the age at which they appear to discriminate changes in the path and manner of visual motion events (Pulverman, 2004). It is therefore important to determine whether younger infants, who have not yet acquired such experience, are capable of spontaneously decomposing visual events into independent representations of objects and their spatio-temporal relations.

2. Experiment 1: Object/movement representations in 4-month-old infants

In Experiment 1, we tested 4-month-old infants' ability to spontaneously decompose moving objects into independent object and movement representations. We devised a novel Rapid Visual Recognition (RVR) procedure that presents infants with a dual choice task between a partially matching and a novel test event, measuring the recognition of spontaneous representations in multiple interleaved trials. Infants were thus presented in each trial with a brief familiarization event of a moving object immediately followed by two simultaneously presented test events. One of these test events contained either the familiarization object (Object recognition trials) or the familiarization movement (Movement recognition trials) paired with a novel counterpart (movement or object, respectively). The other test event contained both a novel object and a