Cognition 133 (2014) 304–316

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Comparison of active and purely visual performance in a multiple-string means-end task in infants

Lauriane Rat-Fischer *, Jacqueline Fagard, J. Kevin O'Regan

Laboratoire Psychologie de la Perception, Université Paris Descartes, CNRS UMR 8158, Centre Biomédical des Saints-Pères, 45 rue des Saints-Pères, 75006 Paris, France

ARTICLE INFO

Article history:
Received 26 August 2013
Revised 12 May 2014
Accepted 10 June 2014

Keywords:
String task
Means-end
Infants
Inhibitory control
Eye movements

ABSTRACT

The aim of the present study was to understand what factors influence infants' problem-solving behaviours on the multiple-string task. The main question focused on why infants usually solve the single string-pulling task at 12 months at the latest, whereas most 16-month-old infants still cannot solve the task when several strings are presented, only one of which is attached to the desired object. We investigated whether this difficulty is related to infants' ability to inhibit their spontaneous immediate actions by comparing active and purely visual performance in this task. During the first part of the experiment, we assessed the ability of infants aged 16–20 months to solve the multiple-string task. The infants were then divided into three groups based on performance (a "failure" group, an "intermediate" group, and a "success" group). The results of this action task suggest that there were differences in infants' performance according to their level of inhibitory control of their preferred hand. In the second part of the experiment, the three groups' predictive looking strategies were compared when seeing an adult performing the task. We found that only infants who successfully performed the action task also visually anticipated which string the adult had to pull in the visual task. Our results suggests that inhibitory control was not the only factor influencing infants' performance on the task. Furthermore, the data support the direct matching hypothesis (Rizzolatti and Fadiga, 2005), according to which infants need to be able to perform actions themselves before being able to anticipate similar actions performed by others.

1. Introduction

Physical properties of objects and their relations to other objects are detected very early in infancy. Studies using visual habituation paradigms have shown that abilities such as identifying an object's height (Hespos & Baillargeon, 2001), solidity or continuity (Spelke, Breinlinger, Macomber, & Jacobson, 1992) emerge before 6 months of age. At this age, infants also understand some dynamic aspects of objects, in particular the cohesion of two objects moving together in the same direction (Spelke et al., 1992) and the principle of contact (Leslie and Keeble, 1987) wherein one object is affected by another only if there is contact between them.

In studies where infants' understanding is probed by investigating their ability to act, this notion of contact between objects, also known as "connectedness", has been explored in older infants, mainly using two paradigms: pulling a support to retrieve an out-of-reach object placed on top of it, and pulling a string attached to the out-of-reach object. Some studies have shown that infants are able to use the support as a means for bringing the goal object within reach at around 9–10 months of age (Bates,

* Corresponding author. Tel.: +33 614927963.
E-mail address: Lratfischer@gmail.com (L. Rat-Fischer).

http://dx.doi.org/10.1016/j.cognition.2014.06.005
0010-0277/

Carlsonluden, & Bretherton, 1980; Piaget, 1936/1952; Schlesinger & Langer, 1999; Uzgiris & Hunt, 1975; Willatts, 1984, 1999). Concerning the string paradigm, Richardson (1932) was, to our knowledge, the first to write about the string task in infants. He reported an increase in the occurrence of pulling a string when an object was attached to it around 10 months. Piaget reported from observations on his own children that the capacity to pull a string to retrieve an object emerged at about 11 months of age (Piaget, 1936/1952). For each of his three children, Piaget noted that they discovered the pulling effect of the string through active exploration. Later, the string behaviour was included in assessments of psychological development, and the age of 10–12 months was found to be the period when infants began solving the string problem (Uzgiris & Hunt, 1975). Thus, it appeared that at this period, infants understand the notion of connectedness between objects.

One way to decide whether infants understand a physical concept is to give them a choice of possible ways to perform a particular task. Some tool use studies for example have investigated whether infants are capable of selecting the correct, functional tool from among a set of non-functional alternatives to retrieve an out-of-reach object (e.g., Brown, 1990; Chen & Siegler, 2000). Perceiving which tool affords the retrieval of the object and being able to complete the task with the correct tool has been interpreted as an indicator of true understanding of the tool's use. Following this principle in a substantially simpler situation, one way to evaluate whether infants understand and use the notion of connectedness in the string- and cloth-pulling situations is to present infants with a choice of strings, only one of which is connected to the toy. Infants who understand the notion of connectedness should identify which string is connected to the toy, therefore affording its retrieval. Richardson (1932) noted that the ability to ignore strings not attached to the object increases around 10 months; however, even at 12 months of age, infants rarely succeeded on their first attempt at the task by pulling the connected string. In a more recent study, Brown (1990) found that the capacity to ignore the unattached strings increases with age during the second year of life. However she noted that infants did not immediately succeed in choosing to pull the attached string among three strings aligned toward the object at 14 months. According to the author, infants at this age need to succeed with fewer strings before solving the situation with more strings. In an exploratory study on 14 infants aged 16 months (unpublished data), we also observed that infants rarely chose the correct string among a set of four including three non-connected strings. Such age differences between the time when infants apparently understand the notion of connectedness and the age where they can use the notion in choice situations are striking. What factors are responsible for this delay?

One candidate possibly influencing infants' performance at the task is inhibitory motor control. Infants presented with multiple strings have to inhibit motor responses of pulling the strings, in order to choose the correct string. In the literature, inhibitory motor control is reported to develop between 8 and 12 months of age in situations involving object retrieval or detour reaching (Diamond, 1991). Inhibiting this natural response may be that much more difficult, given the complexity of the multiple-string task, involving (1) scanning the multiple-string scene in order to (2) isolate the correct spatial information, followed by (3) choosing and (4) pulling the correct string until the object is retrieved. This might be reinforced by the fact that in general it is not particularly costly for infants to pull the strings randomly until they retrieve the object.

To investigate whether infants' difficulties with the multiple-strings task result from inhibitory limitations, we designed a perception–action experiment. We compared infants' actual physical performance on the multiple string-pulling task with their looking behaviour during passive observation of the experimenter accomplishing the task. Eye-tracking techniques are ideal to measure infants' visual exploration of experimental scenes (e.g., Franchak, Kretch, Soska, & Adolf, 2011). The experiment was divided into two parts: an action task and a vision task. In the action task, infants were presented with four strings, only one of which was connected to an out-of-reach attractive toy. The infants' task was to choose the correct string in order to retrieve the toy. The vision task involved the same situation as the action task, but the string was pulled by an adult rather than by the infant, while the infant's looking behaviour was recorded. In particular, we checked for predictive gaze toward the connected string before the adult chose which string to pull. Predictive gaze has recently been used as a measure of infants' ability to anticipate an outcome when observing ongoing actions (see Biro, 2013, for a brief review). This situation allowed us to isolate infants' visual exploratory behaviour from their motor activity, in a task where no motor response was required. Thus, we expected that if a lack of inhibitory control were the only factor responsible for infants' failure at the action task, all infants would show similar visual anticipatory behaviour on the vision task, independently of their success or failure at the action task. In contrast, if infants failed at the action task because of limitations other than a lack of manual inhibition, we expected infants who failed to pull the correct string in action, to also fail to visually identify the correct string in the vision task. In this case, looking strategies on the vision task should differ between infants who fail at the action task and those who succeed. To test these predictions, we compared infants' looking strategies as a function of their performance on the string task, independently of their age, which ranged from 16 to 20 months. This age range was chosen because preliminary observations suggested that over this age period some infants fail to solve the multiple-strings problem while others succeed, thus enabling comparison between the looking strategies of the two categories of infants. Since the coding of "true" success was sometimes ambiguous due to bimanual string choices, we assigned infants to three groups based on performance (failure, intermediate and success) as described in Section 2. If the inhibitory control hypothesis is correct, we expected to find no differences in looking strategy between groups. In contrast, if inhibition is not involved, or at least if it is not the only factor involved in infants' difficulty in