Cognition 166 (2017) 23–27

Contents lists available at ScienceDirect

Cognition

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

Brief article

Discriminating relational and perceptual judgments: Evidence from human toddlers

Caren M. Walker [a,*], Alison Gopnik [b]

[a] University of California San Diego, Department of Psychology, 9500 Gilman Dr., La Jolla, CA 92093-0109, United States
[b] University of California Berkeley, Department of Psychology, 3210 Tolman Hall, Berkeley, CA 94720, United States

ARTICLE INFO

Article history:
Received 29 January 2017
Revised 10 May 2017
Accepted 11 May 2017
Available online 26 May 2017

Keywords:
Cognitive development
Causal inference
Relational reasoning
Perceptual processes

ABSTRACT

The ability to represent *same-different* relations is an important condition for abstract thought. However, there is mixed evidence for when this ability develops, both ontogenetically and phylogenetically. Apparent success in relational reasoning may be evidence for genuine conceptual understanding or may be the result of low-level, perceptual strategies. We introduce a method to discriminate these possibilities by pitting two conditions that are perceptually matched but conceptually different: in a "fused" condition, same and different objects are joined, creating single objects that have the same perceptual features as the two object pairs in the "relational" condition. However, the "fused" objects do not provide evidence for the relation 'same.' Using this method with human toddlers in a causal relational reasoning task provides evidence for genuine conceptual understanding. This novel technique offers a simple manipulation that may be applied to a variety of existing match-to-sample procedures used to assess *same-different* reasoning to include in future research with non-human animals across species, as well as human infants.

1. Introduction

The ability to represent relations between objects and events is an essential condition for abstract thought; some have suggested that relational abilities may be the key to the cognitive differences between humans and other animals (Penn, Holyoak, & Povinelli, 2008). However, there is mixed evidence about when this ability develops, both ontogenetically and phylogenetically. Traditionally, there was little evidence for relational reasoning in either young children or non-human animals. More recent results, particularly involving the foundational relations "same" and "different" challenge that conclusion. Ducklings can generalize these relations in an imprinting paradigm (Martinho & Kacelnik, 2016). Human infants are able to generalize these relations in looking-time experiments. In particular, pre-verbal infants can be habituated to pairs of *same* and *different* objects (Addyman & Mareschal, 2010; Ferry, Hespos, & Gentner, 2015; Hochmann, Mody, & Carey, 2016; Tyrell, Stauffer, & Snowman, 1991), discriminate and generalize patterns of repeated visual or auditory elements (ABA/AAB/ABB) (Dawson & Gerken, 2009; Johnson et al., 2009; Marcus, Vijayan, Bandi Rao, & Vishton, 1999; Saffran, Pollak, Seibel, & Shkolnik, 2007), and provide a conditioned response to pairs of identical stimuli (Hochmann, 2010; Kovács, 2014). Moreover, very young toddlers can apparently use *same-different* relations in an active causal learning paradigm (Walker & Gopnik, 2014), although this ability declines in the preschool period (Walker, Bridgers, & Gopnik, 2016). In these studies, toddlers, aged 18–30-months, were able to infer *same-different* relations in a causal version of a match to sample task (i.e., matching AA′ with BB′, not CD, and matching EF with CD, not BB′).

On the other hand, it is possible that these successes may be mediated by perceptual factors that are quite separate from the abstract *same-different* concepts that these tasks are intended to assess (see Addyman & Mareschal, 2010 for a review). It is clear that both human and non-human animals are able to *perceive* the similarity of objects, agents, and events in their environment; these abilities are necessary for basic cognitive functions (Hochmann et al., 2016; Martinho & Kacelnik, 2016). However, noticing similarity does not necessarily imply the existence of the conceptual representation, *same*. This distinction is difficult to make, and this point has been widely debated in the comparative literature (Penn et al., 2008; Thompson & Oden, 1996).

For example, non-human primates (Wasserman, Fagot, & Young, 2001) and several species of birds (Pepperberg, 1987; Smirnova, Zorina, Obozova, & Wasserman, 2015) have succeeded

* Corresponding author at: Department of Psychology, University of California San Diego, 9500 Gilman Drive, McGill Hall, #109, La Jolla, CA 92093-0109, United States.
E-mail address: carenwalker@ucsd.edu (C.M. Walker).

http://dx.doi.org/10.1016/j.cognition.2017.05.013
0010-0277/

in solving similar relational problems, in the context of multiple trials in reinforcement learning paradigms (Pepperberg, 1987; Smirnova et al., 2015; Wasserman et al., 2001), suggesting that these species, like humans, may possess the ability to learn abstract relational properties (Cook & Wasserman, 2007). However, there is also growing evidence indicating that these trained abilities may be grounded in perceptual expertise, reflecting learned sensitivity to surface cues, rather than higher-order reasoning, per se (Thompson & Oden, 2000).

This suggests that the match to sample tasks that have historically served as the standard for assessing *same-different* understanding across species may be passed in the absence of genuine conceptual representations. In particular, lower-level, perceptual strategies, like attention to the symmetry, contrast, and the variance of the stimuli could contribute to success (Blaisdell & Cook, 2005; Smith, Redford, Haas, Coutinho, & Couchman, 2008; Young & Wasserman, 2001). Might infants, toddlers, and non-human animals in an imprinting paradigm, like non-human animals in reinforcement training, be responding to a perceptual analysis of the stimuli pairs rather than a *same-different* strategy?

One candidate for such a strategy is a low-level heuristic, called "perceptual entropy," that has been proposed to facilitate relational recognition in non-human animals (Fagot, Wasserman, & Young, 2001; Penn et al., 2008; Wasserman & Young, 2010; Wasserman, Young, & Cook, 2004; Wasserman et al., 2001; Young & Wasserman, 1997; Zentall, Wasserman, Lazareva, Thompson, & Rattermann, 2008). In particular, any visual display can be reduced to "a continuous analog estimate of the degree of perceptual variability between the elements" (Penn et al., 2008, pg. 112), a strategy similar to a process of conceptual chunking (Halford, Wilson, & Phillips, 1998). In other words, because there is a lower amount of variability among the elements for 'same' displays (AA′) than for 'different' displays (AB), toddlers (as well as human infants and non-human animals) may succeed by learning and applying the following rule: *If the variability of the effective training sample is low, select the test pair that also has low variability.* This attention to variance would also subsume a range of other perceptual cues including symmetry, oddity, and spatial orientation, among others (Cook & Wasserman, 2007). Adult humans show some sensitivity to the amount of perceptual variance in a display, but this evidence is not sufficient to prove that it is responsible for their performance. In fact, previous findings suggest that additional processes of categorization likely play a role in the human conceptualization of "same-different" relations (Fagot et al., 2001; Smith et al., 2008). Interestingly, similar findings have been recently found with baboons (Flemming, Thompson, & Fagot, 2013).

Discriminating between conceptual and perceptual learning strategies in non-verbal relational reasoning tasks is a notoriously difficult problem to solve in both developmental and comparative contexts. In the current study, we introduce a novel method designed to directly pit the perceptual and conceptual accounts against one another. The method involves a contrast between one condition relying upon a traditional match to sample task involving *same-different* relations and a "fused" object condition. Exactly the same objects are used in the two conditions, but in the "fused" condition the objects are physically joined to create a single object. Importantly, the amount of perceptual entropy, or variance, as well as other perceptual features such as symmetry is matched between the two conditions. However, only the unfused/relational condition also provides evidence for the higher-order relation 'same.' In the fused/single object case, there is no relation *between* objects to learn – there is only one object present.

As a proof of concept, we applied this method to assess human toddlers in a causal match to sample task originally developed by Walker and colleagues (Walker & Gopnik, 2014; Walker et al., 2016). In the current study, children observed two trials in which a pair of 'same' objects, or a fusion of those objects, activated a machine, but a pair or fusion of two 'different' objects did not. Then, children had to select a novel pair of objects or a novel fused object to activate the machine. If children are indeed relying upon a low-level perceptual heuristic, they should select the lower entropy pair consistently across both conditions. On the other hand, if children learn the abstract relation 'same,' they should privilege this test pair *only* in the unfused/relational condition, where these is a relation to learn.

Although the current study applies this method to assess human reasoning in a previously published causal learning paradigm, this same technique is intended to be used for discriminating perceptual strategies from genuine relational reasoning in a variety of existing paradigms, across species.

2. Method

2.1. Participants

A total of 80 18–30-month-olds participated ($M = 24.3$ months; $SD = 3.6$ months; range = 17.9–31.1 months; 40 girls), with 40 toddlers randomly assigned to one of two conditions (*fused/single object* or *unfused/relational*). There was no difference in age between conditions, $t(1) = 1.21$, $p = 0.23$, and approximately equal numbers of males and females were assigned to each. Sixteen additional children were tested but excluded for failure to complete the study (11) or due to experimenter error (5).

All participants were recruited from a local children's museum. Although we did not collect specific demographic information for each child, the following demographic information describes the population of the recruitment location. The museum visitors include the following racial/ethnic groups: 60% Caucasion, 28% Asian, 1% American Indian or Alaskan Native, 14% Latino or Hispanic, 4% African American, and 13% Mixed racial/ethnic background. The average income for museum visitors is between $100,000 and $150,000 per year.

2.2. Materials

The toy was a 10″ × 6″ × 4″ opaque cardboard box containing a wireless doorbell. When a block or pair of blocks "activated" the toy, the doorbell played a novel melody. In fact, the toy was surreptitiously activated by a remote control. Eight painted wooden blocks in assorted colors and shapes (2 pairs of 'same' blocks and 2 pairs of 'different' blocks) were placed on the toy in pairs during the *unfused/relational* condition training. The 'same/lower entropy' blocks were identical in color and shape, and the 'different/higher entropy' blocks were distinct in color and shape. An identical set of these eight painted blocks were used to create the "fused" blocks to be placed on the toy as single objects in the *fused/single object* condition training. In this condition, each pair of training blocks were glued together to create a single, larger block. Four additional blocks were used during the test phase of each condition, including 1 novel pair of 'same' and 1 novel pair of 'different' blocks. The test blocks either appeared as two pairs of blocks or as two fused, single objects, depending upon condition (see Fig. 1). The pairs of test blocks in each condition were placed on 4″ × 4″ plastic trays.

Two complete sets of blocks were constructed for each condition. In the *simple* set, all blocks were composed of simple, symmetrical geometric shapes (e.g., cubes, cylinders) with a single, solid color. In the *complex* set, all blocks were composed of asymmetrical, irregular polygons. Half of the children in each condition were randomly assigned to receive each stimuli set.