Behavioural Processes 112 (2015) 72–80

Contents lists available at ScienceDirect

Behavioural Processes

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

Endpoint distinctiveness facilitates analogical mapping in pigeons

Carl Erick Hagmann, Robert G. Cook*

Tufts University, USA

ARTICLE INFO

Article history:
Available online 15 November 2014

Keywords:
Pigeons
Categorization
Relational learning
Analogy
Dimensional mapping

ABSTRACT

Analogical thinking necessitates mapping shared relations across two separate domains. We investigated whether pigeons could learn faster with ordinal mapping of relations across two physical dimensions (circle size & choice spatial position) relative to random mapping of these relations. Pigeons were trained to relate six circular samples of different sizes to horizontally positioned choice locations in a six alternative matching-to-sample task. Three pigeons were trained in a *mapped condition* in which circle size mapped directly onto choice spatial position. Three other pigeons were trained in *a random condition* in which the relations between size and choice position were arbitrarily assigned. The mapped group showed an advantage over the random group in acquiring this task. In a subsequent second phase, relations between the dimensions were ordinally reversed for the mapped group and re-randomized for the random group. There was no difference in how quickly matching accuracy re-emerged in the two groups, although the mapped group eventually performed more accurately. Analyses suggested this mapped advantage was likely due to endpoint distinctiveness and the benefits of proximity errors during choice responding rather than a conceptual or relational advantage attributable to the common or ordinal mapping of the two dimensions. This potential difficulty in mapping relations across dimensions may limit the pigeons' capacity for more advanced types of analogical reasoning.

This article is part of a Special Issue entitled: Tribute to Tom Zentall.

1. Introduction

Categorization is fundamental in a variety of knowledge domains. Appreciating the mechanisms underlying categorization across different species is key to understanding the evolution of cognition and intelligence and its importance in organizing behavior. In particular, it has been valuable to distinguish among different classes of conceptual behavior (Zentall et al., 2008). It has been well and long established, for example, that a wide variety of animals can learn to make perceptual classifications based on shared visual attributes among a set of pictures or objects (Herrnstein et al., 1976). More recently, considerable attention has focused on how animals learn relational concepts (Cook and Wasserman, 2006). Here it is the matching or difference relationship among two or more stimuli that is critical. This kind of categorical discrimination can be thought of as the abstraction of information within a *first-order relation* across stimuli. In this latter domain, Zentall and his colleagues were particularly important in advancing early attempts to identify relational learning in pigeons (Zentall et al., 1980a,b; Zentall and Hogan, 1974, 1976, 1978). Since then, abundant evidence has shown that humans, monkeys, dolphins, and birds can learn rule-like categories based on such first-order relations in several contexts (e.g., Cook, 2002; Mercado et al., 2000; Pepperberg, 1987; Wasserman et al., 2001; Wright et al., 1983, 1988; Young and Wasserman, 2001).

Success in identifying the capacity of various animals to form perceptual classes and to learn first-order conceptual relationships has engendered a number of attempts to look for more advanced forms of categorization. The ability to categorize *second-order relations*, or the *relations between relations*, expands the knowledge that can be generalized and applied across domains. For example, the ability to form abstract concepts based on second-order relations allows for *analogical reasoning*. Analogical reasoning has been proposed to be critically important to the development of human intelligence (Gentner et al., 2001). To form an analogy requires the perception and evaluation of first-order relations and the recognition of the sameness and difference of these relations across multiple domains (French, 1995; Gentner and Markman, 1997; Thompson and Oden, 2000) As a result, analogies are derived from common relational structures across domains, not just from overlapping or distinguishable features among stimuli. Thus, analogical reasoning comes from not only being able to compare and

---

* Corresponding author at: Department of Psychology, Tufts University, 490 Boston Avenue, Medford, MA 02155, USA. Tel.: +1 617 627 2546;
fax: +1 617 381 3189.
E-mail address: Robert.cook@tufts.edu (R.G. Cook).

http://dx.doi.org/10.1016/j.beproc.2014.11.007
0376-6357/© 2014 Elsevier B.V. All rights reserved.

contrast features within specific domains, but across domains and feature dimensions by cognitively and computationally mapping their internal structures or relations on to one another (French, 2002). Humans develop analogical reasoning relatively early in childhood. For instance, Rattermann and Gentner (1998) had children solve analogical completion tasks. Children that were 3–4 years old relied on object similarity, whereas by five years old, the children had undergone a “relational shift,” allowing them to map the domains of one relationship to another. In part, the development of relational language seems to be important to relational learning.

Because of its possible ties to language, studying analogical reasoning in non-human animals has been of particular interest. Various tests of analogical reasoning in animals have produced mixed results. Typically, analogical reasoning is tested in animals by examining whether they can recognize and transfer the second-order same or difference relations of two or more first-order relations. Studies exploring analogical reasoning have used first-order relations typically built from shapes and colors in a relational matching task. On second-order *same* trials, the items across two physically distinct sets of stimuli share the same relation (both same or both different). On second-order *different* trials, the two physically distinct sets of stimuli have different relations (one same and one different).

Chimpanzees (*Pan troglodytes*) have provided the strongest and most abundant evidence for the existence of analogical reasoning among animals (Flemming et al., 2008; Flemming and Kennedy, 2011; Gillan et al., 1981; Haun and Call, 2009; Thompson and Oden, 2000; Thompson et al., 1997). Using symbols to represent the concepts “same” and “different,” for example, Sarah demonstrated analogical reasoning even when a simpler associative strategy would have sufficed (Oden et al., 2001). Thompson and Oden (2000) suggested that analogical judgment of second-order relations by Sarah was possible only with the development of a symbolic concept system. However, Flemming and Kennedy (2011) showed that three chimpanzees could use relative information to show analogical reasoning without symbolic training. Here the animals saw food being placed under one of three different sized cups. When tested with a different set of plastic cups with the same size relations, the chimpanzees used relational rather than absolute size information to choose the correct cup based on the prior size relations. This outcome indicates the chimpanzees could map the ordinal size relations of one set of cups onto the size relations of another set.

Evidence for analogical reasoning in monkeys has been less robust, but the experiments have helped elucidate the perceptual and cognitive demands of analogical reasoning (Flemming et al., 2008; Thompson and Oden, 1995). Fagot et al. (2001) successfully trained two baboons (*Papio papio*) to discriminate 16-item displays of icons that were either all the same or all different in a relational matching task. These animals successfully transferred to novel displays. Further tests suggested that entropy played an important role in these results. Flemming et al. (2011) found that providing differential reward enhanced the ability of macaques (*Macaca mulatta*) to perform a relational MTS tasks. To reduce the role of perceptual grouping, Fagot and Parron (2010) tested baboons with pairs of color rectangles in a relational matching task. When the colored rectangles were located close together, baboons successfully transferred their relational matching discrimination to novel color sets. However, any gap between the stimuli dropped the discrimination to chance levels. Fagot and Thompson (2011) used pairs of shapes. Only six out of 29 symbol-naïve baboons could learn a relational MTS task, although five of these six monkeys could then transfer this skill to novel stimuli. Flemming et al. (2013) subsequently determined that categorical abstraction took priority over perceptual similarity in a relational task consisting of four-item displays for both humans and baboons.

Among new world monkeys, the results are less promising but the research is far from complete. Capuchins (*Cebus apella*) show little evidence of analogical reasoning abilities when asked to perform relational MTS (Thompson et al., 2007), except perhaps under specific stimulus conditions (Truppa et al., 2011). Kennedy and Fragaszy (2008) tested four capuchin monkeys with a task similar to Flemming and Kennedy’s (2011) relative cup size search task. Only one of the four capuchins tested was able to perform this task by mapping across the shared dimension of size.

Few non-primate species have been tested with similar analogical reasoning tasks. Cook and Wasserman (2007) tested pigeons in a relational matching task. Using same and different displays consisting of 16 computer icons each, pigeons successfully learned this task by matching samples to test stimuli consisting of physically different sets of icons that had the same first-order relationship (same to same; different to different). More importantly, the pigeons transferred this discrimination to novel stimulus sets at above chance levels of accuracy (although not to the same degree as observed with apes). As new stimulus sets were added to their training and testing repertoire, the pigeons showed savings by learning the new sets more rapidly than previous ones. Cook and Wasserman argued that such results suggested pigeons might have the rudimentary perceptual and cognitive foundations for analogical reasoning.

To better understand the evolutionary origins of analogical cognition and whether it exists in non-primates, we thought it would be valuable to see if some of the cognitive subsystems or components necessary for analogical reasoning were present in pigeons. By better understanding the simpler task of how the different parts of an analogy are process, it might serve as a platform for better testing more full-fledged analogical capacities. One key step in making an analogy requires mapping a relationship from a *source* to a *target* domain (French, 1995). In humans, relations among these domains can be very complex and highly multidimensional. To test the pigeons, we sought to simplify the relations, by asking if and how they could learn the relational mapping of one ordinal dimension onto another. If an observer can use the structure of one dimension to guide behavior along another, then the capacity to eventually form more complex analogies may also be present.

The mapping of ordered dimensions has previously been investigated in humans and animals using number and space. The spatial-numerical association of response codes, or SNARC effect, occurs when the smallest numbers in a set are implicitly coded as mapping onto an endpoint of a spatial position. Each increasing numerical value is then mapped onto each successive location. Drucker and Brannon (2014) examined the SNARC effect in rhesus monkeys with a vertical array of five homogeneous shapes. The monkeys were trained to pick the second item from the top, and showed robust transfer to novel shapes, colors, inter-item spacing, and positioning. When presented with a horizontal array, for instance, the monkeys chose the second position from the right. Similar findings in infants (de Hevia and Spelke, 2009) and chicks (Rugani et al., 2010, 2011) suggest that number–space mapping is an evolved cognitive trait rather than one developed based on cultural reading norms.

The goal of the present experiment was to examine whether pigeons would benefit from the mapping of the ordinal structure of one physical dimension onto a physically different dimensions. If so, it would suggest they possess one of the cognitive components needed to provide the scaffolding for more advanced analogical reasoning. The two physical dimensions selected consisted of the size of six yellow circular samples and the right to left spatial position of six identical red square choice locations. The dimensions