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## Original Articles

# Infants learn a rule predicated on the relation same but fail to simultaneously learn a rule predicated on the relation different

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## ABSTRACT

In two experiments, we assessed whether infants are able to learn rules predicated on two abstract relations linked by negation: *same* and *different* (*not same*). In an anticipatory looking paradigm, the relation between successive colored geometrical shapes predicted the location where a puppet would appear next. In Experiment 1, 7-month-olds learned and generalized a rule predicated on the relation *same*, but not a rule predicated on the relation *different*. Similarly, in Experiment 2, 12-month-olds learned a rule predicated on the relation *same-shape*, but not a rule predicated on the relation *different-shape*. Comparing our data with that from previous experiments in the speech domain, we found no effect of age, modality or rule complexity. We conclude that, in the first year of life, infants already possess a representation of the abstract relation same, which serves as input to a rule. In contrast, we find no evidence that they represent the relation different.

## 1. Introduction

The adult human mind is unique in its productivity, which sets us apart from other animals. We can produce and comprehend an indefinite number of sentences – many sentences of this paper have never been written before – and think an indefinite number of thoughts (Chomsky, 1957; Fodor, 1975; von von Humboldt, 1836). As a result, our species could invent new concepts such as *atom*, *oxygen atom*, *engine* and *autism* and represent propositions such as “All men are created equal.” Nothing remotely comparable has ever been observed in non-human animals, and the phylogenetic origin of these abilities is unclear. Parallel questions arise in the case of ontogenesis. Is infant cognition productive in this way as well? Or does productivity await the development of other capacities such as syntax and/or the lexicon?

Here, we investigate abstract combinatorial representations in infancy through a case study of infants’ concepts *same* and *different*. As has been recognized at least since Premack’s (1983) seminal work, three considerations have led these concepts to be taken as a good case study for this purpose (see, for example, Penn, Holyoak, & Povinelli, 2008). First, they are abstract relational concepts; their content cannot be captured in terms of perceptual features of individuals or sets of individuals (in contrast to concepts like *green* for instance). Second, they are at the core of analogical reasoning (Gentner, Holyoak, & Kokinov, 2001; Premack, 1983), and constitute what William James

famously called *the very keel and backbone of our thinking* (James, 1890/1950, p. 459). Third, *same* and *different* are linked by negation, so that one of these concepts can be defined in terms of the negation of the other; i.e., *same* is *not different* and *different* is *not same*. *Same* and *different* therefore exemplify productivity, as it is likely that the representation of one of these relations is a constituent of the representation of the other (most likely, for adults, *different* is *not same*; see Clark, 1974; Hochmann, Mody, & Carey, 2016; Hochmann, Zhu, & Carey, in preparation).

Many studies suggest that a wide variety of animal species, from bees to chimps, can condition behaviors on sameness and difference (e.g., Giurfa, Zhang, Jenett, Menzel, & Srinivasan, 2001; Harley, Putman, & Roitblat, 2003; Mumby, 2001; Thompson & Oden, 1996; Wright, Cook, Rivera, Sands, & Delius, 1988), and young infants, years before they learn the words “same” and “different”, also appear to have these capacities (Addyman & Mareschal, 2010; Diamond, 2006; Ferry, Hespos, & Gentner, 2015; Hochmann et al., 2016; Kovács, 2014; Tyrell, Stauffer, & Snowman, 1991; Tyrell, Zingaro, & Minard, 1993; Walker & Gopnik, 2014). However, for each behavior that might reflect representations of same and/or different, one must identify what representation the animal or infant actually uses to pass the task. Is there a plausible account that does not involve the representation of an abstract relation? Are both relations, same and different, represented or only one of them? What is the format of these representations? It is

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obvious upon reflection, but easy to lose sight of, that the fact that the experimenter designed the study to probe representations of sameness and difference does not guarantee that representations of these relations actually underlie successful performance.

The earliest data that were taken as evidence for representations of both same and different derived from the capacity of animals and infants to solve the match-to-sample and the non-match-to-sample tasks (bees: Giurfa et al., 2001; pigeons: Blough, 1959; Wright et al., 1988; dolphins: Harley et al., 2003; rats: Mumby, 2001; apes: Oden, Thompson, & Premack, 1988; human infants: Diamond, 2006; Hochmann et al., 2016). In the match-to-sample (MTS) task, participants must learn to choose between two possible choices the stimulus that is the same as the sample (e.g., between a square and a triangle, if the sample is a square choose the other square) and generalize the rule to novel stimuli. In the non-match to sample task (NMTS), the rule is to choose the stimulus that is different from the sample (i.e., in the above example, if the sample is the square, choose the triangle). Because the rule learned generalizes freely to novel stimuli, it is likely that some representations of same and/or different underlie success. With respect to what these representations may be like, Zentall, Edwards, Moore, and Hogan (1981) and Hochmann et al. (2016) provide evidence that performance on both MTS and NMTS relies on the representation *same* alone. Briefly, after having learned the MTS rule, if given partial information in a test trial (e.g., the sample is X and the potential known choice is X, whereas the other choice is unknown), infants successfully choose X, for they have seen the input to the rule “choose same.” But after having learned the NMTS rule and given partial information (i.e., the sample is Y, and the potential known choice is X, whereas the other choice is unknown), infants *choose at chance*, even though they have seen input that instantiates the rule “choose different.” Rather, they *succeed* if they have seen the sample X and the potential choice X, whereas the other choice is unknown: they choose the alternative unknown choice, as if the rule they are following is “avoid same.” Importantly, these results are consistent with the absence of a representation *different*, or *not same*, that can be the input to a decision (choice or avoidance).

Moreover, Hochmann et al. (2016) suggest that the representation *same* implicated in MTS and NMTS may be entirely implicit, carried by a match computation. It is important to emphasize that the capacity for match and mismatch computations is not in doubt—either for non-human animals or young infants. Match and mismatch computations play a role in the processes underlying recognition, categorization and habituation/dishabituation, and are part of the computational repertoire of even very simple organisms. Rather, what is debated is whether representations of the relations same and/or different are available as input into learned generalizations or learned rules that can be held in working memory and guide behavior. Hochmann et al. (2016) suggest that the procedure infants and animals may be using in MTS could be: place representation of sample in working memory: *x*; subsequently, if encounter *x*, select *x*, whereas in NMTS, the procedure might be: place representation of sample in working memory: *x*; subsequently, if encounter *x*, avoid *x*. The abstractness in these procedures is carried by lack of constraints on the content of the variable *x*. The representation is considered “implicit” with respect to the content *same* as there is no mental symbol for the relation same in this procedure.

One paradigm taken to provide unequivocal evidence that creatures represent the relations same and different with symbols that can articulate rules that can be held in working memory is the relational match-to-sample (RMTS). Initially developed by Premack (1983), 2-item RMTS has proved extremely difficult for non-human animals and human children younger than 5 years (Hochmann et al., 2017; Premack, 1983; Thompson & Oden, 1996; Wasserman & Young, 2010). In 2-item RMTS, participants must learn to match two pairs of stimuli depending on the relations that define each pair; i.e. matching AA to BB and CD to EF. In animals as well as in children, this task appears hard to solve without resorting to summary explicit symbols for the relations

same and different such as the words “same” and “different”, or symbols that previously acquired those meanings (Hochmann et al., 2017; Premack, 1983; Thompson, Oden & Boysen, 1997; see also Christie & Gentner, 2014).

Are word-like symbols necessary for representing the abstract relations same and/or different? Another paradigm used with success in the animal literature, the conditional same-different discrimination task suggests that this may not be the case. Two versions of this task exist. In one version, animals are simultaneously presented with one array of same stimuli and one array of different stimuli, and must select the *same* array or the *different* array depending on a contextual cue (e.g., the color of the background; Castro, Kennedy, & Wasserman, 2010; Flemming, 2011; Flemming, Beran, & Washburn, 2007; Russel & Burke, 2016; Thomas & Crosby, 1977; Thomas & Kerr, 1976). In another version of the task, animals are trained to respond in one way to a set of same stimuli (e.g., searching under the left stimulus) and in another way to a set of different stimuli (e.g., searching under the right stimulus; Burdyn & Thomas, 1984; Czerny & Thomas, 1975; Flemming et al., 2007). Success in this second version of the task very likely requires the representation of two rules, with the content *if same choose left* and *if different choose right*. However, whatever representations underlie success on this task, they do not allow all the computations that the human adult representations allow, as these animals still largely fail the RMTS task (Flemming et al., 2007; though see Obozova, Smirnova, Zorina, & Wasserman, 2015; Smirnova, Zorina, Obozova, & Wasserman, 2015; Thompson et al., 1997). Moreover, it is possible that animal successes in the conditional same-different discrimination or on RMTS could be explained by responses conditioned to symmetry vs. asymmetry or high vs. low entropy (Wasserman & Young, 2010).

A handful of studies have examined infant performance in a conditional same/different discrimination procedure. Kovács (2014) taught 7- and 12-month-old infants that pairs of same syllables (e.g. *la la, di di*) predicted that a toy would appear in one location, whereas pairs of different syllables (e.g., *bo mu, to na*) predicted that a toy would appear in another location. Infants learned and generalized to novel pairs the rule formulated over the relation same, suggesting the availability of some sort of symbol for same that can be the antecedent to a learned rule. However, they failed to learn the rule formulated over the relations different. Similarly, Hochmann, Benavides-Varela, Nespór, and Mehler (2011) and Hochmann, Benavides-Varela, Fló, Nespór, and Mehler (2018) found, using this paradigm, that 7- and 12-month-old infants could learn that pairs of syllables with the same vowel (e.g., *la da, gi bi*) predicted that a toy would appear in one location, while failing to learn that pairs of syllables with different vowels (e.g., *bo mu, to na*) predicted a toy would appear in another location. Spatial symmetry cannot be a basis of success on this task. Thus, these results suggest that some kind of symbol for same is available to articulate rules held in working memory at least by 7 months of age under circumstances in which infants fail to demonstrate any representation of the relation different.

However, these investigations are so far limited to speech stimuli, raising questions about the generalizability of the results. Reduplication is used in the morphology of many languages, marking plural or expressing the frequentative or distributive meaning of verbs (Broselow & McCarthy, 1983; Marantz, 1982). For instance, Walpiri, an aboriginal language in Australia, forms the plural of certain nouns by total reduplication (cited in Marantz, 1982):

Singular	Plural	Meaning
kurdu	kurdukurdu	“child/children”
kamina	kaminakamina	“girl/girls”
mardukuja	mardukujamardukuja	“woman/women”

Similarly, Samoan forms plurals of verbs by duplicating one syllable (cited in Broselow & McCarthy, 1983):

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