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Rule-based category use in preschool children

Fabien Mathy [a,*], Ori Friedman [b], Brigitte Courenq [a], Lucie Laurent [a,c], Jean-Louis Millot [d]

[a] BCL Lab, UMR 7320, Department of Psychology, Université Nice Sophia Antipolis, 06357 Nice, France
[b] Department of Psychology, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada
[c] Maison des Sciences de l'Homme et de l'Environnement Ledoux, Université de Franche-Comté, 25030 Besançon cedex, France
[d] Neurosciences Laboratory of Besançon EA-481, Université de Franche-Comté, 25030 Besançon cedex, France

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ABSTRACT

We report two experiments suggesting that development of rule use in children can be predicted by applying metrics of complexity from studies of rule-based category learning in adults. In Experiment 1, 124 3- to 5-year-olds completed three new rule-use tasks. The tasks featured similar instructions but varied in the complexity of the rule structures that could be abstracted from the instructions. This measure of complexity predicted children's difficulty with the tasks. Children also completed a version of the Advanced Dimensional Change Card Sorting task. Although this task featured quite different instructions from those in our "complex" task, performance on these two tasks was correlated, as predicted by the rule-based category approach. Experiment 2 predicted findings of the relative difficulty of the three new tasks in 36 5-year-olds and also showed that response times varied with rule structure complexity. Together, these findings suggest that children's rule use depends on processes also involved in rule-based category learning. The findings likewise suggest that the development of rule use during childhood is protracted, and the findings bolster claims that some of children's difficulty in rule use stems from limits in their ability to represent complex rule structures.

* Corresponding author.
E-mail address: fabien.mathy@unice.fr (F. Mathy).

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Introduction

Many rules guide people's behavior in everyday life. These include rules of courtesy and politeness (e.g., when asking for something, say "please"), of law (e.g., stop on red, go on green), of safety (e.g., do not touch a hot stove), and of games and sports (e.g., collect $200 when you pass "go"). Rule systems often change across contexts, so people must often override or disregard previously relevant rules and flexibly adopt current ones.

Children often have difficulty in using simple rules, and the ability to successfully follow rules improves with age. For example, preschool-aged children have difficulty with a variety of tasks in which using rules requires avoiding dominant response tendencies (Zelazo & Carlson, 2012). This can be observed in the day–night task, where children have difficulty in following rules requiring them to say "night" to pictures showing the sun and "day" to pictures showing the moon (Diamond, Kirkham, & Amso, 2002; Gerstadt, Hong, & Diamond, 1994); this difficulty presumably arises because these rules conflict with children's more dominant tendencies to say "day" for the sun and "moon" for the night. Another example is children's performance on the Dimensional Change Card Sort (DCCS) task. In this task, children first follow one sorting rule to sort cards according to one of two dimensions (e.g., color) but then switch rules and sort according to a second dimension (e.g., shape). Whereas 3-year-olds mostly fail to make this switch and continue sorting using the first rule, 4- and 5-year-olds succeed in switching (Frye, Zelazo, & Palfai, 1995; Hanania & Smith, 2009; van Bers, Visser, van Schijndel, Mandell, & Raijmakers, 2011; Zelazo, Frye, & Rapus, 1996; Zelazo, Müller, Frye, & Marcovitch, 2003a). However, difficulties remain for these older children in the advanced version of the task, which requires switching between the shape and color rules on consecutive trials (Carlson, 2005; Chevalier & Blaye, 2009; Hongwanishkul, Happaney, Lee, & Zelazo, 2005). Similar difficulties even arise for adults if we consider their response times (Diamond & Kirkham, 2005).

Rule-based category learning

In the current article, we suggest that insight into the development of rule use in children can be gained from an existing literature on rule-based category learning. This field has mostly sought to explain adults' difficulties in learning various artificial rule-based categories (for the seminal studies, see Shepard, Hovland, & Jenkins, 1961, and Medin & Schaffer, 1978; for more recent important developments, see Nosofsky, Gluck, Palmeri, McKinley, & Gauthier, 1994, and Rehder & Hoffman, 2005). Some articles have examined rule-based category learning in children as well (e.g., Minda, Desroches, & Church, 2008).

To explain how rule-based categories are learned and represented, the field has developed a formalism based on Boolean complexity minimization. This formalism allows rule-based categories to be represented using logical disjunctive normal formulas such as "*a* and *b* OR *c*." "*Elephant = huge animal with a trunk with large ears (if African)* OR *small ears (if Indian)*" and "*my favorite pet = white cat* OR *black dog*" are examples of disjunctive normal forms. A disjunction is a logical formula that expresses categories for which objects do not resemble one another, which automatically increases the complexity of a category (Mathy, Haladjian, Laurent, & Goldstone, 2013). Nearly all studies on rule-based category learning have focused on complex rule-based categories with a minimum of three dimensions. This includes both more recent studies in this field (Bradmetz & Mathy, 2008; Feldman, 2000, 2003b; Lafond, Lacouture, & Mineau, 2007; Minda et al., 2008; Vigo, 2006) and older studies (Bourne, 1970; Bruner, Goodnow, & Austin, 1956; Hovland, 1966; Levine, 1966; Shepard et al., 1961). Because we aim to apply this work to rule use in preschoolers, we instead focus on two-dimensional artificial categories that are used to classify two-dimensional stimuli such as "red square" and "dark flower."

Such formulas are thought to represent the product of an abstraction process. They allow people to build rule-based categories from simple and independent features. Consider a set of four kinds of objects varying only in color and shape: *dark flower*, *light flower*, *dark butterfly*, and *light butterfly*. For this set, one simple rule-based category is "*dark*," which is a minimization of the "*dark flower*, *dark butterfly*" set of objects. This category can be used to classify the four objects into two groups by