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Dual processes in decision making and developmental neuroscience: A fuzzy-trace model

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ABSTRACT

From Piaget to the present, traditional and dual-process theories have predicted improvement in reasoning from childhood to adulthood, and improvement has been observed. However, developmental reversals—that reasoning biases emerge with development—have also been observed in a growing list of paradigms. We explain how fuzzy-trace theory predicts both improvement and developmental reversals in reasoning and decision making. Drawing on research on logical and quantitative reasoning, as well as on risky decision making in the laboratory and in life, we illustrate how the same small set of theoretical principles apply to typical neurodevelopment, encompassing childhood, adolescence, and adulthood, and to neurological conditions such as autism and Alzheimer's disease. For example, framing effects—that risk preferences shift when the same decisions are phrased in terms of gains vs. losses—emerge in early adolescence as gist-based intuition develops. In autistic individuals, who rely less on gist-based intuition and more on verbatim-based analysis, framing biases are attenuated (i.e., they outperform typically developing control subjects). In adults, simple manipulations based on fuzzy-trace theory can make framing effects appear and disappear depending on whether gist-based intuition or verbatim-based analysis is induced. These theoretical principles are summarized and integrated in a new mathematical model that specifies how dual modes of reasoning combine to produce predictable variability in performance. In particular, we show how the most popular and extensively studied model of decision making—prospect

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theory—can be derived from fuzzy-trace theory by combining analytical (verbatim-based) and intuitive (gist-based) processes.

Introduction

Biases in adult reasoning and decision making have been well documented (Evans, 2003; Gilovich, Griffin, & Kahneman, 2002; Tversky & Kahneman, 1986; Wason & Johnson-Laird, 1972). In order to explain such biases, dual-process theorists have posited an evolutionarily primitive system of thought that relies on intuition and emotion rather than reflection and analysis (e.g., Chaiken & Trope, 1999; Epstein, 1994; Evans, 2008; Tversky & Kahneman, 1983). According to standard dual-process theories, intuitive thinking is quick, automatic, and unconscious, whereas analytical thinking is the opposite (i.e., slow, controlled, and conscious). Stanovich and West (e.g., 2000) dubbed these collections of attributes System 1 and 2, respectively, capturing the order of their appearance phylogenetically and ontogenetically. Developmental neuroscientists make similar distinctions between early emerging emotional and reward systems (e.g., limbic structures such as the ventral striatum) and later developing cognitive control systems (e.g., the prefrontal cortex) (e.g., Somerville, Jones, & Casey, 2010; Steinberg, 2008).

From Piaget to the present, developmental theories have predicted improvement in the ability to reason from childhood to adulthood (Bjorklund, 2012; Haines & Moore, 2003). The mechanisms of improvement differ among neo-Piagetian, information-processing, developmental-neuroscience, and standard dual-process theories: better logical and analytical skills, larger working memory capacity, enhanced inhibitory capabilities, increased myelination (and, hence, faster processing speed), or greater metacognitive awareness. These mechanisms have been used to explain why reasoning ought to progressively conform to the canons of logic and mathematics, including probability theory. However, the endpoint of development, the adult logician-scientist of developmental theory, evolving away from intuitive thought, does not resemble the intuitive adult of the judgment-and-decision-making literature. The disparity is not between ideal competence vs. actual performance, but between different views of competence: As Reyna and Brainerd (1994) concluded, "the heuristics and biases research and the developmental research imply diametrically opposed views of adult competence" (p. 264).

Adult variability of this kind is grist for the mill for dual-process theories, which were designed to accommodate it. However, none of the traditional or standard dual-process theories predict that reasoning biases should *in*crease from childhood to adulthood. (Indeed, they predict that reasoning becomes more analytical and less intuitive, e.g., Stanovich, Toplak, & West, 2008.) Nevertheless, beginning in 1991 with findings by Jacobs and Potenza, a growing list of studies provide evidence for surprising developmental reversals, showing that children reasoned better than adults did (De Neys & Vanderputte, 2011; Morsanyi & Handley, 2008; see Table 3 in Reyna & Farley, 2006). Although some of these findings can be explained in terms of developmental differences in knowledge (e.g., about social stereotypes; Stanovich, West, & Toplak, in press), many reversal effects cannot be explained this way (e.g., Brainerd, Reyna, & Ceci, 2008; Davidson, 1991; Reyna, Estrada et al. 2011; Reyna & Ellis, 1994). These developmental reversals are not explained simply by alternative modes of processing; in these tasks, performance does not become more variable, but, rather, declines systematically from childhood to adulthood.

Because traditional and standard dual-process theories cannot supply mechanisms for developmental reversals, they are left with post hoc rationalizations of such findings (see Stanovich, West, & Toplak, 2011). These post hoc rationalizations (of better performance among children than adults) also do not explain why adults fail to override System 1 biases with System 2 reasoning, especially given that adults have the needed analytical competence. Certainly, dual-process theories are on the right track in assuming that there are multiple modes of reasoning, but post hoc classification of reasoning is a poor substitute for prediction. As we discuss, it is possible to conserve features of standard dual-process models, address some of the recent criticisms of those models (e.g., Keren &