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Development of implicit and explicit category learning

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ABSTRACT

We present two studies that examined developmental differences in the implicit and explicit acquisition of category knowledge. College-attending adults consistently outperformed school-age children on two separate information-integration paradigms due to children's more frequent use of an explicit rule-based strategy. Accuracy rates were also higher for adults on a unidimensional rule-based task due to children's more frequent use of the irrelevant dimension to guide their behavior. Results across these two studies suggest that the ability to learn categorization structures may be dependent on a child's ability to inhibit output from the explicit system.

Introduction

Category formation allows people to make adaptive responses across a wide variety of situations and, therefore, is one of the most fundamental decision-making processes needed for survival. According to the COVIS (competition between verbal and implicit systems) model (Ashby, Alfonso-Reese, Turken, & Waldron, 1998), there exist at least two separate, but partially overlapping, categorization systems to guide correct decision making, and both contribute to performance in day-to-day life.

The first system consciously identifies an explicit rule (i.e., if A, then B) or a set of conjunctive rules (i.e., if A and B, then C) through active hypothesis testing and is a form of explicit learning. This system involves a network of late-developing structures that includes the prefrontal and medial temporal cortices, the anterior cingulate cortex, and the head of the caudate (Ashby et al., 1998; Gabrieli, Brewer, Desmond, & Glover, 1997; Schacter & Wagner, 1999). As such, the ability to learn an increasingly complex set of explicit rules over time is dependent on the health and development of these structures to

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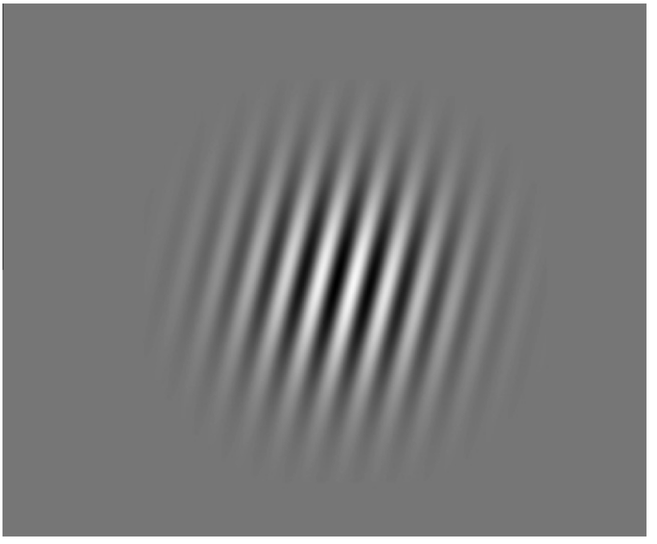

Fig. 1. Example Gabor patch.

represent such rules. The Wisconsin Card Sorting Test (WCST), a task in which participants learn to sort cards by color, number, or shape, would be an example of a task that not only indexes executive flexibility and set shifting but also taps an explicit category learning system.

The second learning system is procedurally based. It is better suited than the explicit system to handle situations in which hundreds, if not thousands, of exemplars exist and for which the relation among them cannot be expressed easily, if at all, using a verbalizable rule-based algorithm (for reviews, see Ashby & Maddox, 2005; Keri, 2003). The implicit system learns not by active hypothesis testing but rather by automatically and gradually recognizing subtle covariations within the environment. The knowledge base that is formed is often not fully accessible to consciousness.

Information-integration category learning tasks are believed to tap the implicit learning system. In these paradigms, participants are asked to sort into two groups, stimuli that are created by randomly sampling from two bivariate normal distributions (e.g., line orientation and spatial frequency [see Fig. 1]). The optimal strategy requires the participant to combine both values prior to the decision stage (Ashby & Ell, 2001; Filoteo, Maddox, Salmon, & Song, 2005). In the current study, we examined the developmental differences in performance when the decisional bound is quadratic in shape (Study 1 [see Fig. 2]) and when it is linear (Study 2 [see Fig. 5]), neither of which can easily be verbally described.

What developmental differences, if any, might be seen for implicit category formation and why? According to the COVIS model, implicit category learning is dependent on a set of frontal–striatal structures, and the posterior caudate in particular, that develops within the first year of life (Ashby & Ell, 2001; Ashby et al., 1998; Nomura et al., 2007; Seger, 2008; Seger & Cincotta, 2005). Therefore, we might expect implicit concept formation to be age invariant (e.g., Reber, 1992). Indeed, the ability to integrate information across two bivariate normal distributions (e.g., speed and direction [Herbranson, Fremouw, & Shimp, 2002]) and to learn complex artificial grammars is present even in pigeons (Herbranson & Shimp, 2003), which lack the cortical input that would support an explicit hypothesis testing learning strategy.

Critically, however, the COVIS model proposes that a competition exists between the frontally mediated rule-based system and the subcortically mediated information-integration system, the outcome of which determines which system will dominate the response to any given trial. Both humans