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A computational model for solving problems from the Raven's Progressive Matrices intelligence test using iconic visual representations

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Abstract

We describe a computational model for solving problems from Raven's Progressive Matrices (RPM), a family of standardized intelligence tests. Existing computational models for solving RPM problems generally reason over amodal propositional representations of test inputs. However, there is considerable evidence that humans can also apply imagery-based reasoning strategies to RPM problems, in which processes rooted in perception operate over modal representations of test inputs. In this paper, we present the "affine model," a computational model that simulates modal reasoning by using iconic visual representations together with affine and set transformations over these representations to solve a given RPM problem. Various configurations of the affine model successfully solve between 33 and 38 of the 60 problems on the Standard Progressive Matrices, which matches levels of performance for typically developing 9- to 11-year-old children. This suggests that, for at least a sizeable subset of RPM problems, it is not always necessary to extract amodal symbols in order to arrive at the correct answer, and iconic visual representations constitute a sufficient form of representation to successfully solve these problems. We intend for the affine model to serve as a complementary computational account to existing propositional models, which together may provide an integrated, dual-process account of human problem solving on the RPM.

Keywords: Affine transformations; Analogy; Iconic representations; Intelligence tests; Mental imagery; Raven's Progressive Matrices

1. Introduction

Raven's Progressive Matrices (RPM) is a collection of widely-used standardized intelligence tests consisting of analogy problems in which a matrix of geometric figures is presented with one entry missing, and the correct missing entry must be selected from a set of answer choices. Figs. 1 and 2 show examples of two-by-two (2×2) and three-by-three (3×3) matrix problems, respectively, which are similar to actual RPM problems.[1]

There are currently three published versions of the RPM: (1) the original Standard Progressive Matrices (SPM), (2) the Advanced Progressive Matrices (APM), developed as a more difficult test to reduce the ceiling effects sometimes found with the SPM, and (3) the Colored Progressive Matrices (CPM), intended as a simpler test than the SPM to be used with children, the elderly, or other individuals falling into lower IQ brackets (Raven, Raven, & Court, 2003). For the remainder of this paper, we use the term RPM to refer to the above family of tests, and we use the labels SPM, APM, and CPM to refer to specific members of the test family.

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[1] To protect the confidentiality of the RPM, we present example problems that are similar, but not identical, to actual test problems.

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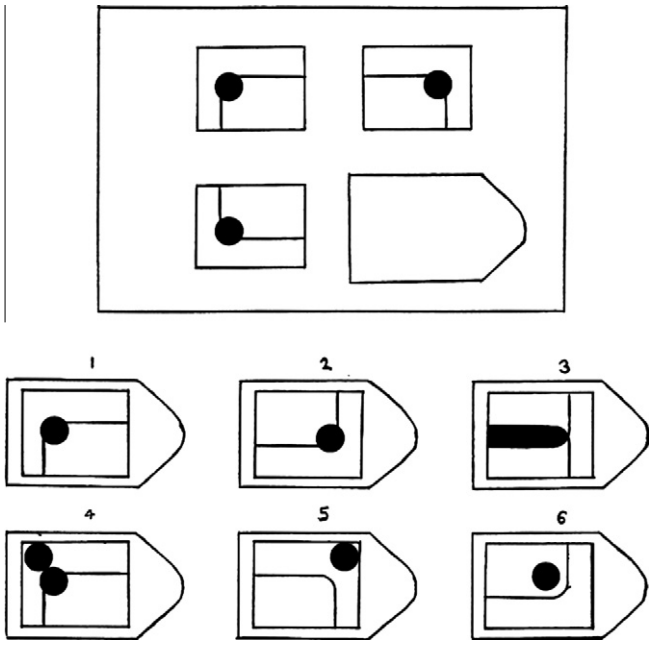

Fig. 1. 2×2 example problem similar to those from the Raven's Progressive Matrices family of tests.

The RPM tests were originally designed to measure only eductive ability, or the ability to extract and understand information from a complex situation, which is sometimes referred to as "fluid intelligence" (Raven et al., 2003). They were intended to be used together with the Mill Hill Vocabulary Scales, which measure reproductive ability, or the ability to recall previously learned information, sometimes called "crystallized intelligence." Together, these two tests would provide a measure of Spearman's general intelligence factor *g*, which Spearman had supposed could be decomposed into eductive and reproductive components (Spearman, 1923). However, over time, it was found that the RPM alone exhibited a very high level of correlation with other intelligence tests, leading the RPM to become widely considered one of the best single psychometric measures of *g* (Snow, Kyllonen, & Marshalek, 1984).

Using the RPM as a measure of general intelligence, though it consists only of problems in a single, visual format, stands in contrast to using broader IQ tests like the Wechsler scales, which are comprised of subtests that span several different verbal and nonverbal domains. In fact, the RPM was originally developed as an easy-to-administer, easy-to-score alternative to traditional multi-domain intelligence tests, which can take many hours to administer and often yield complex, multi-dimensional subscores which must then be combined to create a final IQ score (Raven et al., 2003). Due to its ease of administration and scoring, as well as the fact that it requires little verbal instruction or explicit verbal comprehension, the RPM is widely used as a test of general intelligence in clinical, educational, occupational, and scientific settings.

1.1. Computational models of problem-solving on the RPM

Computational accounts of problem solving must specify what kinds of representations are used to contain problem information and what types of processes operate over these representations to generate solutions. Following

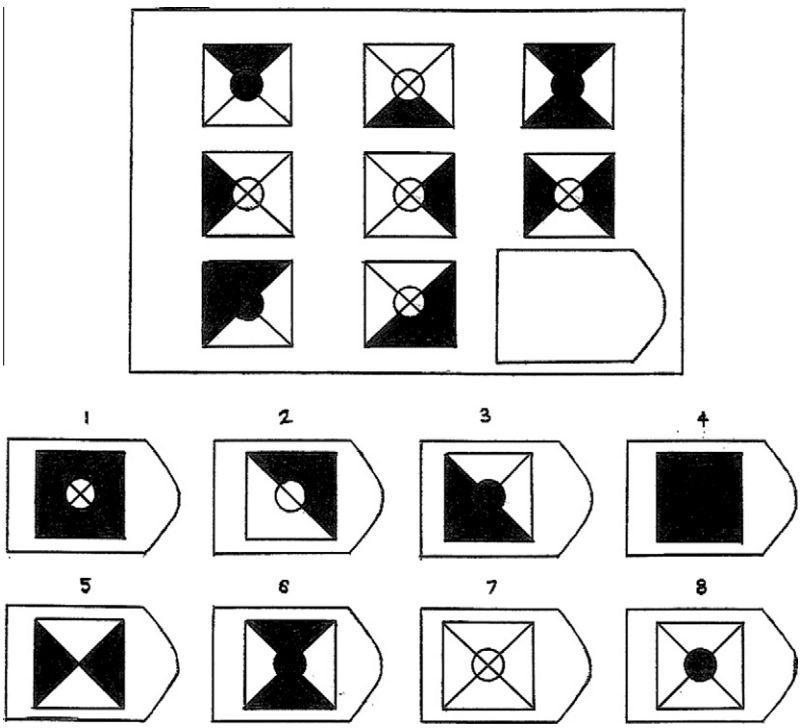

Fig. 2. 3×3 example problem similar to those from the Raven's Progressive Matrices family of tests.