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The structure of choice

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Abstract

An unsolved fundamental problem in decision science concerns the extent to which the nature of the perceived relationships among items in a set of alternatives influences how they are chosen. More specifically, given a choice set with *n* items, how does human choice behavior differ as a function of the perceived relationships between the items of the set? In what follows, we study this problem empirically and theoretically from the standpoint of the dimensional structure of the choice set. In particular, we use generalized invariance structure theory (GIST; Vigo, 2013, 2014) to propose an inverse relationship between the degree of concept learning difficulty of a choice set (as determined by its degree of invariance or internal coherence) and choice response times on its members. To our knowledge, this is the first model that precisely unifies these two fundamental constructs. On average, the model, without free parameters, accounts for nearly 90% of the variance in the data from our two response-time experiments.

Keywords: Concepts; Choice behavior; Categorization; Decision making; Structure; Complexity

1. Introduction

A fundamental open problem in decision science concerns how, and to what degree, an organism's perception of the relationships between alternatives in a choice set influences its choice behavior. To answer this question, an understanding of the fundamental tendency of our perceptual and conceptual systems to implicitly and automatically act as relational information processors (Kroger, Holyoak, & Hummel, 2004; Vigo, 2009a, 2009b; Vigo & Allen, 2009) seems to be a basic prerequisite. For example, the decision regarding which political candidate to support involves not only considering the platform for which they stand but also comparing it to the platforms of the other candidates concurrently in the race. Likewise, when diagnosing a patient, a physician utilizes the patient's symptoms to make a decision that often hinges on the relationship between the duration and severity of the symptoms. Finally, a commonplace set of decisions regarding which groceries to purchase at the supermarket is affected not only by the dimensions of preference, health, and price, but also by the relationships among alternative products. The perceived relationships between the items of the aforementioned real world choice sets may be of such magnitude that whenever a political candidate drops out of a race, a new symptom emerges within the patient, or a product is no longer available, an individual's perception and choice behavior concerning the remaining alternatives may change.

Examples of when these perceptions may be affected, particularly when holding the relationships between the alternatives constant, involve framing effects, commonly interpreted through prospect theory (Kahneman &

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Tversky, 1979; Tversky & Kahneman, 1981). Specifically, one may choose Option A in one instance when the decision frame is expressed in terms of losses, and then choose Option B when the frame is in terms of gains, even though the values between the options remain constant for both decision frames. Essentially, by changing the way a particular choice set is framed, other psychological dimensions may come into play that alter subsequent judgmental processes and, consequently, may cause a reversal in choice behavior (Tversky & Kahneman, 1981). The "decoy effect" (Ariely, 2008) is similar to the aforementioned preference reversal phenomenon but applied to decisions involving advertising and mate selection. Again, introducing a clearly inferior option into the choice set can alter an individual's perception of the relationships between the alternatives (or their Gestalt) and create a type of preference reversal similar to the framing effects discovered by Tversky and Kahneman (1981).

Although decision making takes place within ever-changing environmental contexts, much research has focused on analyzing human choice behavior without regard for the perceived interaction between the components of each alternative in the choice set at hand (*note*: a noteworthy exception is research on independence from irrelevant alternatives; see Busemeyer & Johnson, 2008). Traditionally, a significant number of decision science researchers have attempted to predict an individual's actual choice in situations of risk and uncertainty (i.e., gambles), inferring after the choice is made what judgmental processes may have occurred (see Johnson & Busemeyer, 2010; Rieskamp, 2008 for surveys). Therefore, many theories and much empirical work have relied on determining subjective utilities using weighted features to represent individual preferences for particular alternatives. At the core of this approach lies the presupposition that human decision making is probabilistic in nature (Busemeyer & Townsend, 1993; Johnson & Busemeyer, 2010; Kahneman & Tversky, 1979; Luce, 1959; Restle, 1961; Rieskamp, 2008; Rumelhart & Greeno, 1971; Tversky, 1972; Tversky & Kahneman, 1981). In other words, the decision making behavior of individuals, due to incomplete information from their environment, is determined largely by uncertainty.

One such probabilistic model was proposed by Restle (1961). The suppression-of-aspects (SOA) choice model proposes humans randomly attend to a specific dimension, while suppressing the other dimensions, to help arrive at a choice. Although the approach also linked probabilities to similarity, as does Luce's Choice axiom, it provided better fits to the empirical data because of the nature of its similarity relation (Rumelhart & Greeno, 1971). SOA represented a step forward at measuring how the specific relations among a set of objects (i.e. context), and not just their presence as independent alternatives, affect judgment and decision making processes. In the same spirit, Busemeyer, Forsyth, and Nozawa (1988) developed an extension to the SOA choice model that predicted choice response times for binary choices.

Alternatively, rather than randomly attending to a particular dimension and concurrently suppressing the other dimensions, the elimination-by-aspects (EBA) model proposes that humans undergo a sequential elimination process, dimension by dimension, with the most important dimension being probabilistically chosen first for any individual decision maker (Tversky, 1972). The inclusion of individual preference in dimensional selectivity permits an explanation of consistency—and by extension rationality—for any individual decision maker. Marley (1981) extended the EBA choice model to predict choice response times, and Busemeyer et al. (1988) showed that this EBA extension makes similar predictions to the SOA extension in terms of binary choice probabilities and that the two extensions can be distinguished when predicting choice response times. Similarly, the present study aims to predict and explain choice response times, but not choice probabilities, for preferential decisions involving choice sets consisting of numerous alternatives defined over three and four binary dimensions. It accomplishes this using categorical invariance theory (CIT; Vigo, 2009b, 2011a) and, more specifically, its offspring, generalized invariance structure theory (GIST; Vigo, 2013, 2014).

However, in contrast to the aforementioned notions of contextual choice, GIST offers a non-probabilistic approach to predicting choice response times. Our ultimate goal in using GIST is to discover the quantitative relationship between the degree of difficulty associated with learning a concept from a choice set and the length of time it takes to choose a preferred alternative from the set. The basic idea underlying the GIST approach to choice response times is that when presented with several alternatives from which a choice is to be made, humans detect the atomic patterns (named "categorical invariants") that are inherent to the relationships between the alternatives; these patterns enhance or attenuate aspects of the alternatives which ultimately determine choice response times.

2. Generalized invariance structure theory

GIST and the mathematical model referred to as the "generalized invariance structure theory model", or GISTM, predicts categorization performance for a wide variety of category structures. More specifically, it accounts for about 90% of the variance in proportion of correct responses data from 84 types of category structures sampled from 5100 distinct categories (Vigo, 2009b, 2013; see Section 3.2 for an explanation of these terms). The GISTM does this with a single scaling parameter k which makes it possible to account for individual differences. On the other hand, the "non-parametric" variant of the model referred to as the GISTM-NP performs nearly as well without the use of free parameters. For example, both models account for about 90% of the variance in large scale human classification data and both account for several key concept learning difficulty orderings in the literature, including but not limited to the commonly studied "SHJ