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Research article

Plausibility validation of a decision making model using subjects' explanations of decisions

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ABSTRACT

The purpose of this work is to present a procedure to validate the cognitive plausibility of decision making models generated from a knowledge-based computational modeling method. In order to probe the plausibility of the models, this study compared the explanations given by participants and models when they both make the same decision throughout the Iowa Gambling Task. The procedure used in the comparison is based on the average of the positions of the concepts identified in the participant's explanation in an importance-ordered list of concepts obtained from the model. The results demonstrate a close relation between the knowledge contained in both kinds of explanations.

Introduction

Cognitive science profits from the design and application of computational models that represent cognitive processes. One of these cognitive processes is decision making, which arises from situations where a participant faces a set of options or alternatives and she/he has to choose one. It is worth noting that participants often make decisions without knowing exactly their consequences, which may be inferred from past experience or knowledge extracted from the decision making task. In order to identify this knowledge based on past experience and the decision making task, explanations of decisions must be analyzed. An explanation is considered here as a statement made to clarify a decision and make it understandable. In the case of human beings, the explanations will help to understand the mental processes determining their behavior; in the case of a formal model, the explanations could highlight the computational processes through which the model comes to its decisions. Besides, if the model is neuropsychologically plausible, it is possible to match mental processes with computational processes of the model.

There is evidence that participants often reveal a variety of patterns in choice behavior that appear inconsistent with normative theories like, for example, Utility Theory that scores each alternative using two variables: the value of an outcome and its probability (Starmer, 2000). The study described in Iglesias, del Castillo, Serrano, and Oliva (2012) suggests that participants base their decisions on knowledge that is not limited to the probability and the value of each outcome. Therefore, modeling decision making using a knowledge-based approach may have an impact on Cognitive Science.

The aim of this work is to validate the plausibility of a decision making model, called MAIDEN-IGT (Iglesias et al., 2012), by trying testing the match not only to the output decision of human subjects but also to the explanations to that output. In previous works, it has been proved that the performance of MAIDEN-IGT modeling the behavior of subjects when they make a decision is quantitatively better than other well known theories of decision making (Iglesias et al., 2012). The validation proposed in this paper starts from the assumption that the explanations provided for the choices in a decision making task could help to infer the conscious knowledge used to make them thus contributing to a better understanding of the decision process.

MAIDEN-IGT is mainly based on the knowledge acquired through past experience, the knowledge perceived directly from the display of the decision making task and the relationships (parameters) between the concepts that represent these two kinds of knowledge. In the rest of the paper, the term concept is used as variable representing the problem at hand at any given time, either perceived from the environment or internally stored. The parameter setting of the model is carried out by an evolutionary optimization method. A computational model with many parameters might fall into combinatorial complexity when they are adjusted. That is, the model could produce the same results with very different

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parameter combinations. In such a case, the computational model would lose any explanatory capacity and thus the assumed cognitive plausibility and ultimately its usefulness. So, a way to probe the goodness of the methodology, in the sense of plausibility of the models, is to compare the explanations given by participants and models when they both make the same decision throughout the Iowa Gambling Task.

The remainder of this paper is organized as follows. First, Section 'The Iowa Gambling Task' explains the Iowa Gambling Task, which is the decision making task chosen for the experiment presented in this paper. Next, Section 'Knowledge-based modeling of human behavior in the Iowa Gambling Task' describes MAIDEN-IGT. Next, Section 'Experiment' describes the experimental procedures for supporting the hypothesis presented in this work and the results obtained. Section 'Discussion' contains a discussion and, finally, Section 'Conclusion' presents the concluding remarks.

The Iowa Gambling Task

Research in the field of decision making has used several tasks in order to study different characteristics of the decision making process (Bogacz, Brown, Moehlis, Holmes, & Cohen, 2006; Lawrence, Clarck, Labuzetta, Sahakian, & Vyakarnum, 2008). A representative decision making task is the Iowa Gambling Task (IGT) (Bechara, Damasio, Damasio, & Anderson, 1994), where participants must make a sequence of selections from four decks of cards. Therefore, it is a repetitive task where participants face the same problem many times in similar situations. The IGT was originally developed to capture the role of emotion in decision making in patients with brain damage. The IGT has been widely used to detect decision making deficits in clinical populations, such as substance abusers, schizophrenics and pathological gamblers (Duarte, Woods, Rooney, Atkinson, & Grant, 2012; Toplak, Sorge, Benoit, West, & Stanovich, 2010). Table 1 illustrates the payoff distribution of the IGT for the first 10 trials. In the original version of the IGT, the whole sequence of cards in the decks is fixed and remains the same for all participants. From an statistical viewpoint, this game belongs to the area of k-armed bandit problems with $k = 4$ (Robbins, 1952). In this kind of problems a participant learns the environment behavior by choosing actions and experimenting their consequences (Sutton & Barton, 1998). The participant has to check the different options to find the best one. In the IGT, the participant only has got a limited number of trials and he/she leaves gradually exploring options and takes advantage of the alternative with best outcomes up to this time.

In this paper, a computational version of the IGT is used. Unlike the original version, the location of the four decks and the distribution of the cards are randomized for each participant in order to avoid the participants tell each other and corrupt the tests. Decks are labeled when presented to participants and the number of cards remaining in each deck is also visible. Before making a decision, the gain and loss produced in the previous trial and the current amount of money are displayed to the participant. The number of remaining trials is also visible to the participants. Fig. 1 shows a screenshot of the IGT as an example.

Table 1
Payoff distribution of the Iowa Gambling Task for every 10 trials.

Deck	Gain	Loss	Expected value after 10 trials
A	\$100 on every trial	−\$350 on one trial −\$300 on one trial −\$250 on one trial −\$200 on one trial −\$150 on one trial	−\$250
B	\$100 on every trial	−\$1250 on one trial	−\$250
C	\$50 on every trial	−\$25 on one trial −\$50 on one trial −\$75 on one trial	\$250
D	\$50 on every trial	−\$250 on one trial	\$250

Knowledge-based modeling of human behavior in the Iowa Gambling Task

The study of human behavior has motivated the use of computational models that describe and reproduce human performance in decision making tasks. Computational modeling allows the analysis of different theories and hypotheses concerning human behavior (Fum, Del Missier, & Stocco, 2007). One of the models that emulate human performance during the IGT is called MAIDEN-IGT (Model of Assessment and Inference of DEcisions based on a Net of concepts) (Iglesias et al., 2012). The dynamics of MAIDEN-IGT divide the decision making process into two phases. The first phase lies in the estimation of the decision outcomes using a net of concepts (see Iglesias, del Castillo, Serrano, & Oliva, 2010a for a comparison of connectionist models of decision making). In the second phase, MAIDEN-IGT uses a value function to score each possible alternative. The best scored alternative represents the output of MAIDEN-IGT. The design of MAIDEN-IGT focuses on some psychological and neurophysiological evidence from current research:

- There is psychological evidence supporting the hypothesis that participants use fast strategies for making decisions with a minimum of information (Gigerenzer, 2008). One of the simplifications participants apply to decision making is causal knowledge (Garcia-Retamero & Hoffrage, 2006), which is used to anticipate future outcomes.
- Prospect Theory (Kahneman & Tversky, 1979) distinguishes two phases in the decision process according to psychological evidence: an early phase of editing and a subsequent phase of assessment. The editing phase is a preliminary analysis of the available alternatives that transforms the rewards and their probability values according to cognitive biases. In the second phase, the edited outcomes are evaluated and the alternative of the highest value is chosen. Besides, there is neurophysiological evidence that supports the existence of this phase of assessment (Glimcher, 2009; Kable & Glimcher, 2009).
- MAIDEN-IGT differentiates between gains and losses according to the distinction expressed in Prospect Theory, in which value is assigned to gains and losses rather to final assets. There is also physiological evidence supporting that the brain areas activated

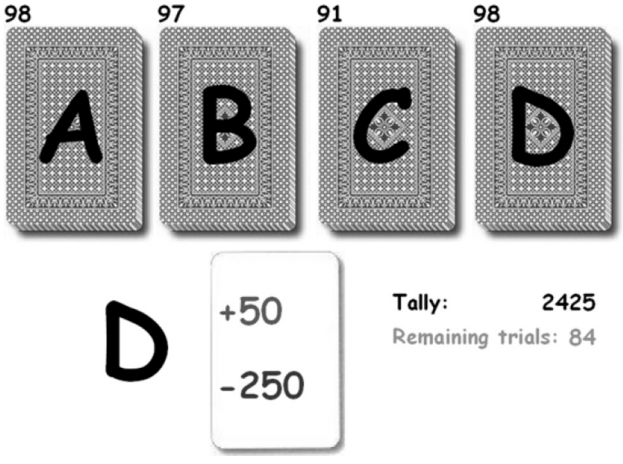

Fig. 1. A sample display of the Iowa Gambling Task.

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