Journal of Mathematical Psychology 64–65 (2015) 17–34

Contents lists available at ScienceDirect

Journal of Mathematical Psychology

journal homepage: www.elsevier.com/locate/jmp

The expectancy valence model of the Iowa Gambling Task: Can it produce reliable estimates for individuals?

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HIGHLIGHTS

- We aim to identify deficits in decision making for individuals completing the IGT using the EVM.
- Individual level parameter estimates are unreliable and/or have little psychological significance.
- Participants in the same group have dissimilar parameter estimates.
- Completing the Iowa Gambling Task three times does not improve parameter estimates.
- Using a 2-parameter EVM improves results.

ARTICLE INFO

Article history:
Received 25 October 2013
Received in revised form
2 October 2014
Available online 11 December 2014

Keywords:
Expectancy Valence model (EVM)
Iowa Gambling Task (IGT)
Individual performance
Decision making
Bayesian estimation
MCMC
2-parameter EVM

ABSTRACT

The Expectancy Valence Model (EVM) of the Iowa Gambling Task (IGT) is commonly used in studies to identify the underlying psychological processes responsible for decision making deficits.

We show the EVM does not provide clear information about decision making processes at the individual level by fitting the EVM, with individual random effects, to a sample of participants from various drug using populations using Bayesian techniques and to a sample of participants who complete the IGT multiple times. In particular, we show that the individual-level parameter estimates from the model may be bi-modally distributed and hence are inherently ambiguous and have little psychological significance.

In an attempt to increase the validity of individual-level parameter estimates, we also considered a 2-parameter version of the EVM in which the consistency parameter was held constant. In the 2-parameter implementation of the EVM, results were clearer and more easily interpretable than when using the traditional EVM.

1. Introduction

Impulsivity is a multidimensional construct; it can, for example, relate to a failure to follow instructions or wait for one's turn (execution impulsivity); responding before all the essential information has been gathered (preparation impulsivity), or failing to delay gratification; focussing on short term or positive outcomes and relatively discounting long term or negative outcomes (outcome impulsivity) (see Evenden (1999b) for a review). Developed by Bechara, Damasio, Damasio, and Anderson (1994), the Iowa Gambling Task (IGT) is a four-armed bandit task designed to measure deficits in decision making among clinical populations, in particular the notion of outcome impulsivity. To complete the IGT, a participant chooses from four computerised decks of cards to try and maximise their long-term return. Successful completion of the task requires the participant to learn that two of the decks are disadvantageous over time (high immediate returns but long term losses) while the remaining two decks are advantageous (low immediate win amounts but long term gains). Highly impulsive individuals will, theoretically, show poor performance on the IGT due to the appeal of the high immediate win amounts associated with the disadvantageous decks (Bechara et al., 1994).

The IGT is currently being sold as a clinical assessment tool for the assessment of individual decision making deficits (Bechara, 2012; Buelow & Suhr, 2009). With multiple, independent studies

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http://dx.doi.org/10.1016/j.jmp.2014.10.002
0022-2496/

showing an association between IGT scores and substance use relapse (De Wilde, Bechara, Sabbe, Hulstijn, & Dom, 2013; De Wilde, Verdejo-García, Sabbe, Hulstijn, & Dom, 2013; Goudriaan, Grekin, & Sher, 2011; Kasar, Gleichgerrcht, Keskinkilic, Tabo, & Manes, 2010; Nejtek, Kaiser, Zhang, & Djokovic, 2013; Passetti, Clark, Mehta, Joyce, & King, 2008; Radat, Chanraud, Di Scala, Dousset, & Allard, 2013; Salgado et al., 2009; Wang et al., 2013), the IGT is a popular choice when developing treatment plans in a clinical setting. Two of the simplest, standard ways of identifying poor performance on the IGT are to examine the overall net return after a specified number of trials, or to look at the frequency of choices from advantageous and disadvantageous decks in blocks across the duration of the task (Brown, Anderson, Symington, & Paul, 2012; Lamers, Bechara, Rizzo, & Ramaekers, 2006; Poletti, Cavedini, & Bonuccelli, 2011; Stout, Busemeyer, Lin, Grant, & Bonson, 2004). However, some studies have demonstrated that these standard measures have questionable validity (Buelow & Suhr, 2009; Lin, Song, Chen, Lee, & Chiu, 2013; Steingroever, Wetzels, Horstmann, Neumann, & Wagenmakers, 2013). More pertinently, both net return and frequency of deck choice measure composites of multiple decision making processes, making it hard to argue that poor performance indicated by these measures is due to impulsive behaviour alone. For example, a participant has to remember multiple outcomes over time in order to make the most advantageous choices in the future, so it is reasonable to think that deficits in learning processes will also lead to poor performance on the IGT.

To disentangle the differences between poor performance on the IGT due to high outcome impulsivity or due to poor learning, a more sophisticated mode of analysis is required. Cognitive models of performance allow the underlying psychological processes driving observed performance to be teased apart and measured. In this way behaviours that are composites of different psychological processes can be understood in greater depth. Although several cognitive models have been proposed to disentangle the psychological processes underlying performance on the IGT (for examples see Ahn, Busemeyer, Wagenmakers, and Stout (2008) and Steingroever, Wetzels, and Wagenmakers (2013)), the Expectancy Valence Model (EVM) proposed by Busemeyer and Stout (2002), has been the most widely implemented. Producing estimates of impulsivity or motivational processes, memory and learning, and response consistency (Busemeyer & Stout, 2002), the EVM has been successfully used to identify high impulsivity levels in cocaine users (Stout et al., 2004), memory deficits in Huntington's sufferers (Busemeyer & Stout, 2002) and differences in a raft of other psychological groups of interest when compared to control groups (for a review of the applications of the EVM on the IGT see Yechiam, Busemeyer, Stout, and Bechara (2005)).

Given the success of the EVM at decomposing performance on the IGT for groups, and given that the IGT is widely used in clinical settings, there would be great potential benefits in applying the EVM of the IGT at the level of the individual. For example, individuals with drug addictions are known to be more likely to relapse following rehabilitation if they are highly impulsive (De Wilde, Verdejo-García et al., 2013; Nejtek et al., 2013; Passetti et al., 2008; Radat et al., 2013). Using the IGT as an assessment tool, and then decomposing behaviour for the individual using the EVM, a clinician would get a clearer estimate of impulsivity for the individual than using the standard, composite measures of performance on the IGT such as net return. If a client was identified as being highly impulsive, then any treatment plan could include extra coping strategies for high risk situations to try and avoid relapse. However, this depends on gaining a *clear and valid* estimate of impulsivity for the individual.

An increasing body of literature shows that estimates using the EVM to identify deficits in the psychological processes required to complete the IGT at the level of the individual produce highly uncertain estimates. Wetzels, Vandekerckhove, Tuerlinckx, and Wagenmakers (2010) highlight this problem by showing that EVM parameter estimates are highly uncertain at the level of the individual, even for simulated data in which the parameter values are known. Without precise estimates, it would be inappropriate to use the EVM to decompose behaviour on the IGT at the level of the individual and there are warnings in the literature against this course of action (Wetzels et al., 2010).

Table 1
Payoff scheme of the traditional IGT Bechara et al. (1994). Decks A & B may yield higher reward amounts but their associated loss amounts are also larger, resulting in net losses if chosen regularly. Decks C & D are, therefore, considered the advantageous decks.

	Bad decks		Good decks	
	A	B	C	D
Reward/Trial	100	100	50	50
Number of losses/10 cards	5	1	5	1
Loss/10 cards	−1250	−1250	−250	−250
Net outcome/10 cards	−250	−250	250	250

If it were possible to reduce the uncertainty associated with EVM estimates of impulsivity and memory when the IGT is used as an individual assessment tool, the EVM could be used to identify potential cognitive deficits leading to poor performance at an individual level. These results would provide more clinically useful information than the composite measures currently in use and would assist in tailoring treatments specific to the needs of the particular person. However, to be able to reduce uncertainty, the reason for the existence of the uncertainty must be determined. In this paper, we aim to explore why the EVM produces such highly uncertain individual-level parameter estimates, and examine an option for reducing uncertainty.

1.1. The Iowa Gambling Task

Proposed as a simulation of real-life decision making in the face of uncertainty, the Iowa Gambling Task (IGT) requires participants to make a series of choices from four virtual decks of cards with the aim of maximising the amount won. The four presented decks have fixed (but undisclosed) win-to-loss ratios and dollar amounts, with two decks culminating in overall wins and two in overall losses (Table 1). Participants with unimpaired decision making processes converge to choices from profitable decks only (Busemeyer & Stout, 2002). A full description of the task is available in Wetzels et al. (2010).

Successful completion of the IGT requires the participant to explore all of the decks and, once all of the decks have been thoroughly explored, exploit the most profitable decks. To achieve this goal, a participant must evaluate the outcome of every deck choice, use this information to update any expectancies about returns associated with the decks and then make subsequent decision based on what has been previously learned. It is proposed that distinct brain regions or systems are responsible for producing each of these three processes and, as such, performance levels in each one of these processes can be depleted or vary independently of performance levels in the other processes (Stocco, Fum, & Napoli, 2009). Poor performance on the IGT may be interpreted as a possible deficit in the relevant process.

2. Theory

2.1. The Expectancy Valence Model

The EVM is a cognitive model designed to interpret performance on the IGT by identifying the underlying psychological processes responsible for deficits in decision making. This utilises a