European Journal of Operational Research 249 (2016) 931–944

Contents lists available at ScienceDirect

European Journal of Operational Research

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

An experimental investigation into the role of simulation models in generating insights

Anastasia Gogi, Antuela A. Tako, Stewart Robinson*

Management Science and Operations Management Group, School of Business and Economics, Loughborough University, Loughborough, Leicestershire LE11 3TU, UK

ARTICLE INFO

Article history:
Received 13 November 2014
Accepted 22 September 2015
Available online 21 October 2015

Keywords:
Discrete-event simulation
Insight
Animation
Experimentation
Behavioural operational research

ABSTRACT

It is often claimed that discrete-event simulation (DES) models are useful for generating insights. There is, however, almost no empirical evidence to support this claim. To address this issue we perform an experimental study which investigates the role of DES, specifically the simulation animation and statistical results, in generating insight (an 'Aha!' moment). Undergraduate students were placed in three separate groups and given a task to solve using a model with only animation, a model with only statistical results, or using no model at all. The task was based around the UK's NHS111 telephone service for non-emergency health care. Performance was measured based on whether participants solved the task with insight, the time taken to achieve insight and the participants' problem-solving patterns. The results show that there is some association between insight generation and the use of a simulation model, particularly the use of the statistical results generated from the model. While there is no evidence that insights were generated more frequently from statistical results than the use of animation, the participants using the statistical results generated insights more rapidly.

1. Introduction

Discrete-event simulation (DES) is a popular modelling technique that is claimed to support problem solving and decision making. Indeed, it is often said that clients gain 'insights' as a result of simulation interventions, especially from the simulation animation (Bayer, Bolt, Brailsford, & Kapsali, 2014; Belton & Elder, 1994; de Vreede & Verbaeck, 1996; Hurrion, 1986; O'Kane, 2004; Pidd, 2010; Proudlove, Black, & Fletcher, 2007; van der Zee & Slomp, 2009). However, the term 'insight' is used quite loosely to mean an improved understanding. Cognitive psychologists explain that *insights* may refer not just to the acquisition of better understanding, but also to the experience of sudden shifts in understanding or *'Aha!' moments*. More specifically, *insight* is defined as '*the cognitive process by which a problem solver suddenly moves from a state of not knowing how to solve a problem to a state of knowing how to solve that problem*' (Mayer, 2010, p. 276).

Given the claims about simulation in insight generation and the huge growth in simulation literature over the last two decades (Powers, Sanchez, & Lucas, 2012), it is surprising that there is almost no empirical evidence to support the claims about insight. Evidence of learning outcomes is scarcely published in simulation papers (Fone et al., 2003). Even where the learning outcomes are reported, there is generally no explanation of the causal mechanism for learning, let alone Aha! moments. Therefore, any claim that the catalyst for insight is a simulation model, and more specifically the animated display of the simulation model, has relied largely on supposition and anecdotal evidence from case studies. Meanwhile, relatively little task-based behavioural research has been conducted aiming to support the above claims; and where it has, the results are mixed (Bell & O'Keefe, 1995).

To address this dearth of evidence, this paper describes an experimental study that aims to test whether and how insights are generated from DES models. Our contribution is to provide a more in-depth understanding of insight in the context of simulation and empirical evidence on the role of simulation in generating insight.

The paper is organised as follows. In Section 2, we describe in more detail the concept of insight and discuss how it relates to the simulation context. Then, we review the limited evidence that exists surrounding the use of simulation models and insight. In Section 3, we present the experimental study, explaining the research hypotheses, the experimental design, the participants, the procedure, the dependent measures and the materials used. Section 4 details the results of the study, followed by a discussion on the value of simulation models in insight generation, the limitations of the study and suggestions for future work (Section 5).

* Corresponding author. Tel.: +44 1509 222432.
E-mail address: s.l.robinson@lboro.ac.uk (S. Robinson).

http://dx.doi.org/10.1016/j.ejor.2015.09.042
0377-2217/

2. Insight and simulation

This section provides the conceptual foundation for our experimental study. We first introduce the concept of insight from relevant fields and we discuss its relevance to the simulation context. We then discuss the evidence that currently exists in the academic literature regarding the role of simulation in generating insight.

2.1. The concept of insight

The word 'insight' is used in two ways. It is used as a state of understanding – that is, to have insight into something (Smith, 1995). Insight is also described as an experience, an Aha! experience, involving a moment of epiphany (Schooler, Fallshore, & Fiore, 1995). This view is originally encountered in the story of Archimedes of Syracuse when he discovered the principle of displacement–'eureka'. For this research we adopt this latter concept, proposing it as an approach to measure the value of simulation as a means for creating knowledge.

To explore Aha! insight in more depth, relevant literature is considered and in particular the theoretical domain of Gestalt theory (Maier, 1940, Mayer, 2010), creative cognitive psychology (Sternberg, 2009) and a collection of studies on insight that have attempted to conceptualise the phenomenon (Kounios & Beeman, 2009, Metcalfe & Wiebe, 1987). Despite the fact that these streams of literature do not share the same theoretical foundations, it seems that they all agree upon the phenomenological perspective of the concept: a satisfactory solution to a problem suddenly emerges after overcoming an impasse. An impasse is the state in which a problem solver realises that initial ideas do not solve the problem, but at the same time feels that all the possibilities have been exhausted (Schooler et al., 1995). Generating insight is a productive activity which is about doing something new or novel. New ideas that do not lead to the solution itself but are relevant to finding the solution are described as false insights (Isaak & Just, 1995). They usually occur when the cause of a problem is misunderstood. In particular, in false insight, a person approaches the problem in a new or novel way, but without having a correct view of the problem. When false insights emerge, the suggested idea is not a satisfactory solution to the problem.

Insight differs from other problem solving approaches, such as intuition, which are often used synonymously in everyday speech. Dane and Pratt (2007) explain that while the concept of insight involves some degree of non-conscious thought, it arises through logical connections between a problem and the solution. Intuition, in contrast, relies on non-conscious associative connections. Insight also differs from guessing in that the latter does not require making any sort of connection (i.e. conscious or unconscious). As a result, in problem solving with insight, a person is able to justify the suggested solution, whereas in problem solving with intuition, or guessing, the person is not.

Social scientists have offered many explanations about the mental mechanisms of insight generation which seem somewhat interrelated. In short, in achieving illumination (i.e. generating insight), a problem solver may overcome implicitly imposed constraints (Weisberg, 1995), change mental representations, become aware of a new association between parts of a system, change the meaning of some problem element, or assimilate possible solutions from the environment (Davidson, 1995). In other words, it is believed that prior knowledge and experience constrain people's worldview, and, as a result, this knowledge may prevent them from seeing the world as it really is. Nevertheless, by using past experience as a building block, avoiding being confined by habits or irrelevant associations, the problem solver may eventually identify the appropriate way to solve a problem; and hence insights emerge. For a more detailed discussion on insight see Gogi, Tako, and Robinson (2014).

Table 1
Some examples of insights found in the simulation literature and possible mental mechanisms of experiencing insight.

Examples of insight in the simulation literature	Possible explanations of the mental mechanism of experiencing insight
Robinson (2001)	
The stakeholders realise that there is no actual need for hiring lower skilled staff to work on the helpline	*Overcoming implicitly imposed constraints*
Lee (2010)	
Two subjects succeed in making significant improvements on their second representation of the water cycle compared to their initial one	*Changing mental representation*
Lee (2010)	
One subject builds new structural associations during the second representation of the water cycle	*Becoming aware of a new association between parts of a system*
Monks et al. (2014)	
Some participants succeed in ceasing a common misconception about the relationship between resource utilisation and service level	*Changing the meaning of some problem element*
Bakken et al. (1992)	
Some participants manage to apply insights learned from the first game to a second one	*Assimilating possible solutions from the environment*

2.2. Insight in the simulation context

Applying the above in the context of DES, it can be claimed that insight occurs when people using a simulation model suddenly know how to improve the performance of a system after several failed alternative attempts (i.e. what-ifs scenarios). The strategy used to achieve major improvements in the system involves doing something new or novel. So, we can identify that insight occurs during the experimentation phase of a simulation project if the users go through a problem solving pattern where an impasse (i.e. a phase in which simulation users only run what-if scenarios which are similar to existing unsuccessful strategies) is followed by a sudden realisation/generation of new or novel ideas that achieve major improvements in the performance of as system. After the experience of an Aha! moment, the users must be able to justify the rationale underlying the suggested solution that has arisen. We note that since a simulation model is a simplification of the real world (Robinson, 2008) insights only relate to the model, and they must be interpreted in the light of wider knowledge about the real-life system.

Table 1 provides a non-exhaustive list of instances of insight found in the simulation literature. For each example, a possible explanation about the mental mechanisms of experiencing insights is suggested with respect to the cognitive psychology theories introduced in Section 2.1.

In this research, we use a single problem (i.e. the NHS111 case study as described in Section 3.6.1) to explore the value of simulation in generating insights. As such, it is not possible to study assimilating possible solutions from the environment (i.e. there is no second game and consequently transferring knowledge acquired from one simulation game to another is not possible). In our case study, we also make explicit the parts of the system and all the associations between them. Therefore, it is not possible to study changing mental representation or becoming aware of some problem elements. Instead, we consider both implicitly imposed constraints and misconceptions of some problem element in order to study the value of simulation in generating insights.

2.3. Empirical evidence on insights with simulation models

There is very limited empirical evidence on the role of DES in learning and generating insight. This is despite Richels' (1981)