Chapter 25
Executive Functions in Digital Games

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ABSTRACT

Despite enhanced appreciation of the nature and scope of the cognitive advantages of playing games, our understanding of the actual mechanisms responsible for generating and maintaining these remains limited. In this chapter, the authors propose that viewing these changes from the information processing perspective of executive functions will help to elucidate the psychological infrastructure that underpins these gains. They apply Anderson's model of executive functions to understanding how games support visual-perceptual processing and higher-level thinking and problem solving. As well as extending our appreciation of how digital games can support learning, research on executive functions highlights the implications of the limitations of our cognitive systems for game design.

INTRODUCTION

It is well known that digital entertainment games provide highly engaging activities but more recent interest has focused on whether games can support learning. Research in this area has two main strands. The first concerns the accumulating evidence that playing digital entertainment games, especially action games, leads to improvements on a range of perceptual, attentional and memory skills. While the link between these skills and learning may not seem immediately obvious, it has been argued that successful performance on visual-spatial tasks underlies success on the key STEM subjects (science, technology, engineering and mathematics) taught at school and university (Subrahmanyam & Greenfield, 1994; Christou, Jones, Mousoulides & Pittalis, 2006; Hung, Hwang, Lee & Su, 2012) and necessary for many 21st century jobs. The second strand of research concerns whether games, either entertainment or educational, can improve problem solving and reasoning abilities. High level thinking skills such as problem solving are increasingly acknowledged

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as important to effective learning (McGuinness, 1997) as well as underpinning the 21st century skills necessary for success in the workplace (National Research Council, 2010).

Serious games are games which are intentionally designed to promote learning, skill acquisition and behaviour change more generally (Boyle, Connolly and Hainey, 2011). Although studies of the benefits of serious games have been informed by pedagogical theories such as experiential learning (Kolb, 1984) and constructivism (Kebritchi & Hiruni, 2008), less attention has been paid to the actual cognitive mechanisms that support the learning process in games. In this chapter we argue that concepts from cognitive psychology which provide explanations of the benefits of games at the level of information processing can advance our understanding of how games support learning.

To date, cognitive accounts have been relatively neglected in research on serious games despite the fact that they offer explanations of the psychological mechanisms at an information processing level which can inform game design, development and evaluation. Although the existing evidence base clearly indicates the benefits of games, no clear and consistent distinction is currently made between the underlying cognitive structures and the skills they support. We propose that examining these gains from the cognitive information processing perspective of executive functions will help elucidate the psychological infrastructure that underpins these gains. Cognitive research distinguishes between lower level and higher level processing, where lower level processing refers to perception, attention and working memory and higher level processing refers to problem-solving, reasoning and decision making. Any information processing system requires control and co-ordination and recent models of cognition have proposed that such control is exercised via executive functioning.

BACKGROUND

'Executive functions' are not straightforward to define. In early theoretical accounts, such as that of Baddeley and Hitch (1974), the central executive was conceptualised as a unitary system. However, the unitary concept of the central executive has undergone 'fractionation' (Baddeley & Della Sala, 1996, p. 1402) into a much wider range of processes which are subsumed under the term 'executive function'. For example, Miyake, Friedman, Emerson, Witzki, & Howerter (2000) carried out a confirmatory factor analysis of performance data from adults and found evidence for inter-related but dissociable contributions from the executive functions of shifting of attention, updating of working memory representations, and inhibition. Andersson (2008) offers an even more fine-grained analysis: 'The key elements of executive function include (a) anticipation and deployment of attention; (b) impulse control and self-regulation; (c) initiation of activity; (d) working memory; (e) mental flexibility and utilisation of feedback; (f) planning ability and organisation; and (g) selection of efficient problem solving strategies' (Andersson, 2008, p. 4).

In short, 'executive processes are responsible for the control of cognition and regulation of behaviour and thought and are intertwined with the notion of volition: the freedom to make appropriate (or inappropriate) choices from a set of possible choices' (Phillips, 1997, p. 186). A further distinction is made by Zelazo and Muller (2002) between 'cool' and 'hot' executive functions (EF) which has implications for an understanding of the processes underlying digital gaming. 'Cool' EF are those which underpin cognitive tasks, while in contrast, 'hot' EF relate to decision-making where the outcomes have some emotional significance, such as in competitive game-play. A note of caution is required however. As a result of the