Computers & Education 72 (2014) 132–144

Contents lists available at ScienceDirect

Computers & Education

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

"Critic-proofing" of the cognitive aspects of simple games☆

Dragana Martinovic [a,*], C.I. Ezeife [b,1], Rob Whent [c,2], Jonathan Reed [d], Gerald H. Burgess [e,3], Chantal M. Pomerleau [f], Yuqi Yang [a], Ritu Chaturvedi [b]

[a] Faculty of Education, University of Windsor, 401 Sunset Ave., Windsor, ON N9B 3P4, Canada
[b] School of Computer Science, University of Windsor, 401 Sunset Ave., Windsor, ON N9B 3P4, Canada
[c] OTEP Inc., Canada
[d] Recolo UK Ltd., 10 Harley St., London, W1G 9PF, UK
[e] Department of Applied Psychology, Canterbury Christ Church University, Salomons Campus at Tunbridge Wells, Broomhill Road, Southborough, Tunbridge Wells, Kent, TN3 0TG, UK
[f] Department of Psychology, University of Windsor, 401 Sunset Ave., Windsor, ON N9B 3P4, Canada

ARTICLE INFO

Article history:
Received 12 June 2013
Received in revised form
29 October 2013
Accepted 31 October 2013

Keywords:
Computer games
Cognition
Learning
Reliable coding
Critic-proofing

ABSTRACT

This paper posits the use of computer games as cognitive development tools that can provide players with transferable skills suitable for learning in the 21st century. We describe a method for categorizing single-player computer games according to the main cognitive function(s) engaged in by the player during gaming. Categorization was done in collaboration with a neuropsychologist, academic researchers, and research assistants. Twelve research assistants, mostly domain novices, were trained to categorize games according to a cognitive matrix developed by the neuropsychologist. They also categorized the games, and evaluated and commented on the relevance of the neuropsychologist's categorization of the games. Through the process of "critic proofing," computer games were reliably classified into primary and secondary cognitive categories, and the team was able to identify problems with both the categorization of certain games and the definitions of some of the cognitive functions in our cognitive matrix. Such an approach allowed for the identification of under-populated cognitive categories in the project's existing repository of games, and for further development of the cognitive representation framework, information useful for both researchers and designers in the gaming industry.

1. Introduction

In this paper, we describe our approach for identifying and categorizing simple, single-player computer games that are "cognitively responsible." This term was generated by Martinovic and Whent in 2011 (personal communication), specifically to describe simple, single-player computer games that utilize several aspects of cognition in the player (e.g., Visual Perception, memory, executive function). Using this term means that we are avoiding the addictive qualities of computer games (e.g., limit on play time) and are considering only games that are not connected to social networks (with associated risks, e.g., privacy); we are considering games that are meant to have an educational and/or cognitive benefit—aspects which we are exploring without definitive answers yet; and that we are using games that are subject to education and psychology expert review and critique. By coming up with the concept, we extended existing taxonomies that classify single-player computer games according to genre (e.g., action, puzzle), level of interactivity, or difficulty (e.g., Apperley, 2006; Van Eck & Hung, 2010) to include categories that relate to the cognitive functions the player engages in during gaming. This method is used as part of a

☆ Mailing address for the whole team: Human Development Technologies Research Lab, Murphy Center, Neal Education Building, University of Windsor, 401 Sunset Ave., Windsor, ON N9B 3P4, Canada. Fax: +1 519 971 3694.

* Corresponding author. Tel.: +1 519 253 3000x3962; fax: +1 519 971 3694.
E-mail addresses: dragana@uwindsor.ca (D. Martinovic), cezeife@uwindsor.ca (C.I. Ezeife), rwhent@otep.com (R. Whent), jonathan@drjonathanreed.co.uk (J. Reed), jerry.burgess@canterbury.ac.uk (G.H. Burgess), pomerlec@uwindsor.ca (C.M. Pomerleau), yang111i@uwindsor.ca (Y. Yang), rituch@uwindsor.ca (R. Chaturvedi).
[1] Tel.: +1 519 253 3000x3012.
[2] Tel.: +1 519 562 1369.
[3] Tel.: +44 1 892 507625; fax: +44 1 892 507660.

0360-1315/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compedu.2013.10.017

larger research and development project[4] described in Whent et al. (2012) in which we plan to involve and evaluate children aged 6 to12 in playing computer games that we deem cognitively responsible.

Our working hypotheses in this multi-year study are that:

(a) The player's performance while playing cognitively responsible computer games may help identify his/her cognitive strengths and weaknesses;
(b) Repeated playing of games that are in the player's weaker cognitive areas will help the player improve his/her cognitive processes; and
(c) The gaming results can be used to determine further human or software intervention (e.g., recommending which other games to play; enriching day-to-day living with additional and targeted cognitive experiences).

While these hypotheses are guiding our research, in this paper we describe the groundwork that was completed in order to set a stage for addressing these and other fundamental premises, which shall inform future game developments. To summarize, our research examined the concept of game play as a cognitive development tool with possible applications for a broader audience than just children.

The literature has shown that training and learning that include purposefully selected computer games can provide players with transferable skills, support lifelong learning, and enhance their reasoning (Bottino, Ferlino, Ott, & Tavella, 2007) and digital skills (Beavis & O'Mara, 2010; Owston, Wideman, & Brown, 2009). The problem is that while millions of children play computer games daily (and often compulsively), many parents fear that their children are engaged in activities that may be detrimental to or at least ineffective for their social and cognitive development. Some parents deliberately avoid having computers at home, while others restrict access for their children out of fear that they will use computers to play games rather than for educational purposes (Dance, 2003).

While it is obvious that computer games engage players cognitively, the specifics of how gaming relates to cognitive development, the games' attributes (i.e., aspects of a game that support learning and engagement), and what is involved in the gaming activity (e.g., how the player's personality, gaming interface, and other factors interact) are far from being well understood. To support children's healthy emotional, cognitive, and learning development, Lieberman, Fisk, and Biely (2009) suggested that more research was needed to understand these areas of development in children when they play computer games. Rebetez and Betrancourt (2007) called for "an empirically based classification of games, depending on their potential effects for an educational purpose, [and for the development of] a unified research paradigm and methodologies to carry on reliable research on video games" (p. 131). Furthermore, Boyle, Connolly, and Hainey (2011) suggested that research into gaming should include psychologists who "can help in exploring and systematising the characteristics of different games and in helping to understand the different kinds of enjoyment and potential for learning linked to specific game characteristics" (p. 72).

In line with these recommendations and to alleviate misconceptions among parents and the general public about the utility of computer games, our multidisciplinary team of educators, computer scientists, and psychologists explored and systematized the characteristics of simple games available at www.DiscoveryGames.com (Whent, 2012), as well as assessing both their suitability for helping to create cognitive profiles of the players and the potential effects these games may have for improved cognition. Cognitive abilities (e.g., auditory, visual, conceptual, speed, and executive; see also Appendix A) affect one's reading, writing, doing mathematics, and communicating effectively. According to Crouse (2010), a child who is lacking in visual processing ability may have problems with mathematical calculation and reasoning as well as with writing mechanics. Remediation may be recommended in such cases, with the child playing more games in his or her weak categories, in addition to any other interventions that may be undertaken by parents, teachers, and/or psychologists.

1.1. Computer games, child cognition, and learning

Statistics Canada (2010) reported an increase in the amount of daily time Canadians spent playing video games from 1 h 48 min in 1998 to 2 h 20 min in 2010. According to Rideout, Roberts, and Foehr (2005), in the U.S., children aged 8 to10 spent more than an hour a day playing video games.

The literature, however, is not unified in its reports and analysis of the social and cognitive consequences of such trends (Martinovic, Freiman, & Karadag, 2011). On one hand, a literature review of computer games from behaviourist, cognitive, constructivist, educationist, and neuroscience perspectives (Yusoff, Crowder, Gilbert, & Wills, 2009) identified aspects of these games that supported learning and engagement, such as incremental learning, sequencing of actions, scaffolding, feedback, rewards, and learner control. Moreover, playing computer and video games has lately been recognized as a valid cognitive activity, as such play affects the player's capability to self-regulate, make right decisions, and problem solve (Bogost, 2007; Gee, 2007).

At the same time, computer games can be addictive and may overload the limited capacity of working memory in children (Tardieu & Gyselinck, 2003) and increase the risk of poor school performance (Chan & Rabinowitz, 2006). Today's children are believed to have a shorter attention span than earlier generations and to need immediate answers (Pedró, 2006), which may be a consequence of the extensive propagation of video games. Since the main features of many video games are quick reaction time (Castel, Pratt, & Drummond, 2005) and immediate feedback (Gentile, 2011), these games may reinforce the inclination towards fast, focused, and repetitive actions that result in direct and limited learning in a short time.

One documented benefit of playing computer games is improved visual intelligence (Gardner, 1983) which may be particularly relevant for subject areas where one needs to manipulate images on a screen, such as science and technology (Subrahmanyam, Kraut, Greenfield, & Gross, 2000). Computer-based games may enhance hand–eye coordination, visual scanning, auditory discrimination, and spatial skills (DeLisi & Wolford, 2002). Moreover, this emphasis on visual information processing may be connected to a significant increase in average non-verbal scores in various psychological tests across all groups tested (Subrahmanyam et al., 2000). A comparative study of children aged 10 to 11 who played two different computer games—one with strong visual content and the other text-based—showed that playing the first game improved spatial performance, while playing the second did not (Subrahmanyam & Greenfield, 1994). Repetitive game playing may

[4] This ongoing project has been funded by NSERC, OBI and FedDev, and SSHRC.