COGNITIVE DESIGN METHODS FOR COMPUTER GAMES CONTENT

J. Breslavets, and A. Horiushkina

Abstract**—**A degree in cognitive science provides the opportunity to work in many fields of human and technology. For instance, cognitive science can be used within usability and design, game development, vehicle, road safety, patient safety, technical aids, speech and dictation, technical writer and other forms of processing. Computer game enthusiasts spend many hours in the game, and this intense activity can change the brain and behavior. We consider the studies, which investigate the ability video games to change processes in spatial knowledge in this study. We will outline the initial stages research of the basic mechanisms of training, and also we will consider possible applications this new knowledge. Several experiments have shown that the game of gaming action causes changes in a number of sensory, perceptual and attention that are important for many tasks in spatial cognition**.**

Keywords— *Video game action, Spatial attention, Learning perception, Gender differences, Brain training, Sensory processes, Attentıon processes.*

I. INTRODUCTION

FUNDAMENTAL PROCESSES THAT SUPPORT SPATIAL COGNITION

FOR the most part, early efforts to explore the effects of video games on cognition focused on the relationship between play and performance on paper and pencil tests of spatial cognition. In short, the researchers approached the issue of training from a psychometric point of view. For example, in one of the early studies that studied how video game learning affects spatial cognition, Dorval and Pepin (1986) used the spatial relationship test from the Canadian version (Bennett, Seashore, Weismann, Chevrier, 1960) of the Differential tests of Aptitudes (Bennett, Seashore, & Weismann, 1947) as their measure of spatial proficiency. This test is based on the ability to identify objects hidden on the distraction.

Therefore, the test elements used by Dorval and Pepin most likely have significant requirements for spatial selective attention and spatial working memory. But the authors did not discuss their measure of spatial ability in terms of underlying sensory and perceptual processes. There was no attempt to explore or characterize the mechanisms of spatial learning. Their approach was mostly psychometric - the authors were just wondering if playing a video game would improve the spatial abilities measured by a standard paper and pencil test. Although experiments of this kind are still relevant and often useful, the focus has shifted since the pioneering experiments of green and Bavele (2003), whose studies were the first to explore how playing video games can affect the basic processes of attention. With this groundbreaking work, experimental research has focused on how video games change the basic sensory and perceptual processes that support spatial cognition (e.g. Feng et al., 2007; Green & Bavelier, 2003, 2006b, 2006c, 2007; Li, Polat, Makous, & Bavelier, 2009; Spence et al., 2009)

Video games provide a wide range of sensory, perceptive and cognitive functions. Some games require a high degree of skill when performing relatively basic perceptual and cognitive tasks, while others require higher level cognitive skills, such as the ability to solve complex logical problems. Certain genres offer more advantages for learning than others (Achtman et al., 2008). For example, Feng et al. (2007) demonstrated that participants who played a combat video game for 10 hours achieved significant performance improvements for both attention and spatial tasks, while participants who played a maze game during the same period of time did not achieve any success. Compared to other genres where there have been positive effects of learning the game on spatial skills (e.g. using dynamic puzzles such as Tetris), gaming video games seem to have a unique advantage in improving low-level features such as spatial selective attention (Fen et al., 2007; Green & Bavelier, 2003), spatial perception (Green & Bavelier, 2007), and contrast sensitivity (Li et al., 2009), in addition to more complex spatial skills such as mental rotation (Feng et al., 2007). Since fundamental sensory, perceptual, and cognitive skills serve as building blocks for higher-level cognition, the ability of action games to improve core processes has made them attractive for further experimentation.

II. COGNITIVE APPROACHES TO DESIGN COMPUTER GAMES

The human brain is the most powerful cognitive dynamic system in existence, whıch to assume for an “artificial” dynamic system the cognitive capabilities of the human brain. At the minimum it must have the capacity to perform the following tasks:

- Learning and memory;
- Planning;
- Attention;
- Interaction with the world (environment).

Explanatory Notes on the Perception-Action Cycle:

1. Perception of the Environment involves:
   - Learning and memory;
   - Attention
2. Action performed on the environment involves:
   - planning
   - Control

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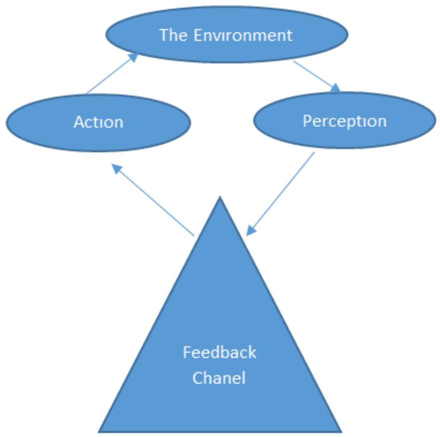

Fig. 1. The Perception-Action Cycle

1) SENSORY PROCESSES

When light hits the retina, it interacts with approximately 100 million specialized neurons (rods, cones, and other cells), causing some of them to shoot. Numerous calculations are performed at this low level of the visual processing hierarchy, and the results are transmitted to other areas of the brain through approximately 1 million fibers in the optic nerve. Further processing takes place on the way to the visual cortex and along subsequent paths between different areas of the cortex. These paths are not passive one-way streets; lower levels of computation often change in response to inputs from higher centers in the brain (Kellman & Garrigan, 2009; Rolls, 2008; Scolari & Sequences, 2009). The early visual system computes elementary functions such as brightness, edge detection, orientation detection, segmentation, shape perception, three-dimensional perception, motion detection and color processing (Palmer, 1999). These basic operations usually occur without awareness; attention is not necessarily required to ensure their completion. However, recent studies have shown that at least some of these elementary functions are modified by top-down attention-reversal processes (e.g. Gutnisky, Hansen, Iliescu, & Dragoi, 2009; Kastner & Ungerleider, 2000; Polat, 2009).

Advances in computer graphics contributed many games now to have photo-realistic three-dimensional visual environment that is much more realistic than the coarse two-dimensional setting, characteristic of the early games. This allows us to better approach our system of perception, which developed in a three-dimensional environment. As a result, the initial sensory processing of the visual environment in a modern video game takes place with a reasonable facsimile of what we see in the real world. In an FPS game, multiple visual events can occur almost simultaneously, often in widely separated locations in a visual environment. Real images of soldiers, guns, missiles, tanks, planes, ships or any other major types of combat actions can appear and disappear at any time. The first priority of the player is to quickly detect potential threats, and this requires effective scanning of the visual scene. Since the player in the game usually has unlimited freedom of exploration (360 degrees), there is a very large landscape to search for threats. So it's likely that the practice provided by the enhanced FPS game may have some positive benefit for touch processing. However, only recently has evidence been obtained to support this hypothesis. Green and Bavelier (2007) demonstrated improved visual spatial resolution after training with game action, and Li et al. (2009) showed that combat training increases contrast, the fundamental ability required for object recognition and spatial attention. For an additional comment on this rather unexpected result, See Caplovitz and Kastner (2009). Further research may reveal even greater improvement in basic sensory functions because of playing games.

2) ATTENTION PROCESSES

The visual system can't handle all the information in the light that reaches the retina. Detailed processing of this continuous data stream would impose a huge and unmanageable computational burden, and in any case such an indiscriminate procedure is not necessary. Most of the raw visual information is not important for survival or for any other relevant purpose and can be ignored. Consequently, the visual system has evolved to be sensitive primarily to changes in position, brightness or other elementary attributes of objects that may be essential for survival. Visual events that are associated with the sudden onset or a change that is especially important, as they say, "attract attention." Attention is immediately directed to the place where the sudden change occurred, for example, when a new object appeared (Yantis & Jonides, 1996). Sudden events are quickly analyzed by the brain using processes that require discrimination, identification, recognition and decision-making, and usually follow eye movements and motor actions. Despite the fact that the mechanism of attenuation capture developed in conditions and circumstances, quite different from today, it remains important. For example, it helps us to be aware of objects that are likely to travel while walking or notice approaching vehicles that may pose a danger when crossing the road. Exciting capture is also very important when playing video games

But attention grabbing is only the first stage - we have to recognize and recognize the objects that have attracted attention while excluding information that is irrelevant to the case. This is visual selective attention. Low-level processes (bottom-up) and processes associated with prior knowledge of objects and their relationships (top-down) are involved; the impact of higher-level cognitive processes is crucial. Working memory, long-term memory and Executive control functions are activated. More than a century of experiments in psychology have shown that many higher-level cognitive processes can be modified through learning (Bourne, Dominowski, & Loftus, 1979); it is therefore reasonable to assume that the practices provided by video game games can also lead to changes in the basic processes of perception and attention as they are affected by higher level cognitive processing. As we have already noted, the processing of visual information is a two-way street. While the perception of lower level provide basic data for cognitive processes of a higher level, these processes are more high level, in turn, affect the systems of perception and attention lower level (Kellman & Garrigan, 2009; Rolls, 2008; Scolari & Serences, 2009).

The player in the game has to detect, identify and track the threats appearing in various locations in a complex and often cluttered visual environment to avoid killing in the game. Thus, practicing in a game can improve the abilities of spatial selective attention, and this improvement of this basic skill can improve performance on other tasks by supporting features that depend on this ability. For example, the practice of recognizing small differences is likely to benefit the perception system as a whole. In a game, the difference between an enemy, a soldier, and a static object far away can be very subtle, especially when the character controlled by the player is moving and the view is constantly changing. To avoid a random attack on a friend and enemy, the player must quickly and accurately identify and identify these small differences while under stress to survive in a dangerous environment. Playing games from most other genres - even dynamic mazes or puzzles that require spatial skills - are unlikely to require such a high degree of skill in spatial selective attention

We can divide our attention into different objects or multiple non-contiguous locations, or we can perform multiple tasks at the same time (Cavanagh & Alvarez, 2005; Kramer & Hahn, 1995). Tracking multiple objects at the same time, visiting multiple locations, or performing two or more tasks at the same time requires sharing attention, but this sharing of attention is expensive - speed and accuracy are likely to be affected. In addition, there is a limit to the number of objects, locations, or tasks that can be present at the same time. This limited ability affects many everyday tasks; for example, using the car's navigation system while driving generally degrades performance on both tasks (Wickens & Holland, 2000). In addition to sharing attention, we can also shift attention from the current location, facility or task to another. This switch also entails costs, usually on processing speed, since it takes time to unlock and re-launch. Quick switching is usually desirable, for example, when the driver has to shift attention to the vehicle entering the intersection to avoid a collision.

In addition to the need to share attention, the dynamic and highly complex visual characteristics of certain game genres require the player to instantly switch attention from one task to another. Games expect the player to face a number of challenges that can quickly follow each other succession. Many situations require an unexpected turn of attention, such as in the case of a sudden attack, when the player's attention on the navigation task has to be paused to deal with an immediate threat. Quick focus away from the current task and quick interaction with the new task are often difficult for novice players. After a certain amount of practice with video games requiring split attention or task switching, the player's ability to share and switch attention is usually improved, and this improved ability can be carried over to support other neon tasks in the real world.

III. CONCLUSIONS

Playing video games can change the brain, perhaps more often than not (Ferguson, 2007). Playing games, in particular create improvements in sensory, perceptive and spatial cognitive functions that are different from the experience gained in the game. The size of the visual field of attention increases (Feng et al., 2007; Green

& Bavelier, 2003, 2006c; Spence et al., 2009) and other functional improvements are observed in the main spatial problems (Green & Bavelier, 2003, 2006c, 2007; Li et al., 2009) and complex spatial problems (Feng et al. 2007), in addition, improvements have been maintained for a long time (Feng et al., 2007; Li et al. In 2009; Spence et al., 2009). These results have profound scientific and educational implications. Studying the effects of playing video games is a new approach to studying long-distance transmission in the learning process and can stimulate the development of new methodologies to study the mechanisms of the brain that are responsible for these effects. Principles based on studying the role of video games in the process of modifying processes in spatial cognition may eventually revolutionize the teaching of spatial skills and concepts to children and even reduce or eliminate gender differences in spatial cognition. Improvements of this kind in basic education will have significant social and economic consequences. At the other end of the educational continuum, new methods of cognitive learning, based on video games for action, can help preserve or even improve spatial cognition as you age. Although the basic science has yet to be done, and although the basic mechanisms of the brain are still only partially understood, the study of the effects of learning computer games desıgnıng is an important and innovative way of exploring learning processes in spatial cognition.

REFERENCES

[1] Subrahmanyam, K., & Greenfield, P. (2008). Media symbol systems and cognitive processes. In S. Calvert & B. J. Wilson (Eds.), The Blackwell handbook of children, media, and development (pp. 166 –187). London: Blackwell Publishing.
[2] Terlecki, M. S., Newcombe, N. S., & Little, M. (2008). Durable and generalized effects of spatial experience on mental rotation: Gender differences in growth patterns. Applied Cognitive Psychology, 22, 996 – 1013.
[3] Haykin,-S. Cognitive Dynamic Systems Cambridge University Press, (2010). COST2102, Spain, Sept. 2009 (Haykin).
[4] McClurg, P. A., & Chaille´, C. (1987). Computer games: Environments for developing spatial cognition. Journal of Educational Computing Re- search, 3, 95–111.
[5] Green, C. S., & Bavelier, D. (2006a). The cognitive neuroscience of video games. In L. Humphreys & P. Messaris (Eds.), Digital media: Trans- formations in human communication (pp. 211–223). New York: Peter Lang Publishing.
[6] Green, C. S., & Bavelier, D. (2006b). Effect of action video games on the spatial distribution of visuospatial attention. Journal of Experimental Psychology: Human Perception and Performance, 32, 1465–1478.
[7] Green, C. S., & Bavelier, D. (2006c). Enumeration versus multiple object tracking: The case of action video game players. Cognition, 101, 217– 245.
[8] Kramer, A. F., & Hahn, S. (1995). Splitting the beam: Distribution of attention over noncontiguous regions of the visual field. Psychological Science, 6, 381–386.
[9] Lepsien, J., & Nobre, A. C. (2006). Cognitive control of attention in the human brain: Insights from orienting attention to mental representations. Brain Research, 1105, 20 –31.
[10] Maccoby, E. E., & Jacklin, C. N. (1974). Psychology of sex differences.
[11] Stanford, CA: Stanford University Press.
[12] Rolls, E. T. (2008). Top-down control of visual perception: Attention in natural vision. Perception, 37, 333–354.
[13] Universal Principles of Design, Revised and Updated, by William Lidwell, Kritina Holden & Jill Butler.

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