ISBN: 978-989-8704-08-5 © 2014

INTERACTIVE LEARNING TO STIMULATE THE BRAIN'S VISUAL CENTER AND TO ENHANCE MEMORY RETENTION

Yang H. Yun[1], Philip A. Allen[2], Kritsakorn Chaumpanich[3] and Yingcai Xiao[3]
[1]*Department of Biomedical Engineering, The University of Akron, Akron, Ohio 44325, USA*
[2]*Department of Psychology, The University of Akron, Akron, Ohio 44325, USA*
[3]*Department of Computer Science, The University of Akron, Akron, Ohio 44325, USA*

ABSTRACT

This short paper describes an ongoing NSF-funded project on enhancing science and engineering education using the latest technology. More specifically, the project aims at developing an interactive learning system with Microsoft Kinect™ and Unity3D game engine. This system promotes active, rather than passive, learning by employing embodied cognition with interactive visual/spatial information, in which human movements could impact a lasting effect on both the short-term episodic and long-term memories of students. Two groups of Biomedical Engineering students at The University of Akron participated in a study of the four educational modules (Cell, DNA, Immune System, and Gene Therapy) and were tested after the conclusion of each educational session. The preliminary results show a trend toward better performance with the system compared to traditional instruction in second-year college students. However, more studies with a larger group and with a younger population, such as K-12, need to be evaluated since these students have a less developed visuo-spatial sketchpad relative to the sophomores in college.

KEYWORDS

Interactive Learning, Visuo-Spatial Sketchpad, Natural User Interface, Embodied Cognition.

1. INTRODUCTION

When teaching educational contents that are inherently graphical in nature, research has shown that learning is more efficient when stimulating the visual component of the brain (the visuo-spatial sketchpad) as compared to the language-based approaches [1]. In the working memory model proposed by Baddeley and Hitch [2], the central executive controls the flow of information from and to the phonological loop (verbal buffer), the visuo-spatial sketchpad (visual buffer), and the episodic buffer (where context is added to short-term-memory codes for storage in long-term memory). We know that both verbal and visual codes are stored in short-term memory because we can use these two types of codes to interfere with working memory performance [2]. Because of the "video game effect," there is accumulating evidence that individuals can use visual codes to help supplement verbal-code information in short-term or working memory.

Furthermore, there is evidence that humans use "embodied cognition" to improve performance [3-5].

That is, we encode the state of the body and use it as a "somatic marker" (or contextual cue) when storing working-memory information in long-term memory [3-6]. Using these assumptions, it is predicted that visual codes and motoric feedback from movements should improve the educational outcomes in learning science and engineering information.

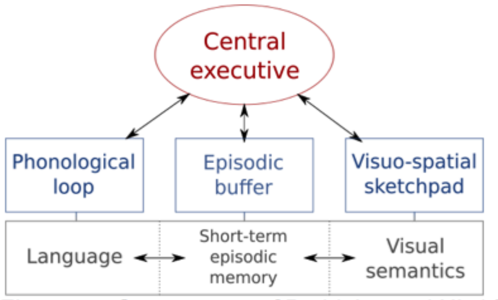

Figure 1. Components of Baddeley and Hitch's updated concept of working memory.

The goal of this project is to refocus science and engineering education by introducing a new technology that is integrated with interactive, educational content that engages, inspires, and stimulates the visual center of the brain. To accomplish these goals, a new curricula has be designed and implemented that engages students and interactively introduce visual information using the Microsoft Kinect™ device [7]. This device will be coupled to a computer system and will allow students, as an example, to actively explore a cell's anatomy and its functions using an interactive spatial interface instead of simply showing pictures with verbal descriptions. This approach also promotes active, rather than passive, learning by employing embodied cognition, where human movements could impact a lasting effect on both the short-term episodic and long-term memories of students [3-6]. In our approach, both the visual/spatial information and the motoric interactions can be stored with a memory trace of the learning event (e.g., structures and functions of an eukaryotic cell and its organelles).

We hypothesize that introducing graphical information that is designed specifically to simulate the visuo-spatial sketchpad with gestures will positively impact the students' learning and have a lasting effect on cognition and episodic memory [8-9]. Since our educational content is also designed similar to a game interface, we will also enhance the emotional states of the students which is associated with potentially better episodic memory performance for remembering events [9] as demonstrated by applications of Damasio's somatic marker hypothesis [3-5]. Thus, encoding the visual information (in visuo-spatial sketchpad), along with integrated gestures, should result in more accurate retrieval of the contextual information than will lead to more efficient learning.

2. SYSTEM DESIGN

Human gesture recognition is an important part of advancement in human-computer interaction [10]. Recent development in natural user interface (NUI) is exemplified by gesture-based interactions. Natural user interfaces are user-centric and allow people to interact with the computer in ways that are easier to learn. By eliminating the mediator of a keyboard or mouse between the user and the computer, gesture-based interactions enable the user to directly interact with the visual content on the computer. Furthermore, if the users are represented as an avatar, they will gain the sense of embodiment and be immersed into the programmed contents.

Kinect™ device is the latest natural user interface that provides real-time gesture recognition [11]. In addition to a RGB color camera, it has a depth camera, which consists of an infrared projector and an infrared sensor [12-14]. Microsoft® has developed an algorithm that utilizes these cameras to recognize human poses [15]. Furthermore, the depth information enables the system to capture gesture motions in three dimensions; therefore, Kinect™ recognizes left-right, up-down, and front-back motions [15].

In this project, we use Kinect™ to capture the motion of students and track their gestures to allow them visually interact with the education contents. We developed a set of educational contents for Biomedical Engineering and created virtual 3D objects for four learning modules: Cell, DNA, Immune System and Gene Therapy. Those virtual objects are then imported into a game engine (Unity3D [16]) for animation and display. User movements captured by Kinect™ are sent to the game engine through the application-programming interface (API) provided by (OpenNI [17] and Zigfu [18]). The students will be able to rotate the virtual objects, for example, the entire cell or its organelles. The students will also be able to zoom onto nano-sized molecules such as DNA, ribosomes, and cellular receptors. They will be able to study not only their structures but also their functions through interactive animation. They will have the control to translocate from outside of the cell into various organelles within the cells. This “first person” perspective will use embodied cognition and should import the relevant contextual information more efficiently into the student’s long-term memory. These and other features will be linked to the student’s gestures that are captured by the Kinect^{TM} system. Since these gestures are intuitive, the leaning curve to use the proposed educational modules and the hardware will be minor.

Figure 2 depicts the architecture of our Kinect^{TM} based system and figure 3 demonstrates the system in action.

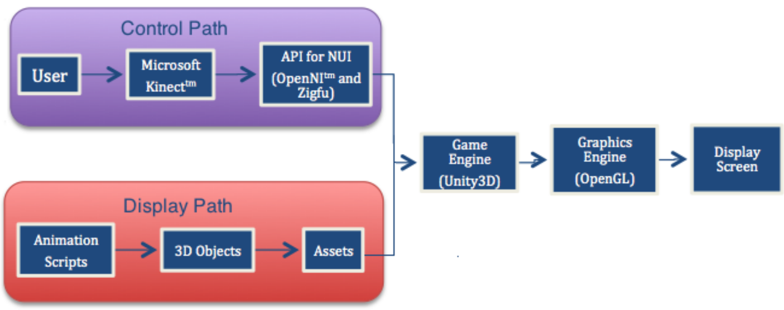

Figure 2. The architecture of the Kinect^{TM} based learning system.

Figure 3. The system in action.

3. EXPERIMENT DESIGN

An experimental goal of the project is to compare the learning outcomes for seniors and sophomores undergraduate students using traditional verses technology-enhanced (Kinect^{TM}) teaching methods in biomedical engineering courses. The rationale for this preliminary experimental design is to compare populations of students with fully developed visuo-spatial sketchpad (seniors) to a group in which this component of their brains is still under development (sophomores). Thus, seniors are more efficient in learning by visual means. The learning and understanding of educational materials related to each module will be tested. The learning and understanding of educational materials related to each module will be tested. The experimental design is given in Table 1. Students will be exposed to both the traditional techniques (through modules 2 and 3) and enhanced teaching using the Kinect^{TM} system (through modules 1 and 4). The contents for Modules 1 - 3 are focused upon biological science. In contrast, module 4 is focused upon biomedical engineering. This experimental design will allow for intragroup and intergroup comparisons. In this way, all students will be exposed to our Kinect^{TM} system. After each session, students were tested. The results for the traditional and technology-enhanced teaching methods were averaged and compared using paired t-test.

Table 1. Experiment groups tested using traditional verses enhance teaching methods.

	Seniors	Sophomores
Module 1 – Cell	Kinect^{TM}	Kinect^{TM}
Module 2 – DNA	Traditional	Traditional
Module 3 – Immune System	Traditional	Traditional
Module 4 – Gene Therapy	Kinect^{TM}	Kinect^{TM}

4. PRELIMINARY RESULTS AND FUTURE WORK

Two groups of Biomedical Engineering students at the University of Akron participated in study of the four educational modules (Cell, DNA, Immune System, and Gene Therapy) and tested after the conclusion of each educational session. We expect that seniors using the Kinect^{TM} system will not perform better with technology-enhanced teaching method, and the preliminary results show that no differences for seniors using both the Kinect^{TM} and traditional approaches (Figure 3, $p = 0.92$). For sophomores using the Kinect^{TM} system, their performance in learning is better with the technology-enhanced method, but the results were not statically different ($p = 0.49$) from the traditional method. However, a correlation exists between the Kinect^{TM} and the traditional method for this group ($p = 0.034$). With $n = 6$ and 5, respectively, for each group, we demonstrated the potential utility of the Kinect^{TM} system's ability to enhance teaching graphical information. However, more studies with a larger group and with a younger population, such as K-12, need to be evaluated since these students have a less developed visuo-spatial sketchpad relative to the sophomores in college.

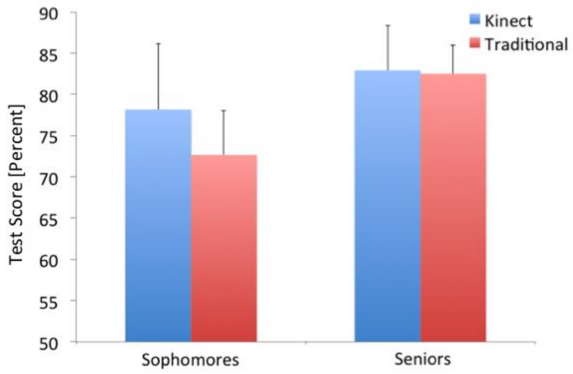

Figure 4. Results of the Kinect^{TM} and the traditional teaching methods for seniors and sophomores.

ACKNOWLEDGEMENT

This project has been supported by a grant from the National Science Foundation of the USA (ECC-1137052).

REFERENCES

1. Kraemer DJ, Rosenberg LM, Thompson-Schill SL. The neural correlates of visual and verbal cognitive styles. *J Neurosci.* 2009;29(12):3792-3798.
2. Baddeley AD, Hitch G. *Working memory.* Vol 8. New York: Academic Press, Inc.; 1974.
3. Damasio AR. *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*. London: William Heinemann; 1999.
4. Damasio AR. *Decartes' Error: Emotion, reason, and the human brain*. NewYork: G.P. Putnam's Sons; 1994.
5. Bechara A, Damasio H, Damasio AR. Emotion, decision making and the orbit of frontal cortex. *Cereb Cortex.* 2000;10(3):295-307.
6. Baddeley A. Working memory. *Science.* 1992;255(5044):556-559.
7. Sung K. Recent Videogame Console Technologies. *Computer.* 2011;44(2):91-93.
8. Allen PA, Kaut KP, Baena E, Lieu MC, Ruthruff E. Individual differences in positive affect moderate age-related declines in episodic long-term memory. *Journal of Cognitive Psychology.* In Press.

ISBN: 978-989-8704-08-5 © 2014

9. Allen PA, Kaut KP, Lord RG, Hall RJ, Grabbe JW, Bowie T. An emotional mediation theory of differential age effects in episodic and semantic memories. *Exp Aging Res.* 2005;31(4):355-391.
10. Wigdor D, Wixon D. *Brave NUI World: Designing Natural User Interfaces for Touch and Gesture*. MK Publications. 2011.
11. Kean S, Hall J, Perry P. *Meet the Kinect: An Introduction to Programming Natural User Interfaces*. Apress. 2011.
12. Wilson AD. Using a depth camera as a touch sensor. Paper presented at *ITS2010: Devices & Algorithms*, 2010; Saarbrücken, Germany.
13. Xbox. Available at: http://www.xbox.com:80/en-US/kinect.
14. Carmody T. How Motion Detection Works in Xbox Kinect. Available at: http://gizmodo.com/5681078/how-motion-detection-works-in-xbox-kinect
15. Shotton J, Fibzgibbon A, Cook M, Sharp T, Finocchio M, Moore R, Kipman A, Blake A. *Real-Time Human Pose Recognition in Parts from Single Depth Images*. Microsoft Research, Cambridge. Available at: http://research.microsoft.com/pubs/145347/BodyPartRecognition.pdf.
16. Unity3D. Available at: http://unity3d.com
17. OpenNI. Available at: http://structure.io/openni
18. Zigfu. Available at: http://zigfu.com