Ogata, H. et al. (Eds.) (2015). Proceedings of the 23rd International Conference on Computers in Education. China: Asia-Pacific Society for Computers in Education

Developing a neurofeedback-based e-book system to maintain an effective learning status

Yu-Cheng Chien[a], Chia-Hung Lai[a], Guan-Yu Chen[a], I-Wei Lu[a], Pei-Yu Cheng[a], Yueh-Min Huang[a*]

[a] *Department of Engineering Science National Cheng Kung University Tainan, Taiwan*

* huang@mail.ncku.edu.tw

Abstract: The development of e-book creates a revolutionary of knowledge dissemination and changes the way of teaching and learning. More and more studies have established that learning by e-book is an effective approach to enhance reading comprehension. On the other hand, learning is an actively processes of cognition, including attention, comprehension, perception, and organization. Past researches had been established that learner's reading attention and anxiety influenced learner's performance obviously. In tradition, it was very difficult for a teacher to maintain every student's learning status effectively. However, in recent years, the relationship between brain and education had been heeded because there was a strong correlation between them. But holding a brainwave experiment in the past was required a lot of preparations and equipment settings. Hence, this study aimed to develop a neurofeedback-based e-book system to maintain an effective learning status through improving reading attention and reducing reading anxiety. It also provided a web-based interface to help teacher to observe student's reading concentration and detect his/her learning status. Finally, an expert interview was adopted to ensure the effectiveness of neurofeedback proposed in this study. Five experts were enrolled in this interview. They stated several important suggestions of neurofeedback, e-book, teaching, and learning phase to improve this e-book system in the future.

Keywords: E-book, neurofeedback, brainwave, attention, anxiety

1. Introduction

In recent years, with the rapid development of technology, learning was no longer confined to paper-based presentation (Huang, Chen, & Mo, 2015; Huang & Chiu, 2015a, 2015b). The development of e-book not only changed the way of traditional publications, but also created a new revolutionary of knowledge dissemination. Undoubtedly, the e-books created a novel way of teaching and learning. Researchers have paid more much focus on e-books, which have become an effective pedagogical tool for educators (Huang & Liang, 2014; Liang & Huang, 2014). Meanwhile, the past studies tried to integrate e-books as knowledge vehicles and implement them into different grade schools. Korat (2010) found that reading e-book could significantly enhance the understanding of vocabulary, use of vocabulary, reading comprehension, and reading ability of preschool children. Grimshaw, Dungworth, McKnight, and Morris (2007) applied e-book with multimedia content to enhance learning motivation of elementary school students. The results indicated that the reading comprehension of students who reading e-books was significantly higher than students who reading paper books.

On the other hand, psychologists have demonstrated that learning is an actively processes of cognition, including attention, comprehension, perception, and organization (RCelsi & Olson, 1988). Attention is considered as a critical factor in cognitive processes (Kalyuga, Chandler, & Sweller, 1999; McDowd & Birren, 1990). Cimprich (1992) stated that learner's sustained attention on learning content affected learning obviously. Learner's reading ability is highly correlated with his/her reading attention (Rabiner, Malone, & Group, 2004; Savage, Cornish, Manly, & Hollis, 2006). Especially in the activities of reading digital content, providing tools or strategies to sustain learner's attention is a very important issue (Schneps, Thomson, Chen, Sonnert, & Pomplun, 2013). Learner's performance will decrease if he/she cannot sustain his/her attention. Therefore, it is necessary to observe learner's sustained attention and focus on reading content in order to improve reading comprehension and performance.

Reading anxiety influences learner's performance obviously (Saito, Garza, & Horwitz, 1999). Huang, Huang, and Wu (2014) developed a mathematics game-based learning system based on Input-Process-Outcome model to mitigate learner's anxiety. Sun (2014) adopted smartphones, which are considered with much familiar devices to college students, as pooling tools to engage learners and reduce their anxiety. Lower anxiety leads better performance (Sellers, 2000; Tsai & Li, 2012). In other words, it is effectiveness to observe and mitigate learner's anxiety in order to enhance their performance (Liu et al., 2015).

The most often approaches to detect learner's attention are based on visual sensors (Frintrop, Rome, & Christensen, 2010). Hsu, Chen, Su, Huang, and Huang (2012) developed a reading concentration monitoring system based on webcam in e-books to help teacher to detect student's reading concentration and understand his/her reading status. Furthermore, detection learner's anxiety general use questionnaire to understand student's reading anxiety.

The relationship between brain and education has been heeded in recent years (Fischer, 2009). It has a strong correlation between EEG and attention (Klimesch, Doppelmayr, Russegger, Pachinger, & Schwaiger, 1998; Loo & Makeig, 2012). On the other hand, learner's anxiety can also be estimated by brainwave (Blackhart, Minnix, & Kline, 2006). Hammond (2005) found that there had a high correlation between EEG and anxiety. Learner's attention can also be detected by brainwave (Rebolledo-Mendez & de Freitas, 2008). However, holding a brainwave experiment in the past was required a lot of preparations and equipment settings.

In order to simplify the measurement of brainwave, NeuroSky Company produced a simple, comfortable, and mobile headset device that can measure learner's attention and meditation easily (Fiolet, 2011). Chen and Huang (2014) implemented NeuroSky Headset into their attention-based self-regulated learning mechanism to enhance learner's sustained attention and promote his/her reading performance. NeuroSky Headset allows teacher to monitor a learner's attention during the learning activities.

Hence, the purpose of this study is developing a neurofeedback-based e-book system, which can provide a way of feedback to affect learner's brain state when he/her learns in e-book. Moreover, this system also provides a web-based interface to teacher. The teacher can use this interface to observe each learner's status and give appropriate tutoring. Finally, this study aims to interview two elementary school teachers and three e-book experts and improve the design of neurofeedback-based e-book system proposed in this study through their comments.

2. Research methodology

2.1 System design

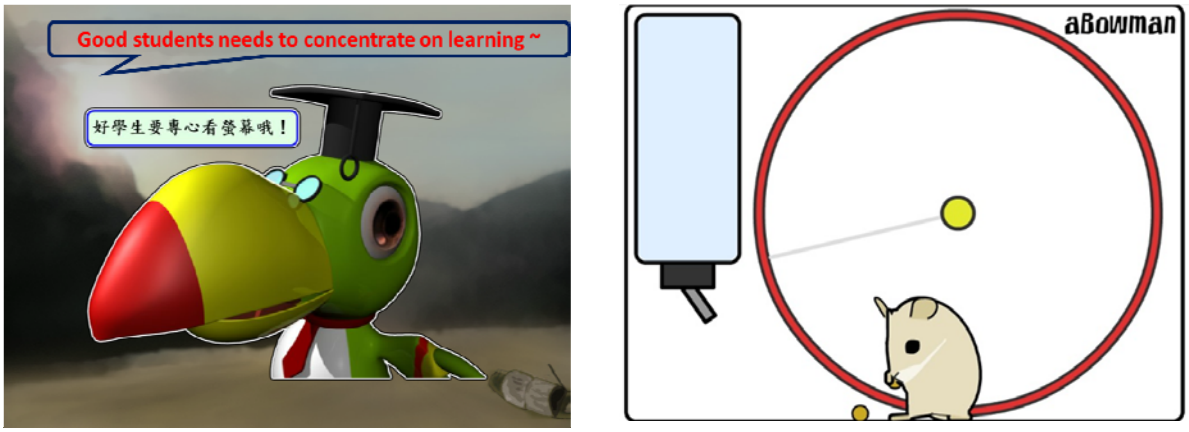
This study adopted the processes of Systems Development Life Cycle (Blanchard, Fabrycky, & Fabrycky, 1990) to develop a neurofeedback-based e-book system, which provided immediate detection and feedback to maintain an effective learning status through measuring learner's brainwave. Moreover, this system was constructed on basic functions of an e-book including text, audio, graphic, and annotation, which are shown as Figure 1.

The main aim of this system was to develop a mechanism to improve learner's reading attention and reduce his/her reading anxiety to maintain an effective learning status. Learner was asked to wear an EEG sensor when reading in e-books. Hence, a feedback technique, which was named neurofeedback, was designed based on EEG. When learner read in the neurofeedback-based e-book system, the brainwave functions were automatically activated to detect learner's attention and anxiety. The estimation period of attention was ten seconds. The measured brainwave data were transferred, stored, and analyzed in the cloud server. When learner's reading attention was detected too low, the e-book system will activate a feedback to improve his/her attention immediately (see Figure 2a). On the other hand, when learner reads difficult content and his/her reading anxiety was detected to high, this e-book system will also activate a feedback immediately. The estimation period of anxiety was thirty seconds. This feedback is a simple game, which can make learner get a short break and reduce his/her anxiety (see Figure 2b).

Moreover, in order to let teacher can observe each learner's reading status effectively, this system provided a web-based interface to illustrate learner's attention and anxiety. The brainwave data were analyzed and drawn as a dynamic graph in the teacher's interface. Teacher can understand

learner's reading status and give appropriate tutoring to enhance teaching and learning. In this interface, when learner's reading status is abnormal, the system will give a warning to teacher immediately. As shown as Figure 3, it denoted that learner's anxiety was too high.

Figure 1. The proposed e-book system.



(a) (b)

Figure 2. The proposed neurofeedback technique.

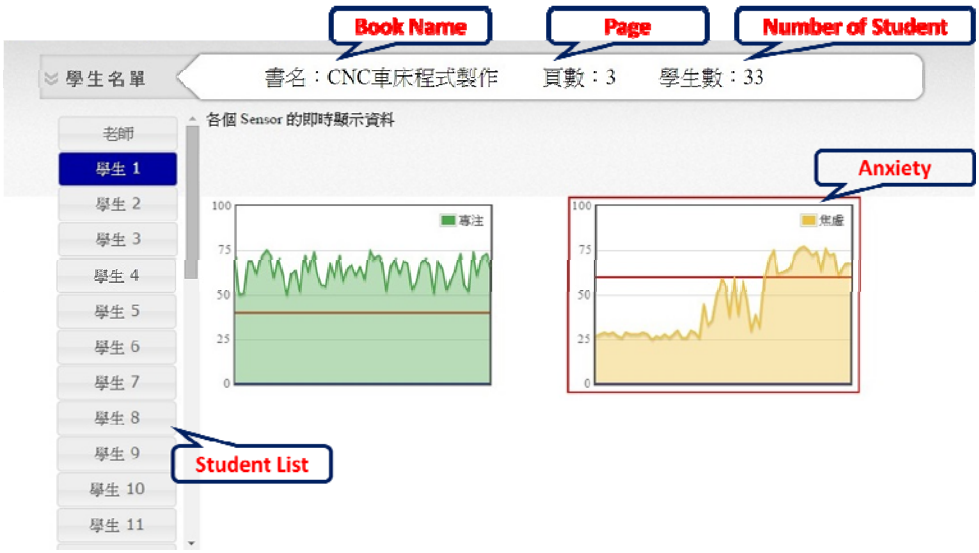


Figure 3. Students' attention and anxiety of dynamic graph.

2.2 Expert interview

In this study, the researchers developed a neurofeedback-based e-book system based on literature reviews. Finally, they focused on learner's reading attention and anxiety. Moreover, in order to ensure the effectiveness of neurofeedback-based e-book system, an expert interview was adopted. The usability of neurofeedback-based e-book system was evaluated with the K-12 grade learning stage, which was proposed by Gibson and Gibb (2011).

The expert interview was involved to confirm the usability of neurofeedback, e-book system, teaching, and learning. Totally, five experts were enrolled in this interview, including two elementary school teachers and three e-book experts in Taiwan. These two elementary school teachers have taught students using e-books more than three years, and the three e-book experts are researchers who designed, developed, and researched in e-books area more five years. The evaluating processes included the e-book system operation (20 minutes) and interview (20 minutes). They focused on observing the characteristics of this e-book system and gave suggestions to improve it. Each expert's background and teaching experience are listed in Table 1.

Table 1: Expert information.

Expert Code	Classification	Experience (years)	Teaching grade
A	Teacher	17	10
B	Teacher	14	11
C	Technologist	8	Null
D	Technologist	12	Null
E	Technologist	9	Null

3. Results & Discussions

The results of expert interview can be broadly classified into two categories. One is the summary insights of the characteristics of this e-book system from each expert, and the other one is the suggestions to this e-book system. After the evaluation of this e-book system, the five experts expressed their summary insights about the neurofeedback-based e-book system. Each expert's comments are listed as follows.

1. For the expert #A: This system can help students to monitor their reading status and support teachers to understand students' learning state. But the detection of anxiety and feedback seem that need more investigation to different high or low achieving students.
2. For the expert #B: For the feedback of reading anxiety, the simple game can make student relax in learning, but it also may lead student to addict in the game and loss learning.
3. For the expert #C: Integrating EEG technology into e-book learning system is a novel and interesting idea, it solves the problem that it is difficult to identify reading attention and anxiety.
4. For the expert #D: The detection of brainwave was accurate, but students wear the EEG sensor when reading in e-book may be a burden in learning.
5. For the expert #E: The proposed system is suggested to add some refocus functions that can help students to concentrate their attention.

In order to investigate the effectiveness of neurofeedback-based e-book system, an interview was involved to verify and improve this study. Five experts gave several important suggestions and insights to maintain the system proposed in this study. The suggestions can be arranged in four phases: neurofeedback phase, e-book phase, teaching phase, and learning phase. They are listed as follows.

1. In the neurofeedback phase, to maintain learner's attention and mitigate their anxiety through neurofeedback-based approach were meaningfulness and usefulness. However, the baseline of attention and anxiety levels to each learner was different. The experts suggested adopting some personalized approaches to detect personal attention and anxiety levels.
2. In the e-book phase, the teachers and experts considered that the neurofeedback-based e-book system could help learner to adjust his/her attention and anxiety but they hoped the system didn't disturb learner too much frequently.

3. In the teaching phase, the teachers thought that the neurofeedback-based e-book system could help them to monitor learner's state. But the teacher observed interface still was too poor. They suggested to improve the usability of the teacher observed interface.
4. In the learning phase, the teachers and experts agree this system was useful to implement into the real classroom since this system can capable to adjust learners' attention and anxiety. The past researches also indicated that enhancing learner's reading attention and reading anxiety influences learner's performance.

4. Conclusion and Future work

A neurofeedback-based e-book system was proposed in this study. Learner's attention and anxiety levels were detected by measuring his/her brainwave. And then, the results of attention and anxiety were feedbacked to learner and teacher. Learner's attention and anxiety could be adjusted by the feedback of e-book; and teacher could observe the learner's brainwave state to arrange the learning content or activities. Through the interview to the teachers and experts, they all considered that the neurofeedback-based e-book system was useful to implement into the real classroom. They also gave several important suggestions to improve this system.

However, there are still some limitations of this study. First, the device used in this study to measure learner's brainwave was too simple. It only has one channel. Its accuracy and validity may be challenged. The much powerful brainwave devices may be considered in future. Second, the principles of detecting low attention and high anxiety need to be verified. Finally, the cues of presenting the neurofeedback also need to be verified. The format and frequency of feedback is help or disturb has to be further study. Therefore, in future, we suggest designing further experiments to verify or enhance the principles and cues adopted in this study.

Acknowledgements

This research is partially supported by the "Aim for the Top University Project" and "Center of Learning Technology for Chinese" of National Taiwan Normal University (NTNU), sponsored by the Ministry of Education, Taiwan, R.O.C. and the "International Research-Intensive Center of Excellence Program" of NTNU and Ministry of Science and Technology, Taiwan, R.O.C. under Grant no. MOST 104-2911-I-003-301, MOST 103-2511-S-006-007-MY3, and MOST 103-2511-S-006-002-MY3.

References

Blackhart, G. C., Minnix, J. A., & Kline, J. P. (2006). Can EEG asymmetry patterns predict future development of anxiety and depression?: A preliminary study. *Biological psychology, 72*(1), 46-50. doi:10.1016/j.biopsycho.2005.06.010

Blanchard, B. S., Fabrycky, W. J., & Fabrycky, W. J. (1990). *Systems engineering and analysis* (Vol. 4): Prentice Hall Englewood Cliffs, New Jersey.

Chen, C. M., & Huang, S. H. (2014). Web- based reading annotation system with an attention- based self-regulated learning mechanism for promoting reading performance. *British Journal of Educational Technology, 45*(5), 959-980. doi:10.1111/bjet.12119

Cimprich, B. (1992). A theoretical perspective on attention and patient education. *Advances in Nursing Science, 14*(3), 39-51.

Fiolet, E. (2011). NeuroSky MindWave Brings Brain-Computer Interface to Education.

Fischer, K. W. (2009). Mind, Brain, and Education: Building a Scientific Groundwork for Learning and Teaching1. *Mind, Brain, and Education, 3*(1), 3-16. doi:10.1111/j.1751-228X.2008.01048.x

Frintrop, S., Rome, E., & Christensen, H. I. (2010). Computational visual attention systems and their cognitive foundations: A survey. *ACM Transactions on Applied Perception (TAP), 7*(1), 6. doi:10.1145/1658349.1658355

Gibson, C., & Gibb, F. (2011). An evaluation of second-generation ebook readers. *The Electronic Library, 29*(3), 303-319.

Grimshaw, S., Dungworth, N., McKnight, C., & Morris, A. (2007). Electronic books: Children's reading and comprehension. *British Journal of Educational Technology, 38*(4), 583-599. doi:10.1111/j.1467-8535.2006.00640.x

Hammond, D. C. (2005). Neurofeedback with anxiety and affective disorders. *Child and adolescent psychiatric clinics of North America, 14*(1), 105-123. doi:10.1016/j.chc.2004.07.008

Hsu, C.-C., Chen, H.-C., Su, Y.-N., Huang, K.-K., & Huang, Y.-M. (2012). Developing a reading concentration monitoring system by applying an artificial bee colony algorithm to e-books in an intelligent classroom. *Sensors, 12*(10), 14158-14178. doi:10.3390/s121014158

Huang, Y.-M., Chen, M.-Y., & Mo, S.-S. (2015). How do we inspire people to contact aboriginal culture with Web2. 0 technology? *Computers & Education, 86*, 71-83. doi:10.1016/j.compedu.2015.03.001

Huang, Y.-M., & Chiu, P.-S. (2015a). The effectiveness of a meaningful learning- based evaluation model for context - aware mobile learning. *British Journal of Educational Technology, 46*(2), 437-447. doi:10.1111/bjet.12147

Huang, Y.-M., & Chiu, P.-S. (2015b). The effectiveness of the meaningful learning-based evaluation for different achieving students in a ubiquitous learning context. *Computers & Education, 87*, 243-253. doi:10.1016/j.compedu.2015.06.009

Huang, Y.-M., Huang, S.-H., & Wu, T.-T. (2014). Embedding diagnostic mechanisms in a digital game for learning mathematics. *Educational Technology Research and Development, 62*(2), 187-207. doi:10.1007/s11423-013-9315-4

Huang, Y. M., & Liang, T. H. (2014). A technique for tracking the reading rate to identify the e- book reading behaviors and comprehension outcomes of elementary school students. *British Journal of Educational Technology*. doi:10.1111/bjet.12182

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing Split-attention and Redundancy in Multimedia Instruction. *Applied cognitive psychology, 13*(4), 351-371. doi:10.1002/(SICI)1099-0720(199908)13:43.0.CO;2-6

Klimesch, W., Doppelmayr, M., Russegger, H., Pachinger, T., & Schwaiger, J. (1998). Induced alpha band power changes in the human EEG and attention. *Neuroscience letters, 244*(2), 73-76. doi:10.1016/S0304-3940(98)00122-0

Korat, O. (2010). Reading electronic books as a support for vocabulary, story comprehension and word reading in kindergarten and first grade. *Computers & Education, 55*(1), 24-31. doi:10.1016/j.compedu.2009.11.014

Liang, T.-H., & Huang, Y.-M. (2014). An investigation of reading rate patterns and retrieval outcomes of elementary school students with e-books. *Journal of Educational Technology & Society, 17*(1), 218-230.

Liu, C.-J., Huang, C.-F., Liu, M.-C., Chien, Y.-C., Lai, C.-H., & Huang, Y.-M. (2015). Does Gender Influence Emotions Resulting from Positive Applause Feedback in Self-Assessment Testing? Evidence from Neuroscience. *Journal of Educational Technology & Society, 18*(1), 337-350.

Loo, S. K., & Makeig, S. (2012). Clinical utility of EEG in attention-deficit/hyperactivity disorder: a research update. *Neurotherapeutics, 9*(3), 569-587. doi:10.1007/s13311-012-0131-z

McDowd, J. M., & Birren, J. E. (1990). Aging and Attentional Processes. *Handbook of the psychology of aging, 3*, 222-233. doi:10.1016/B978-0-12-101280-9.50019-X

Rabiner, D. L., Malone, P. S., & Group, C. P. P. R. (2004). The impact of tutoring on early reading achievement for children with and without attention problems. *Journal of abnormal child psychology, 32*(3), 273-284.

RCelsi, i. L., & Olson, J. C. (1988). The Role of Involvement in Attention and Comprehension Processes. *Journal of Consumer Research, 15*(2), 210-224.

Rebolledo-Mendez, G., & de Freitas, S. (2008). *Attention modeling using inputs from a Brain Computer Interface and user-generated data in Second Life.* Paper presented at the The Tenth International Conference on Multimodal Interfaces (ICMI 2008), Crete, Greece.

Saito, Y., Garza, T. J., & Horwitz, E. K. (1999). Foreign language reading anxiety. *The modern language journal, 83*(2), 202-218. doi:10.1111/0026-7902.00016

Savage, R., Cornish, K., Manly, T., & Hollis, C. (2006). Cognitive processes in children's reading and attention: The role of working memory, divided attention, and response inhibition. *British Journal of Psychology, 97*(3), 365-385.

Schneps, M. H., Thomson, J. M., Chen, C., Sonnert, G., & Pomplun, M. (2013). E-readers are more effective than paper for some with dyslexia. *PloS one, 8*(9), e75634.

Sellers, V. D. (2000). Anxiety and reading comprehension in Spanish as a foreign language. *Foreign Language Annals, 33*(5), 512-520. doi:10.1111/j.1944-9720.2000.tb01995.x

Sun, J. C.-Y. (2014). Influence of polling technologies on student engagement: An analysis of student motivation, academic performance, and brainwave data. *Computers & Education, 72*, 80-89. doi:10.1016/j.compedu.2013.10.010

Tsai, Y.-C., & Li, Y.-C. (2012). Test anxiety and foreign language reading anxiety in a reading-proficiency test. *Journal of Social Sciences, 8*(1), 95-103.