Development of Brain Training Games for a Healthcare Service Robot for Older People

Ho Seok Ahn[1], Mary Pauline Grace Santos[2],
Charu Wadhwa[3], and Bruce MacDonald[4]

Department of Electrical and Computer Engineering, CARES, University of Auckland, Auckland, New Zealand
{hs.ahn,b.macdonald,msan065,cwad018}@auckland.ac.nz

Abstract. Many people suffer from memory loss as they get older. This may lead to severe memory conditions, where everyday communication and activities for a person become much more difficult and independent living is a challenge. Brain training is one therapeutic method for people who are concerned about brain function decline. We previously found that brain training games are helpful and enjoyable for older people. In this paper, we describe the development of new computer-based brain training games based on paper-based brain training exercises created by experts on brain function. We develop four games targeting specific areas of memory, prospective memory, face recognition skills, verbal memory, and short-term memory. These games are deployed on our healthcare service robot, which is used in an individual home environment. We report a usability study with older adults to evaluate our brain training games on a healthcare service robot. Results show the games are usable and people responded positively about them, and some improvements were identified for future development.

Keywords: Brain training game, healthcare robot system, caring of older people, healthcare service, therapeutic method.

1 Introduction

Recently, the older population growth is faster than that of young people [1-2]. Some older people may suffer memory loss, a common example being memory lapses that occur almost every day as people age [3] and hinder a person's ability to remember and recall, an example being trying to remember a loved one's name. A person's concentration, memory and judgment slowly deteriorate, affecting their ability to do daily tasks, making independent living difficult for those affected [4]. Some researchers report that exercising cognitive functions mitigates cognitive decline [5]. Researchers and companies have been developing brain fitness games to exercise cognitive functions. Lumosity is a web based brain fitness application [6]. Most users of Lumosity are between the ages of 25-34; an age group that is unlikely to be affected by cognitive issues [7]. Anti-Aging is another brain training website and their games are designed to exercise and help improve memory [8]. They focus on people

M. Beetz et al. (Eds.): ICSR 2014, LNAI 8755, pp. 1–10, 2014.

who are over 35 years of age, not people with severe brain disorders. Unlike other games, Dakim Brain Fitness is a software program dedicated for users over the age of 60 and focuses on people with a variety of cognitive conditions [9-10].

In our previous research, we designed assistant robots for older people, which provide companionship as well healthcare support. We conducted several studies in the initial design and testing stages. We focused on how effective a healthcare robot is, which functions are useful, what are the important factors for healthcare robot systems, and the differences in various places and people, and found that robots are acceptable to older people [2, 11-30]. Our healthcare robots have several service applications that include a medication reminding function, a caregiver service to guide how to measure vital signs, a video chatting service with medical staff as well as family members, entertainment services to play videos and music [21]. We installed Dakim's Brain Fitness game on our healthcare robots, and older people enjoyed playing the game with the robot. Fig. 1 shows our healthcare robots with users. However some brain training software is not clearly visible on the small screens of some robots, for example on the right in Fig. 1, which is particularly important for older people who may suffer some decline in vision.

In this paper, we introduce new brain training games that are deployed on our healthcare robots, are based on clinical established brain training concepts, and are suitable for smaller screens. Dr. Allison Lamont and Gillian Eadie, founders of the Brain and Memory Foundation and the Healthy Memory Company, created paper-based brain training exercises that exercise the six key areas of memory: working memory, verbal memory, non-verbal memory, short-term memory, face recognition and prospective memory [31], and two initial software prototypes for computer games. We have developed four computer games for brain training since 2012, based on the paper-based exercises and initial software. We plan to develop two more games next year. We considered the requests and feedback from the experts (Dr Lamont and Ms. Eadie) of the paper-based brain training exercises when we designed and developed the games.

Fig. 1. Our healthcare robot systems; a nursing assistant robot system in the hospital environment (left) and a personal healthcare service robot system in the individual home environment (right)

This paper is organized as follows. In Section 2, we introduce the computer version of four brain training games. In Section 3, we present experiments and evaluations. Finally, we conclude this paper in Section 4.

2 Brain Training Games

We have chosen four brain training games from the six paper-based brain training exercises according to the advice of experts. Each brain training game targets a specific area of memory as follows.

- Night at the Movies: Prospective memory
- Cross the Bridge: Short-term memory
- Shopping Spree: Verbal memory
- Wild West Hunt: Face recognition skills

We took advice from the experts regarding the requirements for the software design, in order to maximize the therapeutic effect of the game and minimize divergence of the game from the memory theory behind the paper based exercises, which can occur during the agile, iterative software development process we used. For example, there should be 8-10 levels of increasing difficulty in each game. The difficulty for each level should slowly increase, and the next level can only be unlocked once the previous level has been completed. Hints should be provided to improve performance in each level and feedback is provided on the performance of the user in every level. Instructions on how to play games and information about brain function should be displayed at the start of each game. Sound effects should be heard depending on whether the user passes or fails at each level. The developed game should be deployable on a robot. The Graphical User Interface or the look and feel of the game should be simple and attractive for the 50-70 age group. It should function smoothly without failures or faults. Our robots interact by touch screen input, speech and audio output, so the games should enable touch screen inputs and provide audio output in addition to the screen display; there is no keyboard or mouse input.

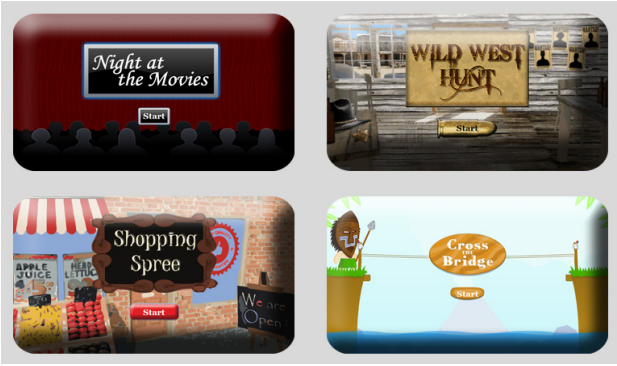

Fig. 2. The main page of the brain training game. It shows four different games and users can start any game as well as re-select games after coming back to this page.

Fig. 2 shows the four developed brain training games. When the user executes the applications through the healthcare software on the robot, it shows the main page where a game can be selected. It is possible to go back to the main page, restart the same game again, and start different games. When each game is started, it shows information about the intended memory therapy effect and instructions. Each game has 10 different levels, and the next level is unlocked if the user clears the current level.

2.1 Night at the Movies

Night at the Movies is a game that strengthens a person's prospective memory, which is related to the ability to remember something in the future, for example, doctor appointments, birthdays, etc. The game works by having the users remember certain parts of a movie clip, indicated by a star, and being able to recall these parts when the video clip is played back the second time. At each level, star timings were randomized by splitting the duration of the clip depending on the number of stars for the level. Users should click the right timing when stars were shown, to succeed in playing the game. Fig. 3 shows sample screenshots of Night at the Movies.

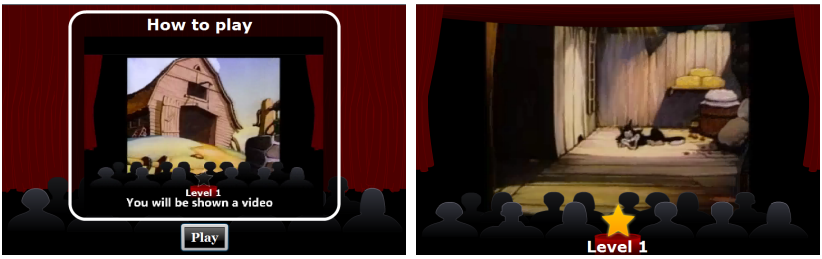

Fig. 3. Screenshots of Night at the Movies; users learn how to play this game from the instructions (left) and should remember the timing star is bright (right)

2.2 Cross the Bridge

Cross the Bridge is a game that strengthens a person's short-term memory. The game works by having the users remember a bridge pattern, consisting of a number of various colored blocks. Users need to reconstruct the bridge correctly, so that the person crossing the bridge will not fall into the water. The array of blocks on the bridge is randomly generated and the numbers of blocks is increased as level increases. Fig. 4 shows screenshots of Cross the Bridge.

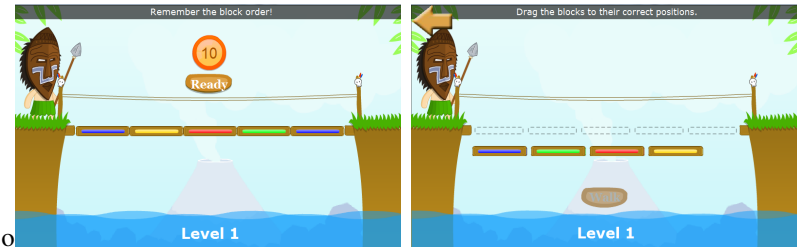

Fig. 4. Screenshots of Cross the Bridge; users should remember the color of blocks on the bridge (left) and drag and drop the correct blocks (right)

2.3 Shopping Spree

Shopping Spree is a game that strengthens a person's verbal memory, which is related to the ability to remember people's names, memorable locations, etc. The game works by having the user remember a written list of items in a shopping list. Users need to correctly identify and select items given in the list, from a shelf of items provided. The shopping list and item placement on shelves are randomly generated and the numbers of items are increased as level goes up. Fig. 5 shows screenshots of Shopping Spree.

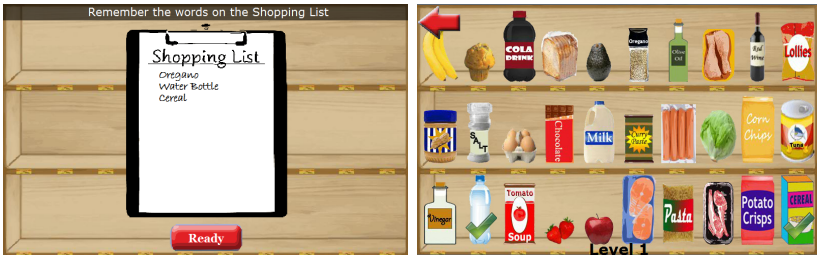

Fig. 5. Screenshots of Shopping Spree; users should remember the shopping list (left) and select the correct items (right)

2.4 Wild West Hunt

Wild West Hunt is a game that strengthens a person's face recognition skills based on features of faces. The game works by having the users remember a cartoon criminal face. Users need to identify the criminal from a line-up of cartoon faces. The criminal and a line-up of cartoon faces are randomly generated and the number of faces is increased as level goes up. Fig. 6 shows screenshots of Wild West Hunt.

Fig. 6. Screenshots of Wild West Hunt; users should remember the cartoon face (left) and select the correct face (right).

3 Experiments and Evaluations

3.1 Overview of Study

We deployed the developed four brain training games on our healthcare service robot iRobiS, shown in Fig. 1 (right), from Yujin robotics in South Korea. It is small

enough to take hold with one hand, in size measuring 45x32x32cm and weigh 7kg [21]. It has an Intel Atom processor based internal computer. Physically, it has two arms, which are used mainly for getting attention, indicating emotions and gesturing. It is also equipped with a number of touch sensors at different locations on its body. This enables the programming of realistic responses when users pat, tap, touch, or nudge the robot. Especially, as it has a 7 inch touchscreen on its body, it is useful to play a game without external input devices. The games were developed by authors Santos and Wadhwa using the Adobe Flex environment which is used by our software framework for the iRobiS, and is suitable for creating animated graphical content.

We undertook two kinds of evaluation; one is a usability study for evaluating the overall design of the games, and the other is analyzing of task completion rate of each game. Prior to the study, we obtained ethics approval from the Ethics committee at the University of Auckland. We advertised for participants for this study, and a total of 10 participants were recruited between the ages of 50 - 70 who lived independently. The participants were required to carry out pre-defined tasks, such as navigating to the instruction screen, completing the first and second levels of all four games. Following the completion of the specified tasks, each participant was given a questionnaire to fill out. Table 1 shows the questionnaire for this study.

Table 1. Instructions and Wording of the brain training game Questionnaire

Scale instructions	Strongly Disagree				Strongly agree
Q1) The games have a similar look and feel	1	2	3	4	5
Q2) The navigation between the different screens is smooth	1	2	3	4	5
Q3) The color scheme is appealing for each of the games	1	2	3	4	5
Q4) The text can be clearly read for each of the games	1	2	3	4	5
Q5) The games are intuitive and simple in nature	1	2	3	4	5
Q6) The difficulty level of the games increases gradually	1	2	3	4	5
Q7) The games are fun and maintain the user's interest	1	2	3	4	5

3.2 Experimental Results

Fig. 7 shows the results of the usability study. Each participant's response was scaled from 1 to 5 for the agree/disagree statements and the sum of each response is the total rating for a particular aspect of the games. From the results, it is evident that smooth navigation between screens (Q1), text readability (Q4) and fun and maintain user's

interest (Q7) were the strengths of the application whereas, the games not having a similar look and feel (Q1) was a weakness. A possible reason for this weakness may be that each game targets different areas of the memory and the theme of each game is quite different. Participants enjoyed playing games, and were satisfied about the performance of the game.

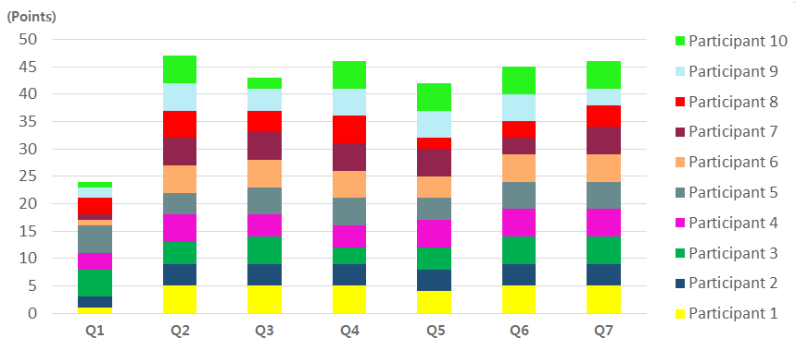

Fig. 7. The result of usability study of brain training games; sum of participants' responses scaled between 1 and 5 based on the questionnaire shown in Table 1

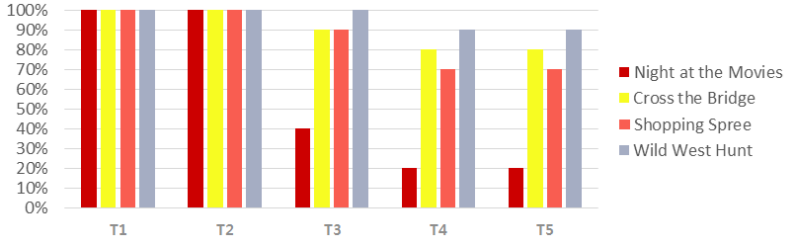

Fig. 8. The result of task completion analysis of brain training games. We used the log data of the usability study. T1: navigation to brain screen, T2: navigation to instruction screen, T3: passing of the first level, T4: passing of the second level, T5: reattempt of the first level.

We analyzed the task completion rate of each brain training game using the log data of the usability study. We analyzed five items; navigation to the brain and instruction screen, passing of the first and second level, and reattempts of the first level. Fig. 8 shows the results. None of the participants had any problem navigating to the brain and instruction screen in any of the four brain training games. There were different results on passing the first and second level in the four brain training games. The passing rate of all games was decreased when participants did the second level. It means that the level of difficulty increased well as the levels go higher, which is one of the design requirements.

The passing rate of each game was quite different. Wild West Hunt had the highest passing rate: 100% for the first level and 90% for the second level, which means that only one participant failed to clear the second level. Whereas, Night at the Movies

had the lowest passing rate: 40% for the first level and 20% for the second level, which means that only two participants succeeded to clear the second level of Night at the Movies. A potential reason for this could be that Night at the Movies requires participants to multitask by watching the video, processing auditory and visual information, and guessing the appearances of stars. The reattempt rate of the first level shows similar patterns to the passing rate of the four brain training games. From the analysis of results, we can consider that participants tended to enjoy easier games again rather than a difficult game. As brain training games are used for therapeutic purposes, it is important to increase the reattempt times, therefore we need to adjust the difficulty of Night at the Movies. We carried out this study with only 10 participants, which is not enough for evaluating the usability of our brain training game in significant detail. We will undertake a larger study shortly.

4 Conclusions

Older adults suffer from memory decline, which is an important brain function for everyday communication and activities. As one of the methods to mitigate the slow progression of memory loss, various brain training games are used, and we used one commercial brain game for our research. We applied it on our healthcare service robots, and found that brain training games are a good application for the elderly. However this software did not present well on small screens of smaller robots. Therefore, we developed a computer version of brain training games based on paper-based brain training exercises, which were created by Dr. Allison Lamont and Gillian Eadie. These paper-based brain training exercises help improve the six key areas of memory: working memory, verbal memory, non-verbal memory, short-term memory, face recognition and prospective memory.

Among them, we selected four exercises and developed software versions of them on the advice of experts: Night at the Movies related to prospective memory, Cross the Bridge related to short-term memory, Shopping Spree related to verbal memory, and Wild West Hunt related to face recognition skills. We designed the games by considering the requests from the experts of the paper-based brain training exercises. We applied the developed brain training games on our healthcare service robot. We conducted a usability study to evaluate our four brain training games with 10 participants between the ages of 50 - 70 who live independently. Another aim was to find any inconsistencies in the design of the games. From the results, we confirmed that our brain training games are well designed and developed for the elderly and the healthcare robot system. Participants had fun with the games and robot, but Night at the Movies had failed to give interest and suffered an increase in the number of reattempt times due to its difficulty. Therefore, we need to adjust the difficulty of Night at the Movies in the future. We will also conduct more usability studies to find any differences for conditions such as age, gender, and cultural background. We will also develop two more games, which are related to working memory and non-verbal memory, and apply them on various platforms such as tablets and web applications. Once the software usability is improved we plan to study the effectiveness of the games for promoting memory function.

References

1. Lutz, W., Sanderson, W., Scherbov, S.: The coming acceleration of global population ageing. Nature 451(7179), 716–719 (2008)
2. Ahn, H.S., MacDonald, B.A., Kuo, I.-H., Datta, C., Stafford, R., Kerse, N., Peri, K., Broadbent, E.: Design of a Kiosk Type Healthcare Robot System for Older People in Private and Public Places. In: International Conference on Simulation, Modeling, and Programming for Autonomous Robots (2014)
3. Smith, M., Robinson, L., Segal, R.: Last Age-Related Memory Loss, helpguide.org (2013), http://www.helpguide.org/life/prevent_memory_loss.htm
4. Robinson, H., MacDonald, B.A., Kerse, N., Broadbent, E.: Suitability of Healthcare Robots for a Dementia Unit and Suggested Improvements. Journal of the American Medical Directors Association 14(1), 34–40 (2013)
5. Willis, S.L., Tennstedt, S.L., Marsiske, M., Ball, K., Elias, J., Koepke, K.M., Morris, J.N., Rebok, G.W., Unverzagt, F.W., Stoddard, A.M., Wright, E.: Long-term effects of cognitive training on everyday functional outcomes in older adults. Journal of the American Medical Association 296, 2805–2814 (2006)
6. http://www.lumosity.com
7. Alban, D.: Lumosity Brain Training Program (2012), http://bebrainfit.com/lifestyle/mental/lumosity-brain-training-program/
8. http://www.anti-aginggames.com/games.html
9. Alban, D.: Brain Training Programs Compared - Which Is Right for You? (2013), http://bebrainfit.com/lifestyle/mental/brain-training-programs-compared-which-is-right-for-you/
10. http://www.dakim.com
11. Robinson, H., MacDonald, B.A., Kerse, N., Broadbent, E.: The Psychosocial Effects of a Companion Robot: A Randomized Controlled Trial. Journal of the American Medical Directors Association 14(9), 661–667 (2013)
12. Kuo, I.H., Rabindran, J.M., Broadbent, E., Lee, Y.I., Kerse, N., Stafford, R.M.Q., MacDonald, B.A.: Age and gender factors in user acceptance of healthcare robots. In: IEEE International Symposium on Robot and Human Interactive Communication (ROMAN 2009), pp. 214–219 (2009)
13. Broadbent, E., Tamagawa, R., Kerse, N., Knock, B., Patience, A., MacDonald, B.: Retirement home staff and residents' preferences for healthcare robots. In: IEEE International Symposium on Robot and Human Interactive Communication (ROMAN 2009), pp. 645–650 (2009)
14. Stafford, R.Q., Broadbent, E., Jayawardena, C., Unger, U., Kuo, I.H., Igic, A., Wong, R., Kerse, N., Watson, C., MacDonald, B.A.: Improved robot attitudes and emotions at a retirement home after meeting a robot. In: IEEE International Symposium on Robot and Human Interactive Communication, pp. 82–87 (2010)
15. Jayawardena, C., Kuo, I., Datta, C., Stafford, R.Q., Broadbent, E., MacDonald, B.A.: Design, implementation and field tests of a socially assistive robot for the elderly: HealthBot Version 2. In: RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics, pp. 1837–1842 (2012)
16. Broadbent, E., Tamagawa, R., Patience, A., Knock, B., Kerse, N., Day, K., MacDonald, B.A.: Attitudes towards health care robots in a retirement village. Australasian Journal on Ageing 31(2), 115–120 (2012)
17. Ahn, H.S., Choi, J.Y.: Can We Teach What Emotions a Robot should Express? In: IEEE International Conference on Intelligent Robots and Systems, pp. 1407–1412 (2012)

18. Ahn, H.S., Lee, D.-W., Choi, D., Lee, D.-Y., Hur, M., Lee, H.: Uses of Facial Expressions of Android Head System according to Gender and Age. In: IEEE International Conference on Systems, Man, and Cybernetics, pp. 2300–2305 (2012)
19. Ahn, H.S., Lee, D.-W., Choi, D., Lee, D.-Y., Hur, M., Lee, H.: Appropriate Emotions for Facial Expressions of 33-DOFs Android Head EveR-4 H33. In: IEEE International Symposium on Robot and Human Interactive Communication, pp. 1115–1120 (2012)
20. Ahn, H.S., Lee, D.-W., Choi, D., Lee, D.-Y., Hur, M., Lee, H.: Difference of Efficiency in Human-Robot Interaction According to Condition of Experimental Environment. In: Ge, S.S., Khatib, O., Cabibihan, J.-J., Simmons, R., Williams, M.-A. (eds.) ICSR 2012. LNCS, vol. 7621, pp. 219–227. Springer, Heidelberg (2012)
21. Datta, C., Yang, H.Y., Kuo, I.-H., Broadbent, E., MacDonald, B.A.: Software platform design for personal service robots in healthcare. In: IEEE International Conference on Robotics, Automation and Mechatronics, pp. 156–161 (2013)
22. Ahn, H.S., Choi, J.Y., Lee, D.-W., Shon, W.H.: A Behavior Combination Generating Method for Reflecting Emotional Probabilities using Simulated Annealing Algorithm. In: IEEE International Symposium on Robot and Human Interactive Communication, pp. 192–197 (2011)
23. Stafford, R.Q., MacDonald, B.A., Jayawardena, C., Wegner, D.M., Broadbent, E.: Does the Robot Have a Mind? Mind Perception and Attitudes Towards Robots Predict Use of an Eldercare Robot. International Journal of Social Robotics 6(1), 17–32 (2014)
24. Ahn, H.S.: Designing of a Personality based Emotional Decision Model for Generating Various Emotional Behavior of Social Robots. Advances in Human-Computer Interaction 2014, 1–14 (2014)
25. Ahn, H.S., Lee, D.-W., Choi, D., Lee, D.-Y., Lee, H., Baeg, M.-H.: Development of an Incarnate Announcing Robot System using Emotional Interaction with Humans. International Journal of Humanoid Robotics 10(2), 1–24 (2013)
26. Kuo, C.J.-H., Broadbent, E., MacDonald, B.A.: Socially Assistive Robot HealthBot: Design, Implementation, and Field Trials. IEEE Systems Journal (2014)
27. Ahn, H.S., Sa, I.-K., Lee, D.-W., Choi, D.: A Playmate Robot System for Playing the Rock-Paper-Scissors Game with Humans. Artificial Life and Robotics 16(2), 142–146 (2011)
28. Lee, D., Ahn, H.S., Choi, J.Y.: A General Behavior Generation Module for Emotional Robots Using Unit Behavior Combination Method. In: IEEE International Symposium on Robot and Human Interactive Communication, pp. 375–380 (2009)
29. Broadbent, E., et al.: Benefits and dis-benefits of healthcare robots in a retirement village: A comparison trial. Australasian Journal on Ageing (2014)
30. Ahn, H.S., Choi, J.Y., Lee, D.-W., Shon, W.H.: Natural Changing of Emotional Expression by Considering Correlation of Behavior History. In: IEEE International Symposium on Consumer Electronics, pp. 369–372 (2011)
31. http://www.brainfit.co.nz