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Computer-Based Cognitive Retraining for Adults with Chronic Acquired Brain Injury: A Pilot Study

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Abstract

This study evaluated the effectiveness of a computer-based cognitive retraining (CBCR) program on improving memory and attention deficits in individuals with a chronic acquired brain injury (ABI). Twelve adults with a chronic ABI demonstrating deficits in memory and attention were recruited from a convenience sample from the community. Using a quasi-experimental one-group pretest-posttest design, a significant improvement was found in both memory and attention scores post-intervention using the cogntive screening tool. This study supported the effectiveness of CBCR programs in improving cognitive deficits in memory and attention in individuals with chronic ABI. Further research is recommended to validate these findings with a larger ABI population and to investigate transfer to improvement in occupational performance that supports daily living skills.

Key Words: *attention, stroke, cerebrovascular accident, cognitive rehabilitation, memory, computer-based intervention, traumatic brain injury*

Introduction

An acquired brain injury (ABI) is an insult to the brain that has occurred after birth, is not hereditary or degenerative, and is often referred to as a "silent" and "invisible" disability (Brain Injury Association of America, 2011). The majority of ABIs are caused by ischemic or hemorrhagic cerebrovascular accident, or trauma induced to the head (Holmqvist, Kamwendo & Ivarsson, 2009). An ABI is considered to be chronic when the resulting cognitive deficits persist after the individual is medically stable. Depending on the location and severity of the brain injury, individuals can exhibit various cognitive deficits that affect cognitive functioning (Holmqvist et al, 2009; Tsaousides & Gordon, 2009). Impairments commonly seen in individuals with chronic ABI vary greatly and include memory deficit, decreased attention, visual impairment, language impairment, and executive function deficit (Ellingsen & Aas, 2009; Handratta, Hsu, Vento, Yang, & Taney, 2010). The occupations, roles, and overall quality of life of individuals with chronic ABI are affected by the deficits they sustained as a result of the injury.

As ABI often results in damaged brain matter, which alters an individual's physical and cognitive functioning, it is possible impairments can be improved utilizing the concept of neuroplasticity. Neuroplasticity, the brain's ability to create, strengthen, and modify neurological connections, allows individuals to learn new knowledge and establish new skills (Defina et al., 2009; Fisher, Holland, Merzenich, & Vinogradov, 2009; Green & Bavelier, 2008). The basic view of neuroplasticity arises from the dynamicity of the cortical presentation in response to environmental demands (Buonomano & Merzenich, 1998; Green & Bavelier, 2008). Given appropriate task repetitions and increasingly complex environmental demands, literature supports learning-induced neuroplastic change (Green & Bavelier, 2008; Kimberley, Samargia, Moore, Shakya & Lang, 2010). Furthermore, individuals undergoing rehabilitation following a brain injury not only can modify their neural connections, but also can lead to functional relearning (Kimberley et al., 2010). To achieve functional relearning, clinicians use both cognitive compensatory and remedial interventions. While cognitive compensatory interventions include internal and external strategies training, cognitive remedial interventions such as computer-based cognitive retraining (CBCR) exercises address cognitive deficits in the areas of memory, attention, language function, executive function, visual and visuospatial functioning.

Cognitive rehabilitation is a specialized process tailored to address specific cognitive impairments. The primary goals of cognitive rehabilitation are to improve the individual's ability to process, interpret, and respond to environmental stimuli, and to facilitate appropriate functional outcomes (Friere et al., 2011). The remediation approach in cognitive rehabilitation "focuses on reinforcing, strengthening, or restoring functions that remain partially intact" (Emergency Care Research Institute, 2011, p.2). Utilizing the concept of neuroplasticity, the remedial approach is put into practice by designing interventions that facilitate neural connections needed for functional skill development.

The Cognitive Rehabilitation Task Force of the American Congress of Rehabilitation Medicine Brain Injury Interdisciplinary Special Interest Group completed two reviews of the literature, from 1998 to 2002 and from 2003 to 2008, in search of evidence for cognitive rehabilitation (Cicerone et al., 2005; Cicerone et al., 2011). In their earlier review, they concluded that cognitive rehabilitation for traumatic brain injury (TBI), in general, should be restricted to those individuals with mild memory and post-acute attention deficits (Cicerone et al., 2005). Rohling, Faust, Beverly & Demakis (2009) further examined the literature reviewed by Cicerone et al. (2005) and found that attention rehabilitation had stronger treatment effects in individuals with stroke who were less than 1-year post-injury, but not in those with TBI or longer than 1-year post-injury. Overall, there was only a modest treatment effect on global cognitive function for individuals with TBI when using attention rehabilitation (Rohling et al., 2009). The second review on the literature from 2003 to 2008 yielded additional recommendations. For post-acute rehabilitation after TBI, Cicerone et al. (2011) concluded evidence that benefited the use of direct attention training and metacognitive training as compensatory interventions for attention deficits. They also recommended the use of internal strategies and external devices as a standard for practice with individuals with TBI who have mild memory impairments, and the use of external compensations directly applicable to specific functional tasks as a guideline in practice for those who have severe memory deficits after TBI or stroke (Cicerone et al., 2011).

Similarly, the Cochrone Stroke Group included six randomized controlled trials in cognitive rehabilitation to study its effect on attention deficits for individuals with stroke (Loetscher & Lincoln, 2013). Their results indicated that although cognitive rehabilitation might bring about a short-term improvement in divided attention, the long-term effect remained unconfirmed (Loestscher & Lincoln, 2013). Another review from the Cochrone Stroke Group by das Nair and Lincoln (2007) also concluded that there was no evidence to support the effectiveness of cognitive rehabilitation in remediating memory deficits for individuals after stroke. As for the TBI population, there was only low evidence in support of a comprehensive cognitive rehabilitation program that might improve quality of life (ECRI, 2011).

One form of remedial cognitive rehabilitation uses CBCR software to restore cognitive abilities and allows an individual to improve the cognitive skills needed to "successfully and accurately receive sensory input, process information, and act in as independently and appropriately a manner as possible" (Tam & Man, 2004, p.461). CBCR is readily available to the general public and offers stimulating, tailored programs that can be modified to the individual's progress (Kirch et al., 2004). In recent years, there has been much literature on CBCR but many of these studies were with the elderly; individuals with Alzheimer's or other neurodegenerative conditions; or individuals with affective disorders or schizophrenia. Only a paucity of research is available showing that CBCR is an effective intervention for improving cognitive deficits in attention and memory for adults with chronic ABI. Additionally, available studies have shown opposing results. One of the studies conducted by Batchelor et al. (1988) demonstrated that CBCR was not more beneficial for cognitive retraining than non computer-based intervention strategies for individuals with severe closed-head injuries. Similarly, a pilot randomized control trial conducted by Barnes et al. (2009) did not find clinical significance improvement in the cognition of the participants in using Posit Science brain training software (Posit Science Corporation, San Francisco, CA)when compared with other computer-based activities.

Conversely, several studies have shown that computer-based training program can be effective in improving working memory and attention skills in individuals with ABI. Westerberg et al. (2007) reported that using a computerized training program for five weeks improved working memory and attention, as well as self-rated cognitive symptoms in a group of participants one to three years post-stroke. Lundqvist, Grundstrom, Samuelsson, and Ronnberg (2010) also reported similar results. Using a crossover design to examine the short- and long-term effects of computerized verbal working memory training, Lindqvist et al. (2010) concluded that CBCR had immediate and lasting effects on the participants' verbal working memory skill and the improvements also supported overall self-rated health 20 weeks after completing the training. In a meta-analysis updating the evidence in cognitive rehabilitation, Cicerone et al.

(2011) recommended the use of computer-based intervention as a practice option, adjunctive to clinician-guided intervention, in the remediation of attention deficits for the individuals with TBI and stroke.

In sum, the effectiveness of the remediation of attention and memory in cognitive rehabilitation and the use of CBCR as a standalone remediation intervention for individuals with chronic ABI remain controveries. The purpose of our study was to determine the effectiveness of a commerically available CBCR program, the Parrot Software (Parrot Software, West Bloomfield, MI), in improving memory and attention for these individuals. Our two hypotheses for the study stated that the CBCR program a) would improve memory and b) would improve attention for individuals with chronic ABI.

Methods

Study Design

This study employed a quantitative quasi-experimental one-group pretest-posttest design. The use of the pretest-posttest design determined any correlational relationships between the CBCR program and participants' improvement in attention and memory.

Participants

The study utilized a convenience sample of 12 English-speaking, community-dwelling adults who sustained an ABI two or more years prior to the study. Participants were recruited via referrals from local neurologists, neuropsychologists, and self-referrals through Craigslist advertisements, flier distributions, and e-mail blast announcements to the Dominican University of Califronia and Brain Injury Network of the Bay Area (BINBA) communities. All screening meetings and interventions were conducted at the BINBA, a non-profit organization dedicated to providing a variety of support services to individuals with ABI in the San Francisco Bay Area.

Inclusion criteria included individuals with memory and attention deficits due to traumatic brain injury, hemorrhagic cerebrovascular accident, or ischemic cerebrovascular accident at least two years prior to participation in the study. Participants were excluded from the study if they sustained an ABI less than two years prior to the study, or had conditions due to encephalopathy, degenerative neurological diseases, brain tumors or brain injury acquired at birth. Participants were also excluded if they self-reported to have visual, visual perceptual, or motor impairments and have previous experience with the Parrot Software during the pre-study interview. In addition, participants with severe ABI, as determined by orientation, memory and attention scores on the Cognistat assessment (Cognistat Inc., Montreal, Canada*)*, were excluded from the study after the initial assessment.

Although 27 individuals participated in the initial screening process, 15 individuals were excluded from the study based on the inclusion/exclusion criteria. The remaining 12 participants fulfilled the inclusion criteria and participated in the study with one participant not completing the study due to personal reasons. Table 1 has the demographics of the 11 participants. The researchers received approval from the Dominican University of California Institutional Review Board on December 9, 2011 to collect data from the greater Marin County community.

Measure

The Cognistat Assessment (2009) is a standardized assessment tool used to assess cognitive functioning across several domains. It was developed with the purpose of providing a reliable screening on cognitive functions across medical and psychiatric settings and it has been widely used in the literature with Stroke, TBI, Dementia and Psychiatrics conditions (see "Peer Review Articles," 2012). The Cognistat Assessment consists of eight sub-tests, assessing attention, orientation, level of consciousness, language, memory, calculation skills, reasoning, and constructional ability. For the purpose of this study, the traditional paper Cognistat Assessment (2009) was used to assess the degree of impairment in attention and memory for participants with chronic ABI.

Individuals were included in the study based on their performances on the sub-tests of orientation, attention, and memory. Orientation was used as an indicator of level of alertness, and was assessed by asking the participants questions about who they were, where they were, and the date and time. Attention was measured by asking the participants to repeat a series of digital sequences, followed by a subtest that required the participant to repeat a four-word list. Memory was measured by asking the participants to repeat the four-word list given previously in the attention subtest later in the assessment, usually after a ten-minute time lapse. Orientation scores ranged from 0-12; attention scores ranged from 0-8; memory scores ranged from 0-12. Severe ABI was determined by a score of 4 or below for orientation, a score of 1 or below for attention, and a score of 0 for memory on the Cognistat Assessment (2009).

Procedures

All participants provided written informed consent or proxy informed consent via their guardians. Potential participants met with the researchers and completed a brief questionnaire which gathered demographic information of the participants, including their age, education level, experience with any CBCR programs, type of ABI sustained, and the amount of time since their brain injury occurred. Eligible participants were then assessed using the paper version of the Cognistat Assessment (2009) for baseline measures. Participants were included in the study if they demonstrated memory and attention deficits, as evidenced by the results from the Cognistat Assessment. Both the initial screening interview to determine eligibility and the Cognistat Assessment were completed during the first visit. In order to control for bias and conform to inter-rater reliability, each researcher was trained in administering the standardized paper version of the Cognistat Assessment (2009) and the CBCR program. Four trained researchers participated in the process of data collection and program administration.

Intervention

The Parrot Software is commercially available through Internet access or CD software, and is an interactive rehabilitation program with over 100 sub-programs designed to improve cognitive reasoning, memory and attention, reading, speech and language, vocabulary and grammar, and word recall. Eight sub-programs were chosen for intervention from a total of 18 sub-programs available for attention and memory in the Parrot Software. The eight sub-programs used were *Attention Perception and Discrimination, Visual Instructions, Concentration, Visual Attention Training, Remembering Visual Patterns, Remembering Written Numbers, Remembering Written Letters, and Remembering Written Directions*. The sub-programs were selected due to their focus on perceptual speed and accuracy, as well as cognitive demand. For example, two sub-programs used were *Visual Attention Training*, and *Remembering Written Letters.* In the *Visual Attention Training* sub-program, the participants were required to watch for a colored box and were instructed to click on the box when it appeared. The box appeared randomly on the screen, and only appeared for a brief period. As the lessons progressed, the participants were given visual distractions, such as additional colors and boxes, and were required to alternate their attention between multiple colors that were shown. In one of the memory sub-programs used, *Remembering Written Letters*, participants were presented a list of letters. The participants were asked to remember the entire list in the correct order, and identify which numbers or letters were used, and in what order. The amount of numbers and letters shown varied depending on each lesson.

Each participant completed eight 60-minute sessions using the attention and memory sub-programs in the Parrot Software at the BINBA. The participants focused on one of the eight sub-programs during each session, with each sub-program containing ten lessons with increasing difficulty. If a participant completed all ten lessons within a sub-program, they returned to the first lesson and completed each lesson again until the allotted 60-minutes was completed. The Cognistat Assessment (2009) was used as posttest reassessment and was conducted on the same day when the participant completed the eighth sessions of the Parrot Software training program. Each participant was initially required to complete one sub-program per week. However, several participants required a different time frame due to outside obligations or dependence on caregiver schedules for transportation, thus the times elapsed for intervention completion ranged from two to eight weeks.

Analysis

A power analysis was completed to determine the sample size necessary to achieve results that were statistically significant. Using the standardization data from the Cognistat Assessment (2009), ten participants were needed for the study. Descriptive statistics was used to report the characteristics of the participants and to report the means and standard deviations of the pretest and posttest results. Inferential statistics was used to test the null hypothesis.

In order to test the hypotheses, the pretest mean for attention was compared with the posttest mean for attention using a two-tailed t-test. The same procedure was used to compare pretest and posttest means for memory. Using a 95% confidence interval, a two-tailed t-test determined the effectiveness of the Parrot software on the participants' memory and attention.

Correlation coefficients were used to determine the strength of the relationship between changes in posttest scores and age, the strength of the relationship between changes in posttest scores and level of education, and between changes in posttest scores and the amount of time that had elapsed since the brain injury occurred. Microsoft Excel and SPSS 12.0 for Windows were used to calculate and interpret the statistical data. Regular consultations with a statistician ensured that all calculations were accurate.

Results

A matched paired t-test showed significant improvement in attention in the participants. The mean attention improvement score was 2.091 with a standard deviation of 1.700 ($t(10) = 4.079$, $p < 0.005$) (See Table 2). The 95% confidence interval shows that the true mean improvement lies between 0.949 and 3.233.

A matched pair t-test showed significant improvement in the memory score with a mean improvement score of 1.73 and a standard deviation of 2.195 ($t(10) = 2.610$, $p < 0.05$) (See Table 3). The 95% confidence interval shows that the true mean improvement lies between 0.253 and 3.202.

There were no significant correlations between attention or memory change and education level ($r=-0.347$, $n=11$, $p=0.296$ and $r= -0.053$, $n=11$, $p=0.877$ respectively). The correlations between attention or memory change and age at injury, and years since injury also did not reach statistical significance. Five participants had previous experience with CBCR, six participants did not. There was a statistically significant difference in average attention change between those who had previous CBCR experience ($M = 3.4$, $SD = 1.34$) and those who did not ($M = 1.0$, $SD = 1.10$), $t(7.76) = 3.207$, $p < .05$. There was not a statistically significant difference in average memory change between those who had previous CBCR ($M = 2.0$, $SD = 1.87$) and those who did not ($M = 1.5$, $SD = 2.59$), $t(8.87) = 0.371$, $p > .05$.

There were no significant correlations between times elapsed for the completion of the CBCR intervention and attention or memory improvement. The correlation between memory improvement and elapsed weeks with intervention was 0.578, $p = 0.063$. The correlation between memory improvement and total weeks with intervention was 0.577, $p = 0.063$.

The following correlations were found to be weak and insignificant: The correlation between memory improvement and days in intervention was 0.300, $p > 0.05$. The correlation between attention improvement and elapsed weeks in intervention was 0.071, $p = 0.836$. The correlation between attention improvement and total weeks in intervention was 0.061, $p = 0.858$. The correlation between attention improvement and days in intervention was 0.068, $p = 0.842$.

Discussion

The purpose of this study was to determine the effectiveness of a commercially available CBCR program, the Parrot Software, in improving memory and attention deficits for individuals with chronic ABI. There was a significant improvement in attention scores post intervention suggesting that the Parrot Software can improve attention for individuals with chronic ABI. Additionally, a significant improvement in memory scores post intervention suggests that the Parrot Software can also improve memory.

Using the software, the participants were required to maneuver the mouse based on the visual stimuli, and were often timed. The ten lessons in each of the sub-programs allowed intensive practice. Each participant focused solely on one sub-program each session, thus incorporating repetitions. The improvements in posttest Cognistat scores demonstrated by the participants is consistent with the findings of Smith et al. (2009), which showed that cognitive training programs incorporating intensive practice with focus on perceptual speed may improve both memory and attention. The participants' improvement in both attention and memory also supports the findings by Kimberly et al. (2010) and Fisher et al. (2009), suggesting learning-induced neuroplasticity can occur after a specific task is performed repetitively.

A significant correlation between previous CBCR and attention was found. This may suggest that it is possible to retrain attention skills in an individual with chronic ABI and that previous gains in attention can carry over and be maintained once training has ended. The carryover of attention skills from previous CBCR may also suggest that CBCR can have a long-standing effect on attention for adults with chronic ABI. However, further research is needed to assess the length of carryover post-cognitive retraining.

Statistical analysis revealed that there was no significant correlation between times elapsed for the completion of the CBCR program and attention or memory improvement. Each participant completed the eight designated sub-programs within varying time frames due to scheduling conflicts and availability. While each participant was initially asked to complete one sub-program per week, several participants required a different time frame due to outside obligations or dependence on caregiver schedules for transportation. The participants spent two to eight weeks in the study ($M = 4.8$, $SD = 2.1$). However, the varying weeks spent using the CBCR program did not have an effect on the post intervention scores in memory and attention, suggesting that the number of sub-programs used may have a greater effect than the duration of the entire intervention in improving memory and attention. This finding can be of clinical importance. Future studies to determine the optimal frequency, duration, total number of practices or total time spent on a CBCR program may give further insight into the benefit of this cognitive remedial intervention.

Another important finding was that there were no significant correlations between both attention and memory changes when analyzed with age, years since injury, or education level. Participants ranged from 24 to 77 years of age. The lack of effect of age on the participants' changes in scores may imply that CBCR can be an effective intervention for adults with ABI.

The time since injury for the 11 participants spanned from four to 50 years status post ABI, which yielded no correlation with changes in memory and attention from the study. Thus, the improvement in memory and attention with the use of the Parrot Software program may be independent of the time passed since the initial insult to the brain, suggesting that the brain has the ability to restore neurological pathways regardless of the time lapse after an injury has occurred. Finally, the wide span of education levels among the participants, coupled with a lack of correlation between changes in memory and attention scores and the amount of schooling indicates that CBCR has a positive effect on these two cognitive domains regardless of previous education level. Although using a CBCR program requires basic knowledge of computer use, it does not necessitate extensive education for it to be effective with adults who have sustained an ABI. Taken together, these findings appear to demonstrate that the changes in scores for memory and attention could be genuinely due to the time spent with the CBCR program, rather than other extraneous variables such as age, years since injury, and education level.

Limitations

There are several limitations to our study, one of which is the lack of a control group. Although 11 qualifying participants were recruited to meet the minimum requirement for statistically significant results, a larger sample would further strengthen the findings of the study and allow for a control group. Future studies including a control group could assess the effectiveness of the CBCR program when compared to a group receiving an alternative or no intervention. Another limitation is the lack of evidence that the improvement gained in attention and memory can be sustained over time. Even though our participants who had previous experience with other CBCR programs demonstrated carryover effect in attention improvement, our failure to include a repeated posttest measure cannot claim the same effect. Thus, future studies with repeated posttest measures will be needed in order to substantiate the possibility of long-term neuroplasticity occurrence with a short-term computer-based training program. Furthermore, the use of the Cognistat Assessment as the outcome measure does not mean that changes in memory and attention have an impact on functional tasks. Further research using assessment of daily life tasks requiring memory and attention are needed. Finally, because the study target a specific population of individuals with chronic ABI due to TBI or stroke only, the results may not generalize to the entire ABI population, such as individuals with acute ABI or ABI due to brain tumor, infection, or anoxia.

Conclusion

The results of this study indicate that the Parrot Software program may be an effective remedial cognitive intervention in improving deficits in the domains of attention and memory for individuals with chronic ABI. Despite the fact that this study did not look at skill transfer or improvement in occupational performance, it provides evidence in support of the use of CBCR, particularly in the chronic TBI and the chronic stroke populations. It is important to point out that chronicity from the time of initial insult to the time of the use of a CBCR does not appear to affect the potential for improvement. It is our hope that this pilot study could provide evidence for clinicians and researchers to further inspect the use of CBCR with the chronic ABI population. Nonetheless, future studies that include skill transfer into improvement in occupational performance will be needed to further validate the role of CBCR in cognitive rehabilitation for the chronic ABI or the larger ABI population.

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