Critical Review:

The effectiveness of computer-assisted treatment of reading ability for adults with acquired neurogenic disorders

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In this critical review, the effectiveness of computer-assisted treatment (CAT), which is the administration of therapy protocols by computers, is investigated for reading rehabilitation for adults with acquired neurogenic disorders, specifically aphasia. A total of 10 articles of varying study design (single group study, randomized clinical trial, and qualitative study) are analyzed. Overall, it is found that this protocol is effective. Future recommendations, clinical implications, and provisions on applications of this research are discussed.

Introduction

In this critical review, the effectiveness of computer-assisted treatment will be investigated in reading rehabilitation for people with acquired neurogenic disorders; specifically, people with aphasia. Aphasia is a neurogenic disorder characterized by disruptions in expressive and receptive language. Stroke is the most common cause of aphasia. Many people with aphasia have difficulty with reading (Katz and Wertz 1992).

Computer-assisted treatment (CAT) is the use of computer-based programs in the treatment of speech and language disorders (Katz 2010). There are many benefits to conducting rehabilitative therapy for reading by computer, such as the self-administration of exercises outside the clinic (Katz and Wertz 1997). The use of computers in therapy has been investigated for people with chronic aphasia; however, investigations of its efficacy in reading rehabilitation have been sparser (Aftonomos, Steele, and Wertz 1997; Katz and Wertz 1997). Although computer-based programs appear promising on the surface, their effectiveness as an interface for therapy, their efficacy as a therapy program, and the possibility of harm warrant exploration in the evidence base before being administered clinically.

Objectives

The primary objective of this paper is to critically analyze studies that address the following research question: Is computer-assisted treatment for reading ability effective for adults with acquired neurogenic disorders?

Methods

Search Strategy

Research studies were searched in the Western University library website online database. The following databases returned relevant articles: PubMed, Scopus, and Linguistics and Language Behaviour Abstracts (LLBA). Search terms included (acquired brain injury or alexia or aphasia) AND (computer assisted technology or rehabilitation) AND (reading).

Selection Criteria

Articles were selected when they involved a therapy protocol administered by a computer within designated treatment sessions with supervision by a clinician. Since CAT is relatively recent, it was not necessary to implement a cut-off date for article inclusion.

Data Collection

Ten articles addressing reading rehabilitation using CAT for adults with aphasia were found: four studies are single group designs; three studies are randomized clinical trials; one study is a non-randomized clinical trial; one study is a qualitative retrospective report; and one study is an expert opinion paper.

Results

Single Group Studies

Katz and Nagy (1982) ran one of the first single group studies on the efficacy of using CAT to rehabilitate reading skills in five people with aphasia. The authors prepared a software program using Applesoft for Apple II Plus computers that combined several reading subtests (e.g. matching letters, understanding sentences, etc.) and several treatment tasks for reading (e.g. word functions, question words, etc.). Assessment subtests were appropriate. Although most participants showed improvement on computer tasks, the authors did not run statistical tests to measure pre-post changes.

The absence of statistical analysis precludes a direct, quantitative appraisal of treatment efficacy. Katz and Nagy (1982) do admit that they did not expect substantial improvement in reading within the length of time of the study. Furthermore, the authors suggest that

increased familiarity with the software itself may have been responsible for the improvements on computer tasks post-treatment. Also, participants would often engage in CAT tasks directly following a session of speech therapy with a clinician; this setup confounds the experimental procedure. It is also difficult to draw large-scale conclusions from the small number of participants. On a positive note, the participants were capable of administering the computer program independently, which suggests utility as a self-administered adjunct treatment program.

Katz and Nagy's (1982) investigation is an early pilot study on the efficacy of a CAT-based program for reading. Although some improvement was observed on computer tasks, these results are not reliable due to the weaknesses in the study. Overall, the level of evidence is equivocal but suggestive of future potential.

In a follow-up study, Katz and Nagy (1983) conducted a single group AB-type study on the efficacy of improving sight word reading using CAT in five people with aphasia. Their flash card-like activity (written for Apple II Plus computers) required participants to select a word from a list of options that matches a word displayed briefly on-screen. Following a period of traditional speech therapy (the A phase), participants engaged in the CAT activity following their traditional speech session (the B phase). Appropriate assessment tests were conducted initially and at the end of each phase. Again, statistical analyses were not run, and no effect of treatment or generalization was found.

The authors reported differences in performance between the high-functioning and severely-impaired participants, with the former showing ceiling effects and the latter showing some improvement. However, these differences were not substantiated by statistical analysis, precluding identification of treatment effect. Furthermore, performance for the high-functioning individuals was near-ceiling at the start of treatment; as such, there were limited opportunities for improvements in performance.

In Katz and Nagy's (1983) study, improvements in word recognition were either minimal or low. This study offers low to medium evidence in support of CAT for improving sight word reading in people with aphasia.

In their final study of this series, Katz and Nagy (1985) investigated the treatment efficacy of a software that provides automatic, online adjustment of the difficulty hierarchy in a CAT reading task in a single group of five participants with aphasia. The clinician familiarized participants with 12 line drawings and their associated words before beginning the CAT program. On the computer, participants were presented with a drawing, the correct word, and a foil; after achieving 92% accuracy over 12 trials, the program added an additional foil to the list. Three participants showed improved accuracy post-treatment; the remaining two, who were severely-impaired, did not show improvement. As before, data were not analyzed statistically.

Once again, no statistical tests were reported. Qualitatively, it appears that this particular intervention was beneficial for the mildly-impaired participants; however, as in Katz and Nagy's previous studies, the severely-impaired participants did not improve. The authors did discover that the type of foil (e.g. visual distracter, semantic distracter) influenced participant performance; however this finding is not analyzed statistically, and so its role in customizing materials for clients cannot be ascertained.

Katz and Nagy's (1985) study demonstrates utility for a self-administered, online-adjusting CAT for reading rehabilitation. However, it appears to be successful only for a mildly-impaired population, and treatment effectiveness was not confirmed. The level of evidence of this study is thus suggestive of future potential.

In a later single group study, Aftonomos, Steele, and Wertz (1997) explored the treatment efficacy of providing 23 veterans with chronic aphasia a CAT-based pictographic language program called the Lingraphica ® System (henceforth LG). Following traditional therapy in the acute phase of post-stroke onset, the clinician provided laptop-delivered training/intervention sessions using LG. Participants were permitted to use LG at home between sessions. Several appropriate assessment tests were used to measure changes in performance. Although improvements appeared to generalize across language measures, there were no statistically significant improvements in percentile rank on reading measures.

The authors chose to conduct a deeper analysis of "midrange" participants (i.e. participants who performed between the 15^{th} and 85^{th} percentiles) in order to eliminate floor and ceiling effects from their analysis. This approach had the consequence of narrowing the sample pool to a handful of individuals in each assessment. Improvement was reported across several language domains (except reading) but was not further explored. Finally, the authors identify additional compounding variables as (1) participants' adeptness at using LG independently, and (2) the amount of time participants used the system outside session.

This study indicates that pictographic language interventions by CAT do not generalize to improvements in reading. Although assessments were appropriate and comprehensive, the regrouping of participants for analysis complicates the conclusion of treatment effectiveness. In all, this study provides moderate evidence on the topic.

Randomized Clinical Trials

In a 1992 preliminary study, Katz and Wertz investigated the use of CAT as a treatment protocol for reading rehabilitation in a randomized clinical trial of 43 adults with aphasia. Participants were randomly assigned to one of three groups: *computer treatment* (*CTx;* n=13), *computer stimulation* (*CS;* n=15), and *no treatment* (*NT,* n=15). The *CTx* group participated in computer-based visual matching and reading comprehension exercises; the program also automatically adjusted the hierarchy level of trials based on the participant's accuracy. The *CS* group was given cognitive activities and arcade-style games. Appropriate assessments were conducted at pre, mid, and post-treatment intervals. Statistical analysis using *t*-tests revealed improvements in the *CTx* group but not in the other groups. *CTx* participants were also able to use the software with minimal assistance from the clinician.

Katz and Wertz (1992) implemented multiple *t*-tests when analyzing within-group changes and analysis of variance (ANOVA) when analyzing between-group differences; they do not justify the choice of statistical test in each instance. The authors provide a quantitative profile of participants (e.g. age, time post-onset). Furthermore, the methods, tasks, and computerized hierarchy are outlined in detail such that the procedure is described sufficiently for replication.

Overall, this study provides compelling evidence for the effectiveness of CAT in improving reading in individuals with aphasia.

Several years later, Katz and Wertz (1997) published results of a more comprehensive randomized clinical trial investigating reading rehabilitation using CAT in 55 adults with aphasia. The overall protocol tasks and groups remained the same as the 1992 study. Statistical analysis again revealed significant improvements in the *CTx* group on several of the assessment subtests; and the authors again found that the *CTx* group improved more than the *CS* and *NT* groups. The *CTx* group also completed more therapy tasks than the *CS* and *NT* groups. Finally, participants in the *CTx* group were able to implement the computer program with minimal assistance from the clinician.

Participants in the *CTx* group improved on several, but not all, assessment subtests; as such, a full ANOVA did not reveal a significant interaction. Nonetheless, the relevant finding is that only the *CTx* group improved on those measures: univariate ANOVA and Student's *t*-test revealed that the *CTx* group made improvements that were not shown by the *CS* and *NT* groups. Indeed, the strength of the study is in the finding that when exposed to CAT for reading, people with aphasia will show significant improvements. Participants were also able to use the program independently; however, the authors reported that participants first required familiarization using the program with the clinician's help.

In all, Katz and Wertz's (1997) comprehensive study demonstrated significant improvements for individuals with aphasia who engage in reading-based CAT. This study offers compelling evidence for the effectiveness of CAT for reading rehabilitation in this population.

More recently, Cherney (2010) investigated the efficacy of administering *Oral Reading for Language in Aphasia* (ORLA), an established protocol for reading rehabilitation, using CAT in 25 individuals with chronic, non-fluent aphasia randomly assigned to a CAT-delivered group (n=12) or to an SLP-delivered group (n=13). An AB-type design was implemented, and appropriate assessments were administered initially, after a period of no treatment (the A phase), and after treatment (the B phase). Student's *t*-test revealed no significant difference in outcome measures between the groups. Appropriate tests of effect size indicated that changes in outcome measures were strong.

Eleven of the twelve participants in the CAT-delivered ORLA treatment group showed improvement on at least one assessment measure, and there was little generalization across assessment measures. Post-treatment effect sizes were also large on some but not all assessment measures. Cherney (2010) argues that because therapy was delivered in low intensity (i.e. 1-3 sessions a week), these results are promising that change would be greater when ORLA is delivered in high intensity (i.e. 5-7 times a week).

In all, Cherney's (2010) study demonstrates that clients improve from CAT-delivered ORLA, and it provides highly compelling evidence for its effectiveness in rehabilitating reading in adults with aphasia.

Finally, in a recent non-randomized clinical trial conducted in Poland, Łojek and Bolewska (2013) investigated the treatment effectiveness of language-based and neuropsychological-based CAT programs in 7 participants with aphasia and in 9 participants with residual acquired brain injury, respectively; each group

was matched to a control group of healthy participants. Participants with aphasia engaged in weekly sessions with *Afa-System*, a CAT program that has specific exercises for several language domains, including reading. Pre-post assessment tests were appropriate. The authors found post-treatment improvements in reading in the aphasia group; furthermore, there was no indication of a difference between the aphasia group and control group on the reading subtest post-treatment.

The authors analyzed within-group post-treatment changes using the Wilcoxon Z test, which is appropriate for small samples. Statistical results indicated that participants with aphasia improved on one subtest measure; on other measures, participants with aphasia performed more poorly than the control group, indicating continued dysfunction post-therapy. The authors do not further analyze reading.

Łojek and Bolewska's (2013) study demonstrated effectiveness of a language-based CAT program in improving reading skills in persons with aphasia, although further exploration of improvements would provide more compelling evidence. In all, this study offers moderate-to-high evidence in favour of reading rehabilitation by CAT.

Qualitative Studies

Wertz and Katz (2004) conducted a qualitative retrospective review of studies on CAT for aphasia in order to quantify and analyze the body of evidence on the topic. The authors report on over 20 studies on CAT for aphasia and categorize the strength of studies by level of evidence and by stage of clinical trial. The authors found only one study (their own 1997 study), which involved a substantiated hypothesis, outcome measures, and treatment protocols that were explored in previous studies. Although many studies offered high levels of evidence, the authors conclude that additional studies on CAT would contribute more evidence to the research base.

Wertz and Katz (2004) reviewed, rated, and ranked each study individually, resulting in a comprehensive and thorough analysis. The authors are also established researchers in the field of CAT for aphasia and can be considered experts. The study was also conducted objectively, based upon procedures and measures defined by another author. On the other hand, a meta-analysis could also have helped reveal patterns across studies and identify the overall strength of results.

In the end, Wertz and Katz's (2004) paper is comprehensive and objective, and it revealed that research conducted to date is effective and promising. Overall, this paper offers a high level of evidence for using CAT for reading rehabilitation.

Finally, Katz (2010) wrote an expert opinion piece on the use of computer-based technologies in the treatment of chronic aphasia with the purpose of educating unfamiliar clinicians with their utility. Katz discusses programs for augmentative and alternative communication, computer only treatment, and computer assisted treatment, elaborating on Katz and Wertz's (1997) study as a premium example of the effectiveness of CAT for reading rehabilitation. He concludes that computer-based technologies are helpful tools for rehabilitating skills like reading for people with chronic aphasia; however, there is a need for more randomized clinical trials on their effectiveness.

Katz selected seminal papers (such as his and Wertz's 1997 study) and popular computer-based programs as examples of high-quality research and therapy tools, respectively. On the other hand, Katz's rating of his and Wertz's (1997) study is somewhat circular: Katz quotes previous work he published (2004) as evidence that previous research he published (1997) was efficacious.

Katz's (2010) paper is a secondary article with the purpose of familiarizing readers with research on a topic area. Although Katz does not offer new empirical findings, the studies he discussed offer a high level of evidence on using CAT for reading rehabilitation for people with chronic aphasia.

Discussion

Overall, the majority of studies support the use of CAT for reading rehabilitation in persons with aphasia. Important findings include:

1. People with aphasia who receive CAT for reading rehabilitation demonstrate improvement.
2. People with aphasia who receive reading-specific tasks by CAT demonstrate more improvements than those who receive non-reading tasks (e.g. cognitive tasks, logographic-based tasks).
3. People with aphasia are capable of implementing CAT without assistance from the clinician.

Katz and Nagy's (1982, 1983, 1985) early studies are pilot investigations. Although they are lacking in statistical substance, their purpose was to explore an empirical avenue for future studies. In that regard, they are seminal papers on the use of CAT in speech therapy.

It is noteworthy that the majority of studies published on this topic were conducted by Richard Katz. Notwithstanding Katz's expertise on the topic, it is clear

that additional studies by a varied number of researchers are necessary in order to further substantiate this treatment protocol.

Assessments selected as measures included the Porch Index for Communication Ability (Katz and Wertz 1992, 1997) and the Western Aphasia Battery (Cherney, 2010); the authors argue that these tests may not identify subtle changes in reading skill, even though they were sensitive to overall changes in ability. In addition, because the protocols focus on surface reading more than on reading comprehension, it is possible that the tests were not sensitive to change in this area.

Finally, it appears that in order to be successful, the protocol on CAT must explicitly target reading. Participants did not improve from the pictographic protocol administered by Aftonomos, Steele, and Wertz (1997); they did, however, improve from the reading-based protocols by Katz and Wertz (1992, 1997), Cherney (2010), and Łojek and Bolewska (2013). It would be of benefit in future research to experimentally contrast the selection of CAT-based reading therapy in order to ascertain which protocol is most efficacious.

Clinical implications

In conclusion, CAT for reading rehabilitation for people with aphasia is recommended. It is an effective adjunct for therapy and can provide self-paced, high intensity treatment outside clinic sessions. The clinician should remain involved in the protocol, as clients appear to require training and support before being capable of administering CAT independently. Furthermore, in order to be effective, the program itself must explicitly target reading, as language activities do not appear to generalize to improvements in reading; furthermore, the client must be willing and capable of devoting many hours to treatment. Under these conditions, CAT shows promise as a powerful tool in reading rehabilitation in this population.

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