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Effectiveness of computer-assisted virtual cognitive retraining in improving reading, dictation, and copying skills among school-going children

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Abstract—A randomized control trial with repeated measures was used with 60 bilingual learners aged 8-10 years from English medium schools to evaluate the effectiveness of Computer-Assisted virtual Cognitive Retraining (CACR) on school-going children with average or above-average IQ and no identified learning impairment. Data collection was done virtually. The experimental group received CACR for five weeks, with 15 sessions of an hour's duration. Learners in the control group did not receive any training. The dependent variables were evaluated by 15 minutes of reading, copying, and dictation tests from their grade level English textbook and using the Language subtests of the Diagnostic Test for Learning Disability (DTLD), a test for diagnosing learning disability validated in the Indian population. Results showed improvements in the learners' academic skills, such as reading fluency, copying, and dictation. The outcome of this study has implications for using virtual computer-based interventions to enhance the academic skills of school-going children.

Keywords: Academic Skills, Bilingual, Children with Average or Above-Average IQ, Randomized Control Trial, Grade-Level Textbook, Learning Poverty

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I. INTRODUCTION

TECHNOLOGY is transforming the pattern of psychological applications in human lives. It has given an utterly novel façade to the traditional ways of providing therapies and treatments to clients. Technology has reshaped the old ways and led to the adoption of tech-based resources among practitioners to meet the high demands for psychological services. Technology has also made disseminating psychological therapies to the remotest areas possible (Jackson, Watts, List, Puryear, Drabble, & Lindquist, 2021). The dream of reaching out to the deprived and disadvantaged sections of society that could not benefit from psychological services due to physical constraints has become a reality. Various internet-based psychotherapies and teletherapy are used widely by mental health professionals worldwide. Technology has made therapies more affordable and convenient (Fairburn & Patel, 2017).

Furthermore, technology has helped develop various rehabilitation software with scientific bases. It utilises the principles of artificial intelligence and machine learning to bring targeted behavioural and cognitive shifts in human behaviours. Research has proved the efficacy of such computer-assisted interventions in treating adults and children with ADHD, Autism, Schizophrenia, PTSD (Wild, Warnock-Parkes, Grey, Stott, Wiedemann, Canvin, Rankin, Shepherd, Forkert, Clark, & Ehlers, 2016), Anxiety (Valmaggia, Latif, Kempton, & Rus-Calafell, 2016), depression, etc.

Computer-based interventional tools for enhancing language and reading skills have been used frequently to assist and remediate children with various learning impairments. Research shows that computer-assisted interventions are used to improve various skills like reading (Kujala, Karma, Ceponiene, Belitz, Turkkila, Tervaniemi, & Näätänen, 2001; Macaruso & Rodman, 2009), writing (Rogowsky, Papamichalis, Villa, Heim, & Tallal, 2013), phonological processing (Callaghan, McIvor, McVeigh, & Rushe, 2016), and auditory-visual perception (Ecalle, Kleinsz, & Magnan, 2013) among individuals with learning disabilities. Reading rate is the number of words read correctly by an individual in each time. It is alternatively called reading speed and is part of a broader skill known as reading fluency (Babbin, 2014). Children who have a slow reading rate are found to be struggling readers. Copying requires a series of specialised visual-cognitive tasks, visual-encoding, construction, and maintenance of a mental representation in working memory and production in writing (Warren, 2021). Whereas in dictation, the listening and writing skills of the child play an important role. Dictation is a decoding and recoding activity (Davis & Rinvolucri, 2002) and is often considered an indicator of a child's wholesome language ability. Li (2020) highlighted that dictation could test an individual's abilities, such as auditory perception and phonemic awareness.

This study is important for educators who brainstorm to fill the learning gaps created among school-going children due to the COVID-19 pandemic. It seeks to improve the basic academic skills of school-going children by utilizing a digitalized intervention model.

II. THEORETICAL FRAMEWORK

Theoretical Background

"Cognitive retraining" is one of the most effective therapeutic methods for enhancing brain functionalities by providing mass practice and appropriate reinforcement of activities designed to upgrade specific cognitive domains in an individual (Velligan, Draper, Stutes, Maples, Mintz, Tai, & Turkington, 2009). It is called "re-training," as the method involves overlearning and extensive practice on various activities by capitalizing on the strong cognitive abilities of an individual. It is a restorative and compensatory approach in which patients with brain impairment are made to practice numerous exercises/activities to strengthen their weakened cognitive skills. Neurocognitive areas like attention and memory, visual and spatial perceptual skills, concentration, language and verbal skills, executive functioning skills, etc., considered basic learning skills, can be retrained using cognitive retraining (Sadasivan, 2017). Children with a learning disability often have weaker cognitive skills than their peers, resulting in difficulties in understanding and processing written and spoken language. Cognitive retraining works wonders with such individuals as it helps increase and improve cognitive abilities and training compensatory strategies. Research has shown that exposure to proper training improves deficits in brain functioning (Kolb & Gibb, 2011). Cognitive retraining utilizes the brain's adaptive ability of "neuroplasticity", making it highly responsive to environmental influence. Repeated and direct attention towards the desired change results in neuronal rewiring, hence aiding in informing of new cognitive skills or enhancing the weakened abilities of an individual. Thus, the human brain's structure, function, and connections can be re-established by providing appropriate training.

Why technology-based interventions?

"Learning poverty" is the major global crisis illuminated (Azevedo, 2020). This phenomenon refers to children who cannot read a simple text by the age of ten or the end of primary school. Around 53% of 10-year-old children from middle and low-income countries face learning poverty. It is one of the major roadblocks to a country's efforts to build on its human capital and overall development (Azevedo, 2020). Attempts toward improvements in learning poverty were already quite slow, and there was an appeal from the World Bank for its global community to cut the rate of learning poverty by at least half by 2030. But post-COVID-19 pandemic, the education sector worldwide has faced a significant shock (Azevedo, 2020). Nearly 1.6 billion children were out of school due to sudden and indefinite lockdowns in various countries across the globe. The school closure period for half of these children has exceeded seven months at a stretch (Azevedo, 2020). Governments tried to maintain the learning integrity of their countries by adopting various remote learning initiatives. However, the extent of learning losses is great due to numerous constraints of virtual education (availability of internet, devices, etc.). It has been estimated that the post-pandemic learning poverty rate will supposedly increase by 10%. Thus, it will change from 53% to 63%. It will add 72 million children to this " poverty " category out of a population of 720 million primary school-age children in low and middle-income countries. Governments and educators must be prepared to handle this grim situation of learning deprivation in children. Education systems must revamp themselves by being more flexible and adaptable to the varying learning needs of children. The solutions that evolved during the COVID-19 pandemic, such as using technology to augment the learning outcomes among children, must be widely brought into practice. Technology-based approaches benefit from remote reach, engaging, time-bound, multisensory, and motivating for children, thus enhancing and rectifying their learning outcomes rapidly (Bansal & Singh, 2021). Technology must be used effectively to create remote learning solutions and accelerated teaching programmes to meet the varying learning needs of learners while protecting the interests of those most vulnerable (Azevedo, 2020).

Importance of grade-level assessment

Grade-level reading, writing, and spelling assessment is an essential criterion for evaluating learning outcomes (Narayan, 1997). This approach to assessment is more preventive, developmental, and predictive than other types of assessment that are demonstrative and are more of crisis intervention (Wallace & McLaughlin, 1975).

III. OBJECTIVE OF THE STUDY

This study aims to assess the effectiveness of Computer-Assisted Cognitive Retraining on academic skills, including reading fluency, copying, and dictation skills of school-going children.

IV. HYPOTHESES OF THE STUDY

Hypothesis 1: It was expected that the children completing 15 CACR sessions would significantly improve their scores in reading, copying, and dictation.

Hypothesis 2: The scores in the language subtests of DTLD would improve significantly for children completing CACR.

V. METHODS

Participants

The sample size for the present study was determined based on a priori power analysis by the G*Power computer program. Using parameters of 0.80 power, 0.80 large sizes, and 0.05 alpha, the sample size for the t-test needed per group was 21 respondents. A randomized control trial with repeated measures was used in this study. Three English medium schools in the National Capital Region (NCR), New Delhi, India, were approached to participate in the study. With the help of the schoolteachers, the parents were informed about the online 15-session cognitive retraining program through a circular sent to them before the commencement of summer break. Those parents who showed interest in their child's participation were made part of the study. Of the 108 learners enrolled in the program, the first 60 who were able to complete the 15 sessions of the program were taken as the sample of the study; dropouts were mainly a result of various issues such as travel, un-availability of internet, health problems, COVID-19 wave or other unspecified reasons. The study was conducted in adherence to the 1964 Declaration of Helsinki and per the research ethics protocol laid by the University Grant Commission, India. Informed virtual consent was obtained from the parents of the children who participated, and it was confirmed that research data would be used anonymously for empirical purposes.

All the participants were between 8 and 10 years old (3rd to 5th grade) and had average or above-average IQ and class performance (according to teacher feedback). Participants in both groups were bilingual; their mother tongue was the Hindi Language, and they all were learning English as a second language. Before the summer break, they regularly attended school classes online (due to COVID-19). None of the participants had any learning disability in either group (Based on the teacher's feedback and the scores obtained on the DTLD test). Participants were randomly allocated to either the experimental group(n=30) that completed 15 sessions of CACR by using web-based online software in 5 weeks duration (thrice a week) or the control group(n=30) that did not do any training. None of the participants in either group were taking any other external support related to their studies during this study.

Students who were not attending online classes conducted by the school before summer break or had any learning disability with comorbid disorders such as seizures were excluded from the study. Parents on the part of their children expressing difficulty completing 15 sessions of cognitive retraining as they did not have a laptop or computer with a mouse were excluded from the study.

Procedures

The present study used purposive sampling as only children attending English medium schools were included as the sample. A randomised control trial with repeated measures was used to study the effectiveness of using CACR with school-going children (Friedman, Kern, & Reynolds, 2010). Data were collected through the virtual one-to-one meeting between the researcher and each participant. The initial two sessions were devoted to collecting all the participants' baseline assessments in the experimental and control groups. After collecting the pre-intervention data, the participants were randomly allocated to either the experimental or a control group by following the simple randomisation method (using the fish-bowl method). The experimental group was asked to complete 15 days of CACR remotely from their systems during their summer break. Once the experimental group completed 15 sessions of CACR, post-intervention data were virtually collected for both groups. After post-intervention data collection, the control group was also allowed to complete 15 sessions of CACR as per the research ethics of GC India.

Intervention

The CACR was provided using a web-based digital cognitive therapy software consisting of various games to enhance the skills required for fluent reading in an individual with learning differences. These games are included in 15 cognitive training sessions, and each session lasts for one hr., completed in 5 weeks by a participant. Each session has nine different games targeting various visual and auditory pathways involved in reading, language domain, and word comprehension (Table 1).

Table 1 Details of games and their target areas included in each session of CACR

Sequence of the gameplay	Target cognitive skill	Activities included	Principle behind activity
Game1	Tracking, Attention	Two identical bee patterns are given, and the participant must drag the bees from their original location to the opposite honeycomb, replicating the pattern.	To enhance attention, ocular motor control, and visual sequential memory
Game 2	Tracking, Attention	Two identical hexagonal patterns are given. Participants must drag coloured hexagons from one side to their identical location on the opposite side.	To enhance attention, ocular motor control, and visual sequential memory
Game 3	Tracking, Attention	Participants will listen to an audio clip in which the narrator speaks a word, which will appear in one of the 3 "pinball bumpers" bouncing around. Participants must listen to the auditory cue and drag specific pinball with the same word as they listened on to the corresponding bumper.	To enhance auditory processing skills, attention skills, and phonemic awareness.
Game 4	Tracking, Attention	The narrator reads a sentence and a set of response lines corresponding with the words of the sentence appears on the screen. Participants must search for the words to build the sentence from the sliding lines across the screen and drag them to its corresponding response line.	To enhance listening skills, attention skills, and phonemic awareness.
Game 5	Spelling, attention	The participant will listen to the initial aural cue from the narrator for the target word, identify it, and drag it to a specified place	To enhance phonemic awareness, decoding and encoding skills
Game 6	Spelling, attention	The participant will listen to the initial aural cue from the narrator for the target word, identify it, and drag it to a specified place	To enhance phonemic awareness, decoding and encoding skills
Game 7	Sound parcel	The narrator speaks a word with emphasis on the first letter and long stretched out enunciation of the entire word. After the presentation of the target word four other rhyming words are presented on screen, participant must click on the target word and drag it to the response box.	To enhance phonological awareness, multisensory approach, Auditory processing, and Visual processing skills
Game 8	Homophones, building vocabulary	Two same-sounding words but visually and meaningfully different words are presented to the participant. An aural sentence consisting of a target word is presented to the participant. A participant is asked to pick the correct word out of two choices according to its meaning and orthographic	To enhance Morphological awareness, multisensory approach, Auditory processing
Game 9	Decoding of words	The participant is asked to code and decode a pig Latin word. Once it is decoded participant must find the word from the floating words on the screen by clicking on it and dragging it to the response line.	To enhance encoding-decoding skills and understanding of language

The key principle's behind the activities used in the cognitive retraining method play a significant role in improving reading and language skills among learners. Thus, mass training on these activities is expected to improve language-related skills in learners. During each session, audio-visual feedback is provided in a point system and fun graphics that continuously reinforce learners to perform better and increase their motivation and engagement in learning (Awasthi, 2021).

Variable Measurement

All dependent variables were measured twice, at the beginning of the study and again after 15 sessions of CACR.

(a) Specific Learning Disability (SLD)

All learners in the study completed the Diagnostic Tool for Learning Disability (DTLD) by Swarup and Mehta (1990) as an inclusion criterion used to diagnose learning disability among Indian children aged 8-11. The tool has ten subtests that measure the various cognitive skills. Thus, it is used to diagnose a learning disability. The reliability coefficient and index for the ten subtests are 0.79 and 0.89, respectively. The validity of the test was examined by content and construct validity.

(b) Expressive Language and Receptive Language

Combined scores on two subtests of DTLD - Expressive Language (Subtest X) and Receptive Language (Subtest IX) were used for the pre-post intervention assessment of language skills and spontaneous semantic processing, ensuring comprehension skills in children. These are referred to as DTLD scores in the present study.

(c) Reading, Copying, and Dictation Skills

A 15-minute reading, dictation, and copying task was done with the experimental and control groups to assess their reading, dictation, and copying skills (Table 2). These tasks were done from the participants' grade-level English textbooks.

In 5 minutes, during the reading task, the participant was first asked to read passages from their grade-level English textbook as pre-intervention data. The researchers recorded the number of words read clearly by him/her in 5 minutes and taken as data for the study. These are then converted into word count per minute (WCPM) by dividing the total number of words by 5 minutes (total words read correctly/5) (Rasinski & Padak, 2005b). This is referred to as reading scores in the present study. The same procedure was followed for post-intervention data of reading scores; the child was asked to read a different passage from the one he/she read at the pre-intervention stage.

In 5 minutes, during the copying task, the participant was asked to copy(re-write) a passage from his/her grade level English textbook pre- and post-intervention. In the pre-intervention stage, the child's total number of words (sensible words) copied clearly in 5 minutes was recorded by the researcher and taken as data for the study. This is referred to as copying scores in the present study. The same procedure was followed for post-intervention data for copying scores, and the child was asked to copy a different passage from the one he/she copied at the pre-intervention stage.

In 5 minutes, during the dictation task, each participant wrote the words dictated to him/her from his/her grade level English textbook during both pre-and post-intervention. In the pre-intervention stage, the researcher recorded the number of words he/she wrote correctly in 5 minutes. For dictation, the correct word % (correct number of words/total words x 100) was taken as data for the study. These are referred to as dictation scores in the present study. The same procedure was followed for post-intervention data on dictation, and the child was given different words from the one he/she was given at the pre-intervention stage.

All the above tasks were repeated thrice in pre- and post-intervention for both the groups using the same set of items before intervention and a different set for the post-intervention assessment. The results of the tasks with three different items were compared to find out the reliability of measures (Cronbach α). Finally, the analysis used the average scores as a raw score for each task.

Table 2 Description of the score used for measurement of Reading Copying and Dictation Skills

Variables	Method of computation
Reading Score	the word count read per minute by each participant (WCPM)
Copying Score	words (sensible words) copied clearly by the child in 5 minutes
Dictation Score	the correct word % was taken as data for the study (correct words/total words x 100) in 5 minutes

Control Variable

The control variable of IQ was included to increase the precision and eliminate any biases caused by the differences between the two groups. Standard Progressive Matrices (SPM) were used to assess the intelligence percentile range of all the children participating in the study. The Raven's SPM is a reliable and valid measure of a person's intellectual development. All the learners included in the study had a percentile of 75 or above on the test.

Statistical Analysis

The data thus collected following the above design and procedure was analysed using the mean, standard deviation, and effect size. A one-tailed test for significance with a significance level of 0.05 (α) was used as directed hypotheses were formulated to assess the effectiveness of CACR. A homogeneity test was conducted on the sample data to ascertain the homogeneity of variance. Similarly, a normality test was also conducted on the sample data to determine if the data were normally distributed. For data analysis, t-tests for the paired and independent-sample t-tests were used together with Effect Size Calculation (Cohen, 1988). Data were analysed using SPSS software version 28. A further linear mixed model was applied to each of the post-measures to identify the fixed and random effects of the intervention, pre-scores, and their interaction effect using JMP version 15.

VI. RESULTS

Cronbach α reliability coefficient was calculated for all the three measures used for pre-post assessment, and values were above 0.8 for all three measures. Homogeneity of variance was established using the Levene test for homogeneity ($p>0.05$), and the normality of data was controlled for a one-sample t-test and independent sample t-test. Kurtosis and skewness have been analysed for the purpose of controlling normality. As a result of the analysis, it is seen that the critical value (z) of kurtosis and skewness of data remains between -1.96 and +1.96.

Linear mixed model and repeated measures ANOVA were used to compare the effects of group (experimental, control), time(pre-post), and the interaction between time and group on the scores (differences in groups with change in time).

Pre-post comparison of variables

Table 3.2: Descriptive statistics and group comparisons of all the four variables

Pre-post comparison of variables

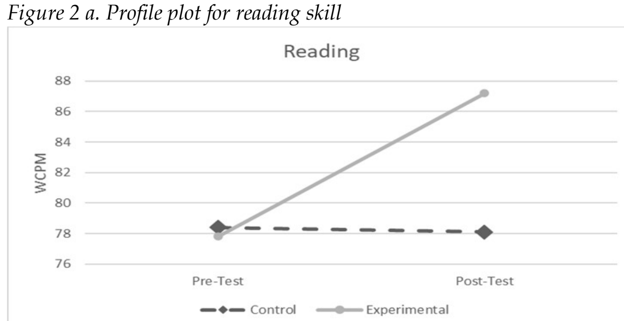
Table 3: Descriptive statistics and group comparisons of all the four variables

Table 3 shows the mean of both groups' pre-intervention and post-intervention, along with their calculated t-values. For the experimental and control groups, the calculated *t* (58) values were non-significant on all three academic skills at $p<0.05$ for the pre-intervention phase, which shows that all the learners in either group had almost similar performance initially. In the experimental group, the *t* (58) value is significant in all three academic skills post-intervention. This shows an improvement in all three assessed skills in the experimental group.

Reading Skills

The interaction effect between the type of group and time had a significant effect, $F(1,58)=60.90$, $p<0.0001$. Similarly, the analysis of the main effect of time showed a significant difference $F(1,58)=25.71$, $p<0.0001$, with both groups showing a difference in scores from pre-test to post-test. The experimental group showed significant improvement in mean reading scores post-intervention (M=87.2, SD=11.04). There was no significant main effect of group $F(1,58)=2.61$, $p=0.116$, suggesting no difference in participants' reading skills belonging to an experimental or control group. Figure 2a depicts the profile plot of the reading scores for both groups.

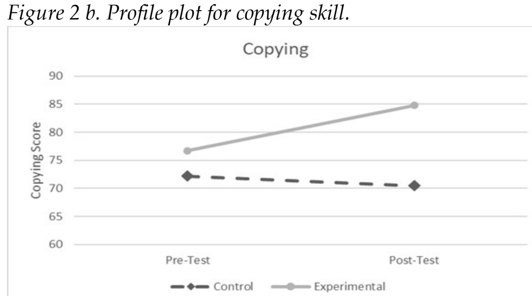
Figure 2 a. Profile plot for reading skill



Copying Skills

The interaction effect between the type of group and time has a significant impact, $F(1,58)=48.66$, $p<0.0001$. Similarly, the analysis of the main effect of time too showed a significant difference $F(1,58)=26.67$, $p<0.0001$, with both groups showing a difference in scores from pre-test to post-test. The experimental group showed significant improvement in mean copying scores post-intervention (M=84.8, SD=13.81). Results of the simple main effect of the group showed that the copying post-test scores were significantly greater in the experimental group than in the control group $F(1,58)=6.91$, $p<0.05$. Figure 2b depicts the profile plot of the copying for both groups.

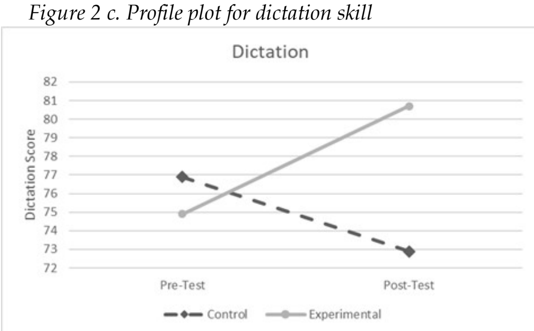
Figure 2 b. Profile plot for copying skill.



Dictation Skills

The interaction effect between the type of group and time had a significant effect, $F(1,58)=45.85$, $p<0.0001$. Similarly, the analysis of the main effect of time showed a significant difference $F(1,58)=36.51$, $p<0.0001$, with both groups showing a difference in scores from pre-test to post-test. The experimental group showed significant improvement in mean reading scores post-intervention (M=80.7, SD=9.05). There was no significant main effect of group F (1,58) =1.39, p=0.26, suggesting no difference in the dictation skill of participants in either the experimental or control group. Figure 2c depicts the profile plot of the dictation scores for both groups.

Figure 2 c. Profile plot for dictation skill



DTLD score

There was statistically no significant difference seen in either the main effect of group F(1,58)=0.028,p=0.59, time F (1,58)=0.0034,p=0.65, or the interaction effect of group and time F(1,58)=0.0074,p=0.51, in the subtests of DTLD suggesting that there was no difference in the performance of participants in either group during pre to post-test assessment. Figure 2d depicts the profile plot of DTLD scores for both groups.

Figure 2 d. Profile plot for DTLD Score

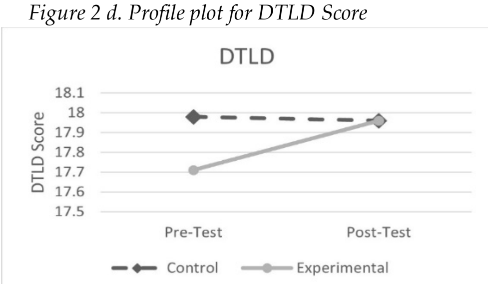


Table 4 Pre-post intervention comparison of academic skills within groups

	Experimental group			Control Group		
Academic skills	*Pre mean*	*post Mean*	*t*	*Pre mean*	*Post Mean*	*T*
Reading	77.8	87.2	27.45***	78.4	78.1	0.22
Copying	76.7	84.8	8.69***	72.1	70.5	1.59
Dictation	74.9	80.7	5.47***	76.9	72.8	7.72***

p*<0.05, p***<0.001

Table 4 shows the pre-post intervention comparison within experimental and control groups. The *t* (58) value shows a significant difference in students' performance in the experimental group on all three academic skills after the intervention. There is a significant increase in the mean scores of all three academic skills. In the control group, there is no significant difference in the copying and reading performance, but in dictation, as the mean score deteriorated in the 5-week period thus, the *t* (58) value was significant.

Mixed model analysis

Since the research design is repeated measures, pre-intervention scores are nested within participants; a Linear mixed-effect model was used to analyse the data further to identify the intra-variability among participants due to intervention and initial (pre-intervention) scores on various academic skills. To identify the influence of the initial cognitive skills of participants on the post-intervention scores, fixed and random effects were analysed using a linear mixed model. The fixed effect of intervention/no-intervention and the pre-intervention scores were analysed on post scores. The random effect of initial scores of other skills on each skill was determined. REML variance component estimate was done for a random effect study using JMP software. We ran three models:

1. Post measure ~ Intervention
2. Post measure~Intevention+pre-measure scores
3. Post measure~Intervention+premeasure scores+pre-measure scores X intervention

Table 5 RMSE scores for all four variables for different models

	RMSE (Model 1)	RMSE (Model 2)	RMSE (Model 3)
Post Reading	*10.3*	*4.67*	*4.52*
Post Copying	*13.93*	*5.25*	*5.17*
Post Dictation	*10.73*	*5.58*	*5.60*
Post DTLD	*1.22*	*1.11*	*1.11*

In Table 5, RMSE (Root Mean Square Error) was observed in all 3 models, and RMSE was found to be lesser in model 3 than in model 1,2.

Table 6 Model summary for post-test scores of all four variables

Reading	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.1683401	4.832405	0.24	0.8098
Intervention	9.6441532	1.168265	8.26	<.0001*
Pre-reading	0.8591893	0.056483	15.21	<.0001*
(Intervention-1.5)*(Pre-reading-78.0833)	0.2501279	0.112967	2.21	0.0309*
Copying	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	-5.431092	3.870257	-1.40	0.1661
Intervention	10.184461	1.353779	7.52	<.0001*
Pre-Copying	0.9085123	0.047691	19.05	<.0001*
(Intervention-1.5)*(Pre-Copying-74.45)	0.1597044	0.095382	1.67	0.0996
Dictation	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	-6.627311	6.50846	-1.02	0.3129
Intervention	9.5866942	1.455512	6.59	<.0001*
Pre-Dictation	0.908596	0.077549	11.72	<.0001*
(Intervention-1.5)*(Pre-Dictation-75.9174)	-0.115478	0.155098	-0.74	0.4597
DTLD	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intervention	0.0671062	0.288863	0.23	0.8171
Pre-DTLD	0.3766481	0.108927	3.46	0.0010*
(Intervention-1.5) *(Pre-DTLD-17.85)	0.2563648	0.217853	1.18	0.2443

In Figure 3 below, the horizontal values of the points are farther from the middle of the plot in the case of the intervention leverage plot in all four measures, indicating that the slope of the line of fit is stable. Whereas the horizontal values in the prescore or its interaction with the intervention leverage plot are clustered towards the middle of the plot, indicating that the slope of the fit line is unstable; hence, intervention exerts more influence on the effect.

Reading

The fixed effect of the initial reading score, intervention, and interaction between intervention and the pre-reading score was significant on post-reading scores (Table 6). The random effect of other initial scores (pre-dictation, pre-copying, and pre-DTLD) and their cross effects was less than 0.50 percent.

Copying

The fixed effect of the initial copying score and intervention was significant on post-copying scores (Table 6). The random effect of other initial scores (pre-dictation, pre-reading, and pre-DTLD) and their cross effects was less than 0.50 percent.

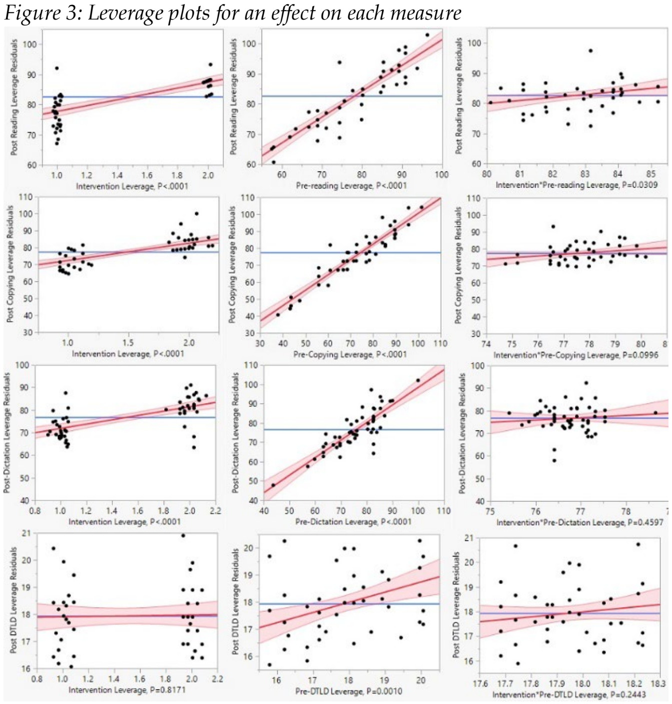
Dictation

The fixed effect of the initial dictation score and intervention was significant on post-dictation scores. At the same time, no significant fixed effect was found of a cross between intervention and initial dictation scores (Table 6). The random effect of other initial scores (pre-reading, pre-copying, and pre-DTLD) and their cross effects was less than 0.50 percent.

DTLD

The fixed effect of the initial DTLD score was only found to be significant on Post DTLD scores. In contrast, no significant fixed effect was found of intervention and interaction between intervention and initial scores (Table 6). The random effect of other initial scores (pre-dictation, pre-copying, and pre-reading) and their cross effects was less than 0.50 percent.

Figure 3: Leverage plots for an effect on each measure



Group comparisons of gain scores

Group differences are significant, and the effect sizes (Cohen, 1988) were large for all three academic skills in the experimental group; even the confidence interval did not cross zero for any assessed academic skills. This led to the conclusion that both groups had a significant difference, and the experimental group performed better.

VII. DISCUSSION

The present study is an endeavour to evaluate the effectiveness of CACR on academic skills or reading rate, copying, and dictation among normal school-going children who have no learning impairments.

All the participants in the study were children with no learning disability and with average or above-average Intelligence percentile. First, we hypothesized that children's CACR scores would significantly improve reading, copying, and dictation skills. The results indicated that the experimental group fared better than the control group. After receiving the intervention, a significant improvement can be seen among students in their academic skills. Children require These three skills during their school years (Van Zyl, 2011). This result is in line with past research, which concluded that computer-assisted interventions improve reading (Kujala et al., 2001; Macaruso & Rodman, 2009), writing (Rogowsky et al., 2013), phonological processing (Callaghan et al., 2016), auditory-visual perception (Ecalle et al., 2013) among individuals with different kinds of intellectual disability. Although none of the participants had a learning disability in the present research, the learners' who received the intervention showed significant gains.

The effect size of these gains was large from the pre-test to the post-test. Thus, it can be concluded that CACR has improved the academic measures in children without any learning impairments. The results can be elucidated with the strengths of involving technology in mainstream education, as computer-assisted Interventions have multi-sensory characteristics and thus have an empowering impact on children's cognitive skills. In the present research, CACR is delivered in the form of various games and activity-based program, which has 15 sessions and requires the active involvement of children; thus, it tends to improve the other cognitive skills of children like attention and concentration. Intervention in the form of games makes it interesting compared to traditional pen-paper-based skill training exercises (Karweit, 1985), (Leiblum, 1989), and immediate reinforcement (Bansal & Singh, 2021) in the form of scores provided at the end of each session encourages students to perform better in upcoming sessions, thus creating a self-stimulating learning environment for the child.

Secondly, we hypothesized that CACR would improve children's language skills, evaluated by DTLD subtests, but no such effects were seen. The reason can be that the sample included in the study had no learning difficulties. Thus, their performance was above the mark in the language subtests of DTLD even before the study was initiated. Secondly, the repeat administration of DTLD in a time gap of 5 weeks could have created a practice effect on the sample. Thirdly, most of the items in the language subtest have fixed answers, thus making the scores almost similar pre-post intervention for children.

Most of the research done supported the fact that there is a beneficial impact of using CACR in western countries where English is the mother tongue. The present study provides evidence of the applicability of such programs to improve bilingual children's academic skills, and English is not their mother tongue. It supports research (Law & Hew, 2017), which also shows the efficacy of computer-assisted interventions in improving children's phonological skills in an Asian context. The efficacy of such an interventional program can be of immense benefit for countries that have bilingual populations. Eventually, more evidence can be gathered regarding the universal effectiveness of such computer-based interventional programs for school-going children. It is assumed that post-COVID-19, there will be a greater need for such technology-based cognitive enhancement programmes that serve the purpose of remediation and better skill attainment (Azevedo, 2020).

VIII. LIMITATIONS

Although the present study results offer valuable insights into the benefits of CACR in improving the academic skills of school-going children, this is a limitation of the study's targeted sample, which leads to its low generalisability. The small sample size limits the use of statistical approaches that can be used to analyze the data and reduces the statistical power of the research. Secondly, the whole study was completed in five weeks. There is no assurance about how long-lasting the positive results and retention are seen in children's academic skills in the experimental group. Thirdly, the intervention sessions were completed by children in the experimental group at their homes, where they had easy access to a computer/laptop with a mouse. Still, access to such equipment on an individual level can be challenging in schools located remotely. Fourthly although grade-level assessment is done for the pre-post comparison of academic skills among the participants, often used as indicators of academic achievement, these are not standardised psychological tests. Thus, future studies must consider these practical challenges to increase the feasibility of this tech-driven intervention method.

IX. FUTURE DIRECTIONS IMPLICATIONS

The study's findings showed significant improvement in the academic skills of children in the experimental group compared to their counterparts in the control group; this suggests the beneficial aspect of CACR in children with no learning impairment. Besides the positive impact of CACR on dictation, copying, and reading skills, there can be more skills like phonological skills, rhyming skills, etc. The impact of CACR can be evaluated. Secondly, the impact of this programme can be evaluated among children in non-English medium schools to investigate whether such programs are effective in producing positive results among children speaking vernacular languages, which serve the vast population globally.

Broadly, a few implications can be derived from the present study.

The finding suggests that post-intervention, a significant improvement can be seen in the academic skills of children who completed 15 sessions of CACR than those who did not. This finding provides empirical evidence that CACR can be immensely beneficial if included in education to improve children's academic skills. It can also be an effective solution to the prevalent learning crisis globally. The use of computer technology in education and remediation makes it reach boundless. The pandemic has already laid the base for virtual learning worldwide, thus making the practical applicability of this research quite high. This study is an effort to support the various government initiatives to handle the learning crisis predicted to increase manifolds post-pandemic. Intertwining technology, psychology, and education will further enhance learners' learning possibilities, and such learning programmes can serve as an effective tool in the armory of educators.

X. CONCLUSION

The results of this study are in perfect extension of previous research, which reported on at-risk children with various learning impairments in their clinical trials. In this study, the focus is on children who have no learning gaps. They still benefitted from their academic skills by completing a 15-session CACR programme. This finding proves the all-around need for such computerized training programs that can be part of the "universal education" system and serve as "good for few and necessary for all".

Secondly, most such studies utilising computer-assisted interventions are done in Western countries. This study is completed in an Asian context to improve the applicability of such programs in countries with bilingual or multilingual populations, and English is not their native language. Similarly, the sample of this study, the normal school-going children, has improved the value by manifolds. There is an urgent need for interventions that can be provided with the help of technology to be reached every nook and corner of the country where the availability of a therapist is not possible. Still, managing "learning problems" can become possible with technology-assisted remediation. Further, its benefits among children with no learning impairment make it more prominent to be used widely. Such a fulfilling use of technology can become a boon globally.

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Table 3: Descriptive statistics and group comparisons of all the four variables

Academic Skills	Assessment	Experimental M (SD)	Control M (SD)	T	Group Effect	Time Effect	Interaction Effect
Reading	Pre-Test	77.8(11.05)	78.4(10.1)	t(58)=0.23	F(1,58)=2.61	F(1,58)=25.71****	F(1,58)=60.90***
	Post-Test	87.2(11.04)	78.1(9.51)	t(58)=3.42***			
Copying	Pre-Test	76.7(13.02)	72.2(15.5)	t(58)=1.22	F(1,58)=6.91*	F(1,58)=26.67****	F(1,58)=48.66***
	Post-Test	84.8(13.81)	70.5(13.82)	t(58)=3.98***			
Dictation	Pre-Test	74.9(8.34)	76.9(11.12)	t(58)=1.21	F(1,58)=1.39	F(1,58)=36.51****	F(1,58)=45.85****
	Post-Test	80.7(9.05)	72.9(12.19)	t(58)=2.81*			
DTLD	Pre-Test	17.71(1.37)	17.98(1.32)	t(58)=0.924	F(1,58)=0.028	F(1,58)=0.0034	F(1,58)=0.0074
	Post-Test	17.96(1.29)	17.96(1.14)	t(58)=0.062			