# Effectiveness of cloud-based rehabilitation in children with developmental language disorder during the COVID-19 pandemic
## A prospective cohort study

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## Abstract

During the coronavirus disease 2019 pandemic, we considered the case of a child with developmental language disorder (DLD) who could not go to the hospital on time to receive timely rehabilitation treatment due to disrupted hospital operations. The application of cloud-based rehabilitation platforms has provided significant advantages and convenience for children with DLD in-home remote rehabilitation. Among them, the JingYun Rehab Cloud Platform is the most widely used in mainland China. It is an interactive telerehabilitation system developed by Weixin Huang that delivers personalized home rehabilitation for special education children. In this study, we used the JingYun Rehab Cloud Platform to investigate the extent to which cloud-based rehabilitation is effective for children with DLD in terms of language and cognitive outcomes. This was a prospective cohort study including all children who were evaluated and diagnosed with DLD through Sign-Significant Relations and were followed up at the rehabilitation clinic of our institute. We followed 162 children with DLD for 3 months, including 84 children with DLD who participated in remote cloud-based rehabilitation on the JingYun Rehab Cloud Platform and 78 children with DLD as the control group who underwent home-based rehabilitation. Language abilities of both groups were assessed using the Chinese version of the Peabody Picture Vocabulary Test-Revised. Several measures of training performance (language, memory, and cognition tasks) were assessed before and after cloud-based rehabilitation in the remote cloud-based rehabilitation group. Children with DLD in the cloud-based rehabilitation group performed significantly better in language abilities, as assessed by the Peabody Picture Vocabulary Test-Revised, than children with DLD in the control group. Furthermore, for children who participated in remote cloud-based rehabilitation, the frequency of training sessions was proportional to their performance on language, memory, and cognition tasks. This study demonstrated the effectiveness of cloud-based rehabilitation on the JingYun Rehab Cloud Platform in treating children with DLD.

**Abbreviations:** ASHA = American Speech-Language-Hearing Association,COVID-19 = coronavirus disease 2019,C-WYCSI = China-Wechsler Younger Children Scale of Intelligence,DLD = Developmental Language Disorder,DSM-5 = Diagnostic and Statistical Manual of Mental Disorders,PIQ = performance intelligence quotient,PPVT-R = Peabody Picture Vocabulary Test-Revised,SLPs = Speech and Language Pathologists,S-S = Sign-Significant Relations,VIQ = verbal intelligence quotient.

**Keywords:** cognitive abilities, frequency of training sessions, language abilities, rehabilitation cloud platform, remote rehabilitation

## 1. Introduction

Developmental language disorder (DLD) is one of the most common childhood developmental disorders worldwide. According to the Diagnostic and Statistical Manual of Mental Disorders-5,[1] the key features of language disorders are difficulties acquiring and using language due to deficits in the comprehension or production of vocabulary, sentence structure, and discourse. It is estimated to affect approximately 7% of the population at school entry, with boys being more affected than girls in a ratio of 2:1.[2]

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Although no single cause has been found to explain DLD, there is clear evidence of the underlying memory and cognitive deficits.[3] Because DLD often manifests in other areas of academics, such as reading and writing,[4] early identification can help in early intervention and remediation, leading to adequate coping skills. If children with DLD receive continuous rehabilitation training during language development,[5] it will be more likely to promote their comprehensive recovery.

However, during the pandemic period of coronavirus disease 2019 (COVID-19), hospitals have closed many types of normal operations and various occupations, while service-providing centers have temporarily been closed due to the necessity of quarantine. The potential threat of COVID-19 to children with DLD has reversed the usual contact-based assessment and treatment services. Families of these children deal with various psychological issues due to their children's problems,[6] which are intensified by their concerns regarding the lack of treatment for their children's speech-language problems. In this context, children with DLD face a unique challenge for speech and language pathologists (SLPs), who usually communicate face-to-face with their patients.

Given the need for continuous therapy sessions to treat DLD, the application of tele-practice may eliminate problems in this area to some extent, while preventing the transmission of COVID-19 and guaranteeing the health of SLPs and children. The Chinese Society of Rehabilitation Medicine emphasizes that contact-based rehabilitation treatment should be reduced as much as possible. SLPs are encouraged to use WeChat, cloud-based rehabilitation platforms, and other online techniques to provide rehabilitation treatment guidance and rehabilitation science education.[7] The American Speech-Language-Hearing Association has also assured that the assessment and treatment process in speech and language pathology can be performed through tele-practice.[8] Therefore, the use of information technology to provide tele-home rehabilitation training for children with DLD has become an essential concern for parents and SLPs during this particular period.

During the COVID-19 pandemic in China, the application of cloud-based rehabilitation platforms has provided significant advantages and convenience for children with DLD in their home remote rehabilitation. Among them, the JingYun Rehab Cloud Platform is the most widely used. It is an interactive telerehabilitation system developed by Weixin Huang that delivers personalized home rehabilitation for special education children. According to other recent studies, telerehabilitation positively impacts patient compliance and adherence,[9,10] which is critical for better functional recovery.

Therefore, the overall objective of this study was to evaluate the effectiveness of a remote cloud-based rehabilitation solution, the JingYun Rehab Cloud Platform, in improving clinical language and cognitive outcomes following children with DLD. This study contributes to the scientific knowledge base on the effects of cloud-based rehabilitation platforms. We hypothesized that a cloud-based rehabilitation program performed through remote evaluation and training of the patient's performance would improve clinical outcomes compared to conventional home-based rehabilitation.

## 2. Participants and Methods

### 2.1. Study design and ethics

This prospective cohort study was conducted at the First Affiliated Hospital of Jinan University between January 25 and April 25, 2020. The study protocol was implemented in accordance with the ethical principles of the Declaration of Helsinki.[11] This study was approved by the Research Ethics Committee of the First Affiliated Hospital of Jinan University, China. Prior to study commencement, the parents or guardians of the children included in this study received an explanation of the study protocol via email or telephone, and provided online informed consent. The flow diagram of the study design is shown in **Figure 1**.

### 2.2. Participants

The inclusion criteria were as follows: children with DLD who had been diagnosed face-to-face by SLPs through Sign-Significant Relations (S-S) assessment at the First Affiliated Hospital of Jinan University prior to the outbreak of COVID-19, and the diagnosis was cross-verified with the diagnostic criteria for DLD specified by the Diagnostic and Statistical Manual of Mental Disorders-5[1]; aged between 42 and 84 months; no hearing impairment, brain injury, cerebral palsy, neurological disorder (including sensory impairment, motor dysfunction, or attention deficit hyperactivity disorder), or other difficulties related to genetic or neurological causes based on parents' reports; the China-Wechsler Younger Children Scale of Intelligence[12] has a Performance Intelligence Quotient (PIQ) of >70; and children whose guardians had online informed consent forms for the cohort study.

A total of 162 children with DLD were recruited and their legal guardians were contacted via email or telephone to propose enrollment and explain the service. The legal guardians of the child participants who agreed to participate were recontacted, and an online informed consent form was sent to them.

According to the choice of children's parents, all participants were divided into 2 groups: 1 group had 84 children (44 boys and 40 girls) with DLD who underwent remote cloud-based rehabilitation on the JingYun Rehab Cloud Platform, and the other was the control group, which included 78 children (42 boys, 36 girls) with DLD who underwent conventional home-based rehabilitation because of their time and economic issues. All participants were native monolingual Mandarin speakers. Based on parents' reports, none of the participants presented with medical conditions that could lead to secondary DLD, such as global developmental delay or autism spectrum disorder.

### 2.3. Assessment

Before rehabilitation, all the children's video calls were performed using appropriately qualified SLPs. The latter were blinded to the children's group assignment and clinical information, which were obtained from the workstations of the JingYun cloud rehabilitation services of the First Affiliated Hospital of Jinan University. The video call function of the WeChat app was used to connect the patients remotely. For children who were not technologically savvy or had issues accessing telehealth, aid from family members was requested.

#### 2.3.1. Evaluate diagnosis and performance characteristics.
In this study, children with DLD were evaluated using S-S. The S-S is an assessment method for diagnosing language delay, which can also describe and analyze the developmental characteristics of children.[13,14] Language development delay was defined when the result of one's language expression ability age was lower than one's actual age or both language expressions, and language comprehension ability age was lower than one's actual age. The S-S was developed by the Speech Committee of the Japanese Phonetics and Speech Medical Association.[15] This technique was standardized by the Language Department of the China Rehabilitation Research Center, based on the Chinese language system.[16] The S-S results included language comprehension, language expression, essential learning ability, and communication attitude. The results of the S-S should be compared with the actual age stage. If the result is lower than the actual age, abnormal results of the corresponding items can be defined. This allowed SLPs to analyze the comprehensive and expressive language abilities and nonverbal cognitive abilities
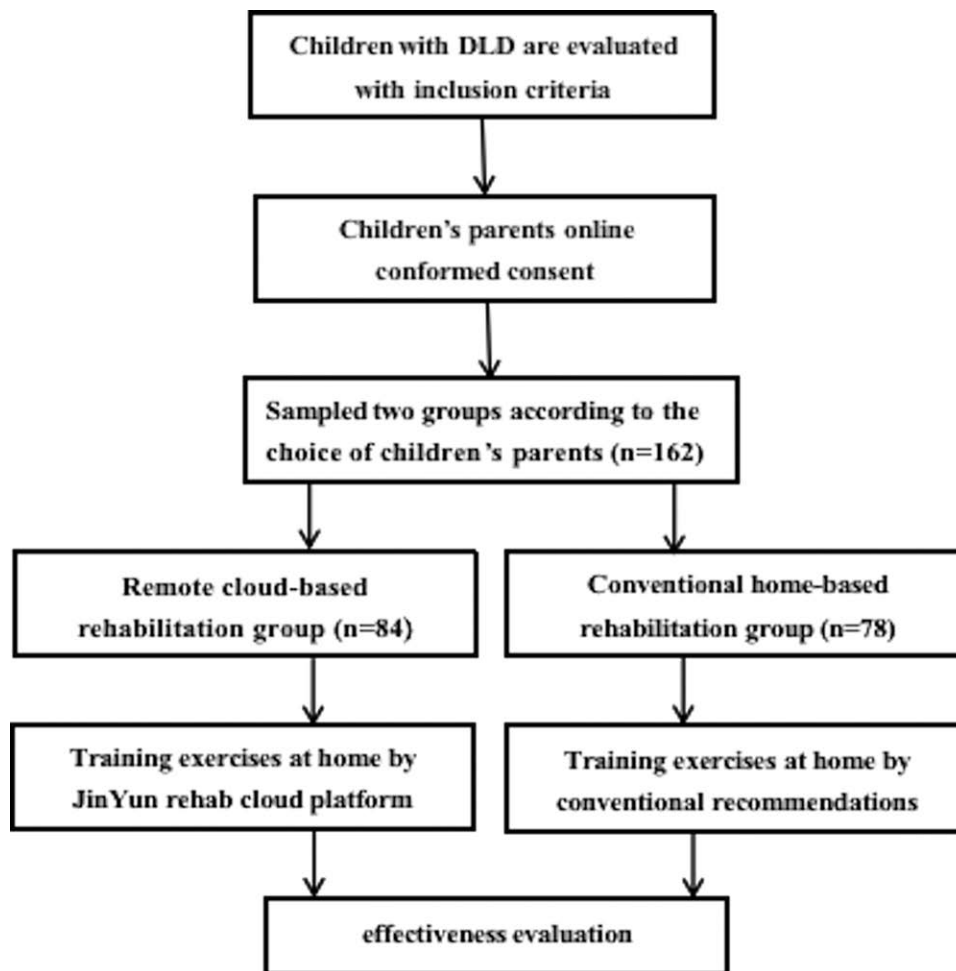
**Figure 1.** The flow diagram of the study design. DLD = developmental language disorder.

of children of different ages, understand the developmental characteristics of children with language deficits in different periods,[17] and provide a scientific basis for the comprehensive rehabilitation of children with DLD.

***2.3.2. Language abilities.*** The Peabody Picture Vocabulary Test-Revised (PPVT-R) assessed the participants' language abilities.[18–20] The Chinese version of the PPVT-R comprises a few available Mandarin standardized language tests used in mainland China.[21] This tool is as consistent as possible with the original version, and only a few language elements that do not conform to Chinese culture and language requirements have been revised. The test is composed of 175 items, and the split-half reliability and test–retest reliability are 0.99 and 0.94, respectively. The correlation coefficient between PPVT-R and performance in a Chinese language course for school-age children was 0.54. One point was awarded each time a picture correctly matched the given word. The raw score was calculated by totaling all correct item scores.

***2.3.3. Nonverbal intellectual abilities.*** The participants' nonverbal intellectual abilities were evaluated using the short form of China-Wechsler Younger Children Scale of Intelligence,[12] which has been widely adopted in previous studies investigating cognitive function.[22] The short-form items[12,23] included 2 tests: Verbal Intelligence Quotient (Information and Vocabulary) test and PIQ (Picture Completion and Block Design) test. The Information subtest required participants to answer questions about everyday knowledge, and participants were given a score of 1 or 0 on a scale of 0 to 23 for each correct or incorrect answer,

respectively. In the Vocabulary subtest, the children were asked to find the correct answer from 4 pictures corresponding to the word indicated by the tester, and were given a score of 1 or 0 on a scale of 0 to 44 for each correct or incorrect answer. The Picture Completion subtest required children to identify and point out the missing part of the picture, and they were given a score of 1 or 0 on a scale of 0 to 25 for each correct or incorrect answer. Finally, the Block Design subtest included a design either from the tester or the test booklet, and the children were given a score from 0 to 4 on a scale of 0 to 29 based on how quickly they completed each design. After evaluation, the raw scores were converted to standard scores based on the instruction manual. The standardized Verbal Intelligence Quotient and PIQ scores were equal to the sum of the Language and Performance subtest scores, respectively. The Full-Scale Intelligence Quotient was estimated using instruction-weighted scores for each subtest (mean = 100, standard deviation = 15.0).

### 2.4. Intervention

The rehabilitation program duration per child with DLD was 3 months, from January 25 to April 25, 2020. Both groups were evaluated for PPVT-R before and after the rehabilitation program to determine who should perform the prescribed training exercises at home. The control group followed conventional home-based rehabilitation recommendations, while the remote cloud-based rehabilitation group used the JingYun Rehab Cloud Platform to perform their training exercises. The details of the intervention for each group are as follows.

**2.4.1. Remote cloud-based rehabilitation group.** The remote cloud-based rehabilitation group received JingYun Rehab Cloud Platform services, which provided by Concentrated Rehab can be divided into 3 categories: direct remote rehabilitation, guided remote rehabilitation, and educational remote rehabilitation. Patients and their family members contact SLPs via videos and use a professional rehabilitation service platform to assess and rehabilitate different disabilities.

Cloud-based rehabilitation includes 2 modules: traditional training and rehabilitation. SLPs select rehabilitation items based on the S-S results and send them to the patient's account. In traditional training tasks, SLPs can select a rehabilitation video based on the patient's disability type. In the rehabilitation tasks module, the system automatically filters out suitable tasks according to the language developmental characteristics of children with DLD, resulting from the S-S results. SLPs will select a training topic and send it to the patient's account for direct rehabilitation training at home. Patients can log into their user terminal to receive reminders of the training tasks and follow the instructions on the page to perform daily training. The children completed the daily tasks set by the SLPs on time and observed the effects after 3 months of continuous training.

To perform rehabilitation training on the JingYun Rehab Cloud Platform, we first opened the website of JingYun (www.ireha.cn) and input the basic information of the case, disease description, and dysfunctional points on the platform. Perform symptomatic, functional, and language developmental assessment on the JingYun Rehab Cloud Platform. Based on these results, SLPs choose the appropriate training tasks for DLD. Each training task was divided into 3 difficulty levels, of which (3) was the most difficult. After each training, the training results, reaction times, and training plan suggestions automatically pop up. Based on the results of each training session, the concentration automatically adjusted the training plan. The children with DLD followed the exercise program with JingYun Rehab Cloud Platform under parental supervision, and the SLPs monitored the patient's progress daily through the platform.

**2.4.2. Control group.** The control group underwent conventional home-based rehabilitation recommendations and did not receive monitoring from SLPs. The patients' parents were asked to fill out a diary to indicate the exercises they performed and the corresponding dates. The children's exercise diaries were collected at the end of the rehabilitation program.

### 2.5. Outcomes and measures

**2.5.1. Peabody Picture Vocabulary Test-Revised.** We compared the results of the PPVT-R between children with DLD in the remote cloud-based rehabilitation group and the control group. The PPVT-R is a standardized test of language ability that has been widely used in language assessments.[24] Moreover, language deficits in DLD have been shown to correlate with deficits in memory capacity,[25] leading to limitations in processing language information[26] and hence, putatively impacting general cognitive development.[27]

**2.5.2. Patients' performance on the language, memory, and cognition training tasks by JingYun Rehab Cloud Platform.** We compared the performance of the remote cloud-based rehabilitation group on language, memory, and cognition training tasks of the JingYun Rehab Cloud Platform. The language training task included picture naming, phrase, and sentence training. The memory-training task included short-term memory training, instantaneous memory training, and auditory memory training. Finally, the cognition training task included mathematical training, thinking training, and attention training.

### 2.6. Statistical methods

All statistical analyses were performed using SPSS 23.0. All tests were 2-sided (where applicable), and significance was defined as $P$ value <.05.

The statistical analysis consisted of 2 parts: first, the study explored the impact of a group (the remote cloud-based rehabilitation group vs the control group that underwent conventional home-based rehabilitation) as the between-subject variable, and test time (prerehabilitation vs postrehabilitation) as within-subject variables on PPVT-R test scores with 2-factor mixed design repeated-measures analysis of variance. Second, for the remote cloud-based rehabilitation group, linear regression analyses were performed with the frequency of training sessions of the children on the language, memory, and matching tasks as the independent variables and the ranking of the language, memory, and cognition training tasks as the dependent variables.

## 3. Results

### 3.1. Demographic characteristics

In total, 162 eligible patients were enrolled in this study. None of the patients were excluded from the study. The maximum and minimum ages were 42 and 82 months, respectively. A total of 84 participants in the remote cloud-based rehabilitation group and 78 participants in the control group who underwent conventional home-based rehabilitation completed the 3-month follow-up visit. No significant between-group differences were

#### Table 1

**Participant demographic characteristics.**

| Parameters | The remote cloud-based rehabilitation group (n = 84) | The control group who underwent conventional home-based rehabilitation (n = 78) | Statistics | P value |
|---|---|---|---|---|
| Age, mo | 58.53 ± 9.48 | 56.29 ± 10.17 | 1.45 | .15 |
| Males, n (%) | 44 (52.38%) | 42 (53.85%) | 0.04 | .85 |
| Paternal educational level, n (%) | | | 1.26 | .74 |
| Postgraduate | 18 (21.43%) | 15 (19.23%) | | |
| Undergraduate | 30 (35.71%) | 27 (34.62%) | | |
| High school | 27 (32.14%) | 23 (29.49%) | | |
| Middle school | 9 (10.71%) | 13 (16.67%) | | |
| C-WYCSI, scores | | | | |
| VIQ | 59.81 ± 9.91 | 56.68 ± 10.87 | 1.92 | .06 |
| PIQ | 90.37 ± 11.35 | 87.59 ± 10.29 | 1.63 | .11 |
| FSIQ | 75.33 ± 9.54 | 72.37 ± 9.59 | 1.97 | .06 |
| PPVT-R | 57.83 ± 11.13 | 55.78 ± 10.72 | 1.19 | .23 |

C-WYCSI = China-Wechsler Younger Children Scale of Intelligence, FSIQ = full-scale intelligence quotient, PIQ = performance intelligence quotient, PPVT-R = Peabody Picture Vocabulary Test-Revised, VIQ = verbal intelligence quotient.
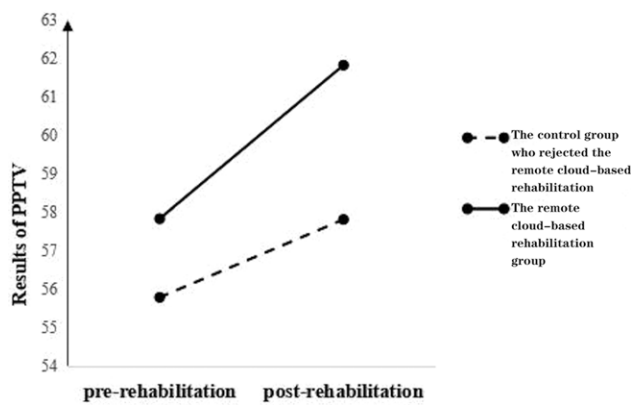
**Figure 2.** PPTV-R test results between the 2 groups (the remote cloud-based rehabilitation group and the control group) in the pre- and postrehabilitation. PPTV-R = Peabody Picture Vocabulary Test-Revised.

observed in sex, age, and paternal educational level, indicating that the general demographic characteristics of the 2 groups were comparable (Table 1).

### 3.2. PPVT-R outcomes in both groups

Figure 2 shows the results of PPVT-R test between the 2 groups in the pre- and postrehabilitation. The results of the analysis of variance showed a significant main effect of test time (prerehabilitation vs postrehabilitation), $F_{(1,160)}$ = 131.56, $P < .001$, $\eta^2 = 0.45$, suggesting that the PPVT-R test results of postrehabilitation were significantly larger than the PPVT-R test results of prerehabilitation. There was a marginally significant main effect of group (the remote cloud-based rehabilitation group vs the control group), $F_{(1,160)}$ = 2.88, $P = .092$, $\eta^2 = 0.018$; PPVT-R test results in cloud-based rehabilitation were significantly larger than those in the control group. In addition, we found a significant interaction effect between the test time and group, $F_{(1,160)}$ = 14.12, $P < .001$, $\eta^2 = 0.081$. Further analysis showed that the interaction between test time and group was significant for postrehabilitation participants. The PPVT-R test results in cloud-based rehabilitation were significantly larger than those in the control group. However, the PPTV-R test results of prerehabilitation did not vary significantly between the remote cloud-based rehabilitation and control groups (see Table 2).

### 3.3. Regression outcomes of the remote cloud-based rehabilitation group

**3.3.1. The language tasks frequency of training sessions.** Table 3 presents the descriptive statistics and regression analysis of the 3 tasks on the frequency of training sessions and scores. The relationship between the frequency of training sessions and training scores for language tasks is shown in Figure 3. Regression analyses were performed with the frequency of training sessions of the children on language tasks as the independent variable and the training scores of language tasks as the dependent variable. The results show that the overall model was significant (see Table 3). The frequency of training sessions on language tasks significantly and positively predicted the child's ranking on the language tasks.

**3.3.2. The memory tasks frequency of training sessions.** The relationship between the frequency of the training sessions and the training scores of the memory tasks is shown in Figure 4. Regression analyses were performed with the frequency of training sessions of the children on the memory tasks as the independent variable and the training scores of the memory tasks as the dependent variable. Tests of the full model specified that the model explained the data well (see Table 3). The frequency of training sessions on the memory tasks significantly and positively predicted the child's ranking on the memory tasks.

**3.3.3. The cognition tasks frequency of training sessions.** The relationship between the frequency of training sessions and training scores for cognition tasks is shown in Figure 5. Regression analyses were performed with the frequency of training sessions of the children on cognition tasks as the independent variable and the training scores of cognition tasks as the dependent variable. The results showed that the model was overall significant (see Table 3). The frequency of training sessions on cognition tasks significantly and positively predicted the child's ranking on cognition tasks.

### 4. Discussion

The purpose of this study was to investigate whether the use of remote cloud-based rehabilitation on the JingYun Rehab Cloud Platform during the COVID-19 pandemic has a positive effect on children with DLD. It was found that the PPVT-R performance of children with DLD who underwent cloud-based rehabilitation improved significantly after completing 3 months of rehabilitation training compared to those who underwent conventional home-based rehabilitation.

**Table 2**

Descriptive statistics and ANOVA of the 2 groups on PPVT-R test.

| | The remote cloud-based rehabilitation group(n = 84, M ± SD) | The control group who underwent conventional home-based rehabilitation(n = 78, M ± SD) | df | F | Sig. | $\eta^2$ |
|---|---|---|---|---|---|---|
| Prerehabilitation | 57.83 ± 11.13 | 55.78 ± 10.72 | (,1160) | 1.42 | .234 | 0.010 |
| Postrehabilitation | 61.83 ± 11.85 | 57.81 ± 11.12 | (1,160) | 4.50 | .035 | 0.027 |

ANOVA = analysis of variance, df = degree of freedom, M = mean, PPVT-R = Peabody Picture Vocabulary Test-Revised, SD = standard deviations.

**Table 3**

Descriptive statistics and regression analysis of the 3 tasks on the frequency of training sessions and scores.

| | Frequency of training sessions (M ± SD) | Training scores (M ± SD) | Regression equation | $R^2$ | df | F | Sig. |
|---|---|---|---|---|---|---|---|
| Language tasks | 79.55 ± 110.50 | 281.44 ± 188.23 | y = 0.388x + 229.94 | 0.15 | (1,60) | 10.66 | .002 |
| Memory tasks | 82.10 ± 102.01 | 139.84 ± 81.43 | y = 0.362x + 115.64 | 0.13 | (1,39) | 5.89 | .020 |
| Cognition tasks | 81.43 ± 112.17 | 257.97 ± 163.52 | y = 0.331x + 218.64 | 0.11 | (1,55) | 6.76 | .010 |

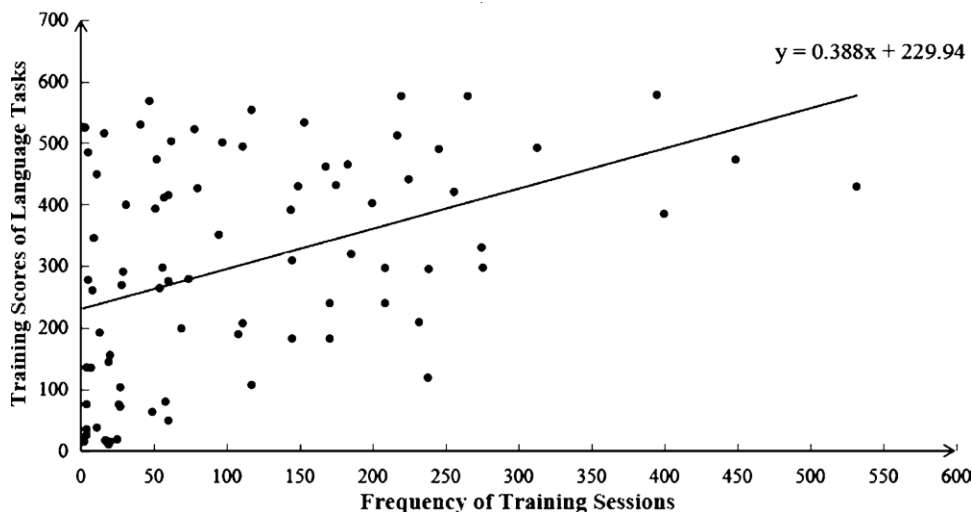M = mean, df = degree of freedom, SD = standard deviations.

**Figure 3.** Regression between the frequency of training sessions and the training scores of language tasks.

Specifically, the PPVT-R results for children with DLD in the cloud-based rehabilitation group were significantly higher than those in the control group were. The study also found that the number of rehabilitation sessions for the cloud-based rehabilitation group effectively predicted their performance on language, memory, and cognition training tasks; that is, the more rehabilitation sessions, the better the outcome for children with DLD.

COVID-19 has made it hard for us to go out, and the task of rehabilitating children with DLD has been severely affected when we were not able to go out. It is crucial to provide scientific and timely treatment and feedback to children with DLD, as they can only recover at home and cannot be promptly evaluated by doctors. Cloud-based rehabilitation can provide scientific and timely treatment protocols and feedback to children with DLD, beyond the limitations of time and space. The results of this study support the effectiveness of cloud-based rehabilitation on the JingYun Rehab Cloud Platform for children with DLD.

The results also showed that the number of training sessions was directly proportional to the performance of children with DLD in language, memory, and cognition training tasks. Skinner's[28] reinforcement theory may provide an explanation for these results. It considers that language, like

other social functions, is acquired through operant reflexes and that children's language acquisition is based on reinforcement theory linking words to their meanings. Thus, the more substantial the associations formed during constant repetition of an activity. Therefore, it is also argued that the more training the children with DLD in this study received, the better their performance on language, memory, and cognition training tasks. Previous studies have also highlighted that speech-language therapy frequency and intensity are critical factors in the recovery of language communication.[29] These suggest that both rehabilitation modality and frequency are essential factors in the rehabilitation of children with DLD.

In addition, the language training task, memory training task, and cognition training task utilized in the study measured children's language and nonverbal cognition abilities, which were found to facilitate the rehabilitation of children with DLD. Children with DLD have problems communicating with and interacting with their peers. As a result, increasingly negative interactions with peers are at a significantly increased risk of developing behavioral problems, such as problems with reading, spelling, and grammar, which have been found to occur in children with DLD.[30] The triple tasks of language, memory, and cognition improved the child's
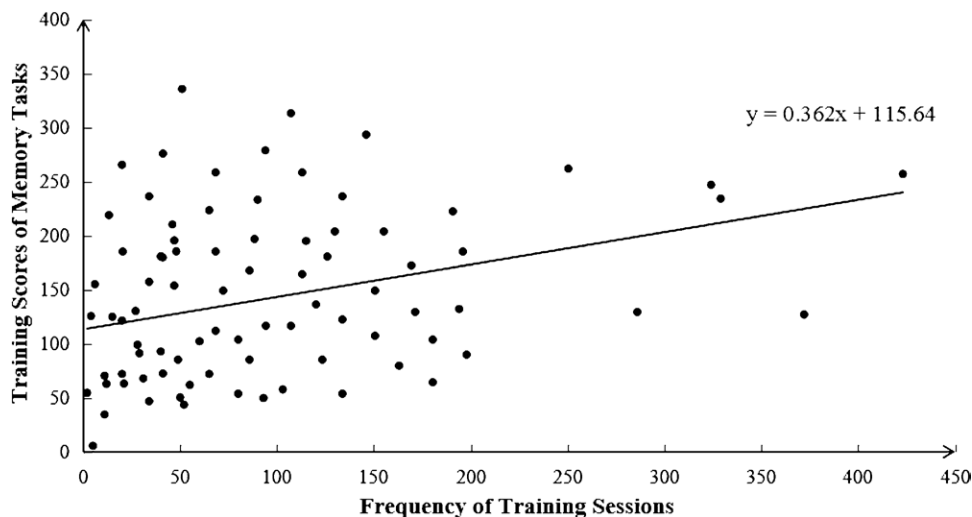


**Figure 4.** Regressions between the frequency of training sessions and the training scores of memory tasks.
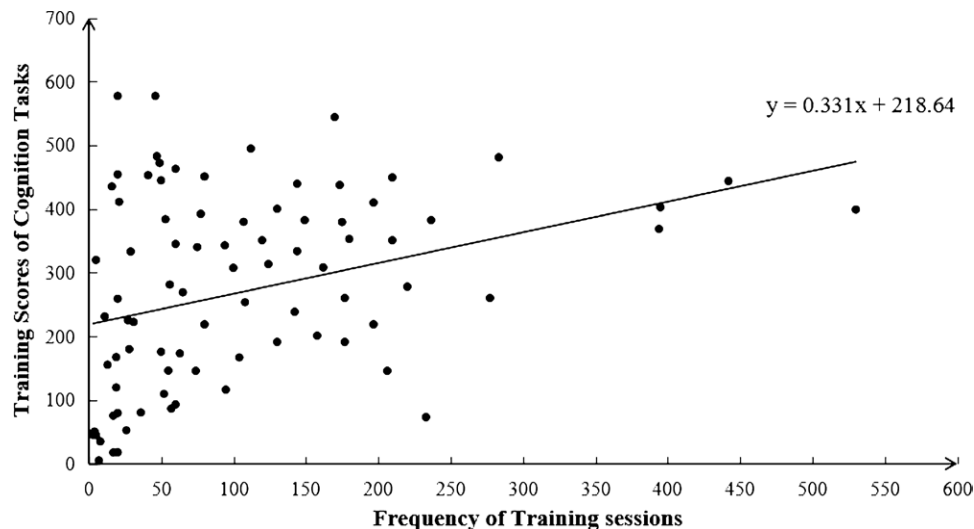
**Figure 5.** Regression between the frequency of training sessions and the training scores of cognition tasks.

response to external stimuli. Previous research has shown that this approach leads to children with language impairments being more proactive in communicating and positively interacting with others, thereby unlocking their latent language abilities.[31]

Lamb[32] proposed the neurocognitive linguistic theory, which states that the language system is part of the human cognitive system. The language relationship network contains several subsystems, such as the conceptual and phonological subsystems[32] The theory indicates that language development is closely related to cognitive development, and at the same time is an indicator of intelligence diagnosis; children's language development can promote growth hormone secretion in children, stimulate brain development, promote children's intellectual development, and have a positive role in improving children's language communication skills. Some researchers have used targeted intervention stimuli to enhance children's ability to observe and feel, and verbal communication training has gradually increased their comprehension. The child's boldness in expressing his thoughts is a simple repetition of rehabilitation training and the beginning of the child's understanding of language and expression of his thoughts, which can awaken latent language skills.[33] Therefore, a more effective treatment method is 1-on-1 training according to the child's condition and guiding the child to learn the language and communicate through sight, hearing, memory, and movement. The design of a more targeted treatment plan for children with DLD or other language and speech disorders is worth exploring.

### 4.1. Study limitations

The current study has limitations and strengths. The unique situation during the COVID-19 pandemic allowed us to study emergency situations and the sudden and total changes in all activities, offering insight into the effectiveness of cloud-based rehabilitation on the JingYun Rehab Cloud Platform in these circumstances. This study had a risk of selection bias. Patients' parents who felt an urgent need for treatment could have accepted cloud-based rehabilitation more easily. The digital divide (no available technology, internet connections, or digital knowledge) of families could also have precluded children with DLD from accessing the services. The social interactions and Full-Scale Intelligence Quotient of children with DLD are also important observation factors, and future studies could explore this issue.

In addition, future studies using electroencephalogram, magnetic resonance imaging, a more extended follow-up period, and comparison of the training effects of the remote cloud-based rehabilitation group and the in-person rehabilitation training group will provide more complete data. This will allow the confirmation of the effectiveness of the services provided in the cloud-based rehabilitation.

## 5. Conclusion

The COVID-19 pandemic has caused numerous problems worldwide. The disease also causes many problems for health care providers and several occupations because of its high transmission rate. In this regard, problems related to service provision relate to SLPs in children. As such, SLPs must dedicate effort to the proper provision of tele-practice services. The current study compared the therapeutic effects of cloud-based rehabilitation on the JingYun Rehab Cloud Platform for children with DLD for 3 months during the epidemic. The results showed that cloud-based rehabilitation positively affected the treatment of children with DLD, with a significant improvement in the PPVT-R scores. The frequency of the training sessions was proportional to their performance on the memory, matching, and language tasks. This study demonstrated the effectiveness of cloud-based rehabilitation on the JingYun Rehab Cloud Platform for the treatment of children with DLD.

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