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Acquisition of Digital Literacy Skills in Learners with Developmental Disabilities

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Acquisition of Digital Literacy Skills in Learners with Developmental Disabilities

One of the key objectives for supporting learners with developmental disabilities is to equip them with skills essential for learning, working, and living as independently as possible. As technology continues to advance and integrate into every aspect of our lives (Erwin & Mohammed, 2022)—from daily communication (e.g., Cihak et al., 2015), navigation (e.g., Hester et al., 2023; Yuan et al., 2019), time management (e.g., Balint-Langel et al., 2020), to financial transactions—digital literacy has become a vital component of these skills. Digital literacy encompasses the abilities to effectively access, understand, navigate, evaluate, and create information using digital technologies (Law et al., 2018). This includes proficiency with digital devices (e.g., computers, tablets, and smartphones), operating systems (e.g., iOS and Android), platforms (e.g., social media, blogs, and online databases), and applications (e.g., Google Maps, Zoom, and online storage applications) for personal, educational, or professional purposes (Helsper et al., 2015).

Digital literacy proficiency has been reported to promote and provide opportunities for education, communication, and employment for learners with developmental disabilities (Baxter & Reeves, 2023; Cihak et al., 2015). Digital technology has also been linked to benefits in their academic engagement, social interactions, and quality of life (Ozkan et al., 2013; Gunderson et al., 2017). For example, Gunderson et al. (2017) provided academic instruction via iPads which improved academic achievement and work completion and engagement among their participants with developmental disabilities. The participants further indicated their preference for iPad-based instruction over more traditional instructional modalities (i.e., teacher-delivered instruction or paper worksheets). Similarly, Cihak et al. (2015) taught three high school students with intellectual disabilities to use email, social bookmarks, and cloud storage. The participants indicated a preference for emailing and social bookmarking, noting these skills were beneficial for communicating with their friends and family. They also expressed a willingness to continue using email and social bookmarking and to recommend these digital tools to their peers. Given the growing usage of and reliance on technology, supporting learners with developmental disabilities will require practitioners to intentionally consider digital literacy as part of the instructional curriculum to facilitate their independent living and meaningful participation in society.

Despite its importance, learners with developmental disabilities often encounter various challenges in digital literacy (Kling & Wilcox, 2010; Tanis et al., 2012), especially with tasks that require multiple steps (Randall et al., 2020; Stierle et al., 2022), such as using digital devices, navigating platforms, and operating applications. For example, common digital activities such as emailing, bookmarking, and using cloud storage have been task-analyzed into more than ten steps by Cihak et al. (2015). Due to the often-sequenced steps involved in these tasks, a chaining procedure (Cooper et al., 2020) should be considered when teaching these complex digital tasks. That is, practitioners need to first conduct a task analysis and break the task down into multiple smaller, teachable discrete steps (Cooper et al., 2020) and teach the chain. Among the chaining procedures, forward chaining has been shown to be effective in prior studies that taught digital literacy tasks to learners with developmental disabilities (e.g., Balint-Langel et al., 2020; Yuan et al., 2019). In forward chaining, the instruction of the task follows its naturally occurring or logical sequence, starting with the initial step. Each subsequent step is only introduced after the mastery of the preceding step, until all steps within the task are mastered. Because the steps are taught in the order they naturally occur in the chain, forward chaining is sometimes considered the easiest to use and may result in sustained long-term performance (Noell et al., 2021). In addition, forward chaining has also been recommended when a learner is unlikely to complete the chain after an error (Noell et al., 2021). It is particularly relevant for tasks on digital applications, as an incorrect step would likely lead to functions unrelated to the tasks and prevent a learner from completing the tasks.

Using forward chaining, Yuan et al. (2019) taught three young adult learners with intellectual and developmental disabilities to plan routes using Google Maps. The skill was first task analyzed and divided into six smaller steps. Then, the authors taught these steps one at a time according to the task sequence. After a participant had mastered one step, they were introduced to the next. The authors kept teaching the subsequent steps until all six steps had been mastered. Similarly, Balint-Langel et al. (2020) also taught three young adults with intellectual and developmental disabilities to schedule university advising appointments using the Calendar application. Similar to Yuan et al. (2019), Balint-Langel et al. analyzed the task into eight steps and taught each step one at a time sequentially, starting from the first step. Both studies demonstrated that learners with developmental disabilities successfully acquired the target digital skills through forward chaining. We further noted that the majority of the participants in both studies were also able to navigate their community and attend scheduled appointments independently, even when they were only taught to set up routes and appointments using digital applications, indicating that teaching learners various digital literacy skills may automatically facilitate their independence in daily life.

Despite the efficacy demonstrated in the studies, forward chaining could be slow to complete (Chazin et al., 2017). For example, learners are only taught one step at a time, and they may not have an opportunity to experience or perform the steps that are not targeted during instruction (e.g., Balint-Langel et al., 2020; Yuan et al., 2019). Total-task chaining could provide learners with opportunities to perform all steps in a task, with the instructor assisting on any steps that they cannot perform (Cooper et al., 2020). However, it could also increase the probability of errors as the chained task becomes more complex (Chazin et al., 2017). As such, a modified procedure—clustered forward chaining (CFC)—could be considered (Chazin et al., 2017). CFC embeds total-task chaining within forward chaining by grouping task steps into several sequenced clusters. Within each cluster, total-task chaining is used, where all steps in the cluster are assessed and taught in a single session. Upon mastery of all steps in a cluster, instruction progresses to the next cluster using forwarding chaining. This is repeated until all clusters of steps are mastered. For example, Chazin et al. (2017) used CFC to teach a young adult with autism to follow three recipes. During this study, each recipe was grouped into three clusters of five steps for a total of 15 steps. The researchers taught all steps in each cluster using total-task chaining and the clusters through forward chaining. Not only did the participant learn to correctly follow all three recipes, but the authors also noted that mastery of each recipe was achieved in fewer instructional sessions (e.g., 14 sessions) compared to the minimum of 45 sessions that would have been required using traditional forward chaining by targeting one step per session.

Even though CFC appears efficient in teaching tasks comprising multiple steps, existing studies have yet to investigate its effects on teaching digital literacy tasks to learners with developmental disabilities. In addition, while a variety of digital literacy tasks have been taught to learners with developmental disabilities in previous studies, none, to our knowledge, has specifically addressed digital transactions that require learners to perform transactions over digital platforms, such as purchasing groceries, ordering food, and booking flights. As acquiring these skills could be beneficial for individuals with developmental disabilities by circumventing some of the challenges associated with traditional in-person monetary transactions (e.g., difficulties in verbal communication and calculating purchase totals and change due; Goo et al., 2016), this current study addressed the following questions: (a) What are the effects of CFC on acquiring various digital transaction tasks in learners with developmental disabilities? (b) How do participants and instructors perceive digital literacy instruction using CFC?

Method

Participants

Three school students participated in this study. The inclusion criteria included (a) a developmental disability diagnosis, (b) the requisite fine motor skills for using digital devices (e.g., touching the screen, pressing a button, etc.) as reported by teachers and parents, (c) the ability to read and write at a second-grade level, and (d) a prioritized need for acquiring digital literacy skills as identified by their parents. Individuals with aggression, frequent noncompliance during classroom instruction, or frequent school absences were excluded. Three participants who met the inclusion criteria were nominated by their teachers. We obtained parental permissions, as well as verbal and written assents from the participants, before enrolling them in the study. All three received a diagnosis of developmental disabilities from medical doctors licensed to make such diagnoses at a local hospital based on ICD-10-CM criteria (World Health Organization, 1992). In addition, they all owned Android phones that were accessible only after school hours. They were proficient in using their phones for basic tasks such as making calls, sending texts, listening to music, and watching videos, but they did not use any other functions.

Lei, a 13-year-old boy, attended the sixth grade at an urban public school in Southern China that serves students with disabilities from kindergarten through grade six. Lei received academic instruction (e.g., reading, writing, and math) and training in independent living skills (e.g., cooking, laundry, and cleaning). According to his teacher, Lei's reading and writing skills were at the third-grade level. He also demonstrated proficiency in managing daily personal tasks, such as dressing, oral hygiene, cooking, and doing laundry.

Yang and Lan, both 16-year-old girls, were enrolled in an urban special education school serving students aged 16 to 18 in Southern China, where they lived on campus. The school focused on vocational, living, and academic skills (e.g., reading, writing, and math). According to their teacher, Yang's reading and writing skills were at the fifth-grade level and Lan's at the third-grade level. They both demonstrated many independent living skills while living on campus, managing tasks such as laundry, cleaning, grocery shopping, and cooking.

Settings and Instructors

Lei's sessions were conducted at his desk in his classroom during extended breaks between classes, each lasting for approximately 30 min. His class typically included six to eight students with developmental disabilities. The classroom, measuring 20 ft by 20 ft, was equipped with a desk for the teacher, several desks and chairs for students, a whiteboard, and a range of leisure and academic items (e.g., toys and books). Prior to each session, his instructor repositioned his desk to a quieter area (e.g., a classroom corner) to minimize distractions. Sessions for Yang and Lan were conducted after school hours in the resource room also measuring 20 ft by 20 ft, equipped with a desk, several chairs, and a variety of leisure and academic materials.

Two undergraduate students served as the instructors in this study. Both majored in special education, conducted the sessions and collected data in this study. Both were completing a special education internship at the participants' schools and had worked with the participants for at least two months before this study. The two instructors had received training in behavioral intervention techniques during their undergraduate courses and had 1 year of experience working with learners with developmental disabilities prior to this study. The first author conducted instructor training for implementing probes and intervention sessions using a procedural checklist consisting of the essential steps for the probe and intervention. The training sessions, each lasting between 20 and 30 min, were conducted before the baseline probes. The training concluded after three sessions for both instructors, as each achieved 100% procedural accuracy for at least two consecutive sessions.

Target Skills and Materials

Four digital literacy skills that involved online transactions were selected for all participants after consulting with their parents: placing restaurant contactless orders, ordering grocery deliveries, scheduling medical appointments, and making flight reservations, given their increasingly common usage in China (China Business Industry Research Institute, 2023). All participants also stated that they were interested in learning these digital skills during the assenting process. Because the study was conducted during school hours, the participants did not have access to their personal Android phones. Therefore, the instructor provided an instructional phone also equipped with the Android operating system. Prior to the baseline phase, all necessary applications were installed on the instructional phone.

Task Analysis and Validation

Each skill was task analyzed into nine steps (see Table 1 for the steps). We followed the procedure below to analyze and break down the tasks into smaller, discrete steps. First, the first author and two instructors used the instructional phone to execute the four skills and recorded the steps (e.g., Cooper et al., 2020; Noell et al., 2021). We then asked the participants' teachers, who had worked with them for at least 2 years, to review these steps. During their review, we asked them to consider the participants' existing skill sets. The steps they considered difficult for the participants were broken down into smaller units, and the steps that they considered easy were consolidated. Through this process, the research team and teachers collaboratively conducted the task analysis for each skill and identified the nine target steps per skill.

To assess whether the participants had the skills necessary to perform the identified steps, the two instructors provided them with the instructional phone and observed their use of the phone and applications unrelated to the current study (e.g., making phone calls, listening to music). Additionally, two special educators and one 13-year-old student with typical development, none of whom were involved in the study, were asked to follow the nine steps to perform the four skills on instructional phones.

Tasks, Notecards, and QR codes

A pool of 15 to 20 tasks was developed for each skill. Instructors selected a task for each session in a semi-random manner to ensure no task was repeated within four consecutive sessions. To assist participants in inputting keywords accurately, notecards were prepared before the study. These cards only displayed key information for the tasks, including names of items for placing grocery delivery and restaurant orders, departure and arrival cities and dates for making flight reservations, and medical specializations and appointment dates for scheduling medical appointments. However, no instructions on how to operate the applications were displayed in the notecards. In addition, for contactless restaurant orders, QR codes identical to those used in the selected restaurants were printed. The selection of these restaurants was based on their availability of contactless ordering via QR code and the participants' preference for them.

Dependent Variables

Probes were conducted across baseline, intervention, and maintenance phases. In each probe, we counted the number of independent correct steps that the participant completed for each skill. An independent correct step was defined as one that the participant correctly performed within 5 s following a task direction or the completion of a preceding step, without prompts. Steps not completed within 5 s or performed incorrectly were scored as incorrect. Similarly, a step performed out of sequence was also considered incorrect.

Experimental Design

We used a concurrent multiple baseline design across skills to evaluate the effects of CFC on the acquisition of digital literacy skills in our participants. To demonstrate the functional relation, the introductions of the intervention were staggered across the four skills at different times (Kazdin, 2011). The effects of the intervention were demonstrated when participant performance changed after and only after the intervention was introduced.

Data Analyses

To determine the effects of the CFC on teaching digital literacy tasks, both visual and statistical analyses were employed. Visual analysis was conducted by examining six data features: level, trend, variability, overlap, immediacy of effects, and consistency across similar phases (Kratochwill et al., 2013). A functional relation was established by assessing whether behavior changes occurred following the introduction of CFC and whether this pattern of change was consistent across the four digital skills.

We also conducted a statistical analysis to complement the visual analysis by quantifying the magnitude of the intervention effects. The between-case standardized mean difference (BC-SMD) was calculated to determine the intervention effects across skills for each participant and overall effects across all the participants of this study (Pustejovsky et al., 2014). We used the

Between-Case Standardized Mean Difference Estimator online calculator to compute BC-SMD effect sizes (Pustejovsky et al., 2022a). The BC-SMD effect size metrics are analogous to Cohen's *d* (Cohen, 1988; Valentine et al., 2016), allowing for a direct comparison of results. Following Cohen's guidelines, effect sizes were interpreted as follows: a small effect is indicated by a *d* value of 0.2, a medium effect by 0.5, and a large effect by 0.8.

Procedure

Baseline Probes

During each baseline session, we provided a participant with a task direction (e.g., "Book a flight from Nanjing to Shenzhen on December 12th," or "Please order iced boba milk tea.") along with a notecard and an unlocked phone placed in front of them. We recorded the number of correct steps completed independently by the participant. If a participant did not perform a step for 5 s or performed an incorrect step, we ended the session (i.e., the single-opportunity method; Lambert et al., 2016) and said, "Thank you. We are done for today." We marked that step as incorrect along with any subsequent steps. No instructions, prompts, or programmed consequences (e.g., feedback) were provided during baseline. If the participant asked any questions, we redirected them to the task and said, "Try your best." Each baseline session lasted between 30 s and 1 min.

Intervention

Each intervention session lasted between 2 and 5 min, during which CFC was used to facilitate the acquisition of digital literacy skills among the participants. Prior to the intervention sessions, the nine steps for each skill were organized into three clusters of three steps each (see Table 1). Each session targeted one cluster, with the steps from the subsequent nontarget clusters demonstrated by the instructors after teaching the current cluster. Instruction of the next cluster took place once the performance in the current cluster met the progression criterion during intervention sessions (i.e., 100% correct independent performance of all steps in the cluster across two consecutive sessions).

Instruction of each cluster of steps started with a 0-s delay to the model prompt. That is, immediately after each task direction (e.g., “Buy a cup of iced boba milk tea.”), the instructor provided the model prompt for the steps in the target cluster. The participant was then asked to perform these steps. Correct completion of the steps produced praise from the instructor, with each step marked as a prompted correct response. If the participant did not perform a modeled step correctly or did not perform a step within 5 s, the instructor repeated the model prompt for the incorrect step and asked the participant to try that step again. Once participants performed the step correctly, they were asked to continue with the remaining steps in the cluster. After completion of the target cluster, the instructor stated, “Now, I will do the rest,” and proceeded to complete the steps from the subsequent clusters.

Upon 100% prompted correct steps in the target cluster for one session, we increased the delay to the model prompts by a constant 5 s (i.e., 5-s constant prompt delay sessions). That is, after the task direction was presented, the participant was given 5 s to perform the steps in the target cluster independently. The instructor delivered praise upon correct independent performance of the steps in the target cluster and recorded each correct step as “independent correct.” If a step was not performed for 5 s or performed incorrectly, a model prompt was provided for that incorrect step. Once a participant’s performance met the progression criterion for a cluster, the instructor started the intervention for the next cluster. The participant was asked to perform the steps in the preceding cluster(s) before receiving intervention for the new cluster.

Intervention and Maintenance Probes

The procedure of intervention and maintenance probes was identical to that of the baseline probes, with each lasting up to 3 min. Intervention probes were administered after each intervention session, and maintenance probes were conducted at least three times, starting one week after the intervention phase had ended.

Participant performance in the intervention probes was also used to determine the termination of the intervention. This termination criterion was independent of the progression criterion for cluster progression. When a participant achieved 100% independent correct performance for all steps within the target skill across two consecutive probes, the intervention phase for that skill was terminated regardless of whether the participant had completed the intervention for all clusters.

Social Validity

Social validity was assessed after the final maintenance probe. A six-item five-point Likert scale survey was used to evaluate social validity among participants. It featured different smiley faces—ranging from a frown to a happy face—for easy comprehension (Reynolds-Keefer et al., 2009; Stierle et al., 2023). Specifically, the scale ranged from a score of 1, shown as a frown face to indicate strong disagreement, to a score of 5, represented by a happy face to indicate strong agreement. Thus, the total possible score ranged from 6 to 30, with a higher score indicating greater acceptance. The survey was used to assess participants' perspectives on various aspects of the intervention, including enjoyment, perceived helpfulness, skill acquisition, efficiency, their willingness to participate in future interventions for learning similar skills, and the application of the target skills in other settings post-intervention. Participants also answered two open-ended questions.

We also administered the Intervention Rating Profile-15 (IRP-15; Witt & Elliott, 1985) to the two instructors to evaluate their acceptance of the intervention. The IRP-15 is a 15-item questionnaire using a 6-point Likert scale, ranging from 1 (strongly disagree) to 6 (strongly agree). The total scores range from 15 to 90, with an intervention considered acceptable if the score is 52.50 or higher.

Procedural Integrity and Interobserver Agreement

A second observer, an undergraduate student in the special education program with no relation to this study, was responsible for assessing interobserver agreement (IOA) and procedural integrity (PI) using the procedure checklists. Before assessing PI and IOA, the observer was trained to use the checklists and collect secondary data until they achieved 100% accuracy on both PI and IOA twice. PI data were collected for at least 50% of the probes in each phase (i.e., baseline, intervention, and maintenance) and the intervention sessions for all skills and participants. IOA data were collected for at least 50% of the probes in each phase across all skills and participants. All probes and intervention sessions were video-recorded, and the second observer reviewed the video recordings to collect PI and IOA data.

PI was calculated by dividing the number of correct steps by the total number of steps as implemented by the instructors. For Lei, the mean PI across skills was 93% (range: 85%-100%) for baseline probes, 95% (range: 90%-100%) for intervention probes, 100% for maintenance probes, and 90% (range: 80%-100%) for intervention sessions. For Yang, the mean PI was 94% (range: 90%-100%) for baseline probes, 100% for intervention and maintenance probes, and 96% (range: 82%-100%) for intervention sessions. For Lan, the mean PI was 100% for baseline, intervention, and maintenance probes, and 95% (range: 90%-100%) for intervention sessions.

IOA was calculated using point-by-point agreement. The IOA was 100% across skills for each participant's probe during all phases.

Results

Figures 1 represents the number of correct steps that the three participants independently completed for each skill during baseline, intervention, and maintenance probes. Table 2 shows the total number of intervention sessions that the participants received.

Visual Analysis

The visual analysis revealed a functional relation between the CFC and the four digital skills, with effects replicated within and across all three participants. Specifically, during baseline, Lei consistently performed the first two steps correctly for placing restaurant contactless orders, while he did not complete any steps correctly for scheduling medical appointments (Figure 1, left panel). For ordering grocery deliveries, Lei performed a maximum of one step (i.e., the first step) correctly. For making flight reservations, Lei did not complete any steps correctly for all but two baseline sessions, in which he performed the first step correctly. When the intervention was introduced, the performance of all the target skills increased. That is, Lei demonstrated immediate improvements in all target skills upon intervention. The data patterns were consistent with stable upward trends across all target skills during the intervention phase with no data overlap between the baseline and intervention phases. For placing restaurant contactless orders, it took Lei seven sessions to meet the termination criterion, with three in Clusters 1 and 2 and one in Cluster 3. He performed a mean of 5.29 correct steps (range: 3-9) during intervention probes. For ordering grocery deliveries, Lei required five sessions to meet the termination criterion, with three in Cluster 1 and two in Cluster 2. That is, his termination criterion was achieved for this skill before the intervention was introduced for Cluster 3. He performed a mean of 5.8 correct steps (range: 2-9) during intervention probes. For scheduling medical appointments, Lei required four sessions to meet the termination criterion, with three in Cluster 1 and one in Cluster 2. Similar to ordering grocery deliveries, the termination criterion was achieved before introducing Cluster 3. He performed a mean of 6.25 correct steps (range: 3-9) during intervention probes. For making flight reservations, Lei required three sessions to meet the termination criterion, all in Cluster 1. We did not introduce intervention for Clusters 2 and 3. He performed a mean of 8.33 correct steps (range: 7-9) during intervention probes. During the maintenance probes, though the data were slightly variable, he maintained a performance level that was comparable to that during intervention probes (M = 7.75; range: 3-9).

Yang did not perform any steps to schedule medical appointments and make flight reservations during baseline (Figure 1, middle panel). For placing grocery delivery orders, Yang also did not complete any steps correctly in all but one baseline probe, where she completed the first step correctly. When assessing placing contactless restaurant orders, Yang consistently performed the first two steps correctly. After introducing the intervention, her performance across all skills increased immediately. Similar to Lei, no data overlap was observed between the baseline and intervention phases for Yang. For scheduling medical appointments, Yang required a total of five sessions to achieve the termination criterion, with three in Cluster 1 and two in Cluster 2. That is, her performance met the termination criterion before the intervention was introduced for Cluster 3. During the intervention probes, she performed a mean of 6.2 correct steps (range: 1-9). For the remaining three skills, it took Yang eight sessions to meet the termination criterion, with three in Clusters 1 and 2 and two in Cluster 3 for the three skills. Her mean number of correct steps was 7.13 steps (range: 6-9) for placing restaurant contactless orders, 6.57 (range: 5-9) for ordering grocery deliveries, and 6.5 (range: 3-9) for making flight reservations. Finally, Yang maintained her performance on all skills as she continued to independently complete all steps correctly one week after intervention sessions.

Finally, Lan did not complete any correct steps for placing grocery delivery orders, scheduling medical appointments, or making flight reservations during baseline (Figure 1, right panel). However, she consistently performed the first two steps correctly for placing restaurant contactless orders. Upon the introduction of the intervention, there was an immediate and stable increase in performance across all target skills, without data overlaps between the phases. For restaurant contactless orders, Lan required 10 sessions to meet the termination criterion, with five in Cluster 1, three in Cluster 2, and two in Cluster 3. During the intervention probes, she performed a mean of 6 correct steps (range: 3-9). For the remaining three skills, Lan required eight sessions to meet the termination criterion for each skill, with three in Clusters 1 and 2 and two in Cluster 3. Her mean numbers of correct steps were 6 steps (range: 3-9) for ordering grocery deliveries, 6 (range: 3-9) for scheduling medical appointments, and 5 (range: 3-9) for making flight reservations. Lan maintained her performance on all the skills with independent completion of all the steps one week after the intervention sessions.

Statistical Analysis

BC-SMD was used to further examine the effects of CFC and to support the findings of the visual analysis. The BC-SMD results for each participant are as follows: 1.39 (SE = 0.42; 95% confidence interval [0.48, 2.31]) for Lei, 1.25 (SE = 0.42; 95% confidence interval [0.28, 2.22]) for Yang, and 0.92 (SE = 0.34; 95% confidence interval [0.11, 1.72]) for Lan. As such, the statistical analysis revealed large intervention effects on all four digital skills for each participant. The overall BC-SMD effect size across all the participants was 1.202 (SE = 0.27; 95% confidence interval [0.67, 1.76]), also indicating a large effect of CFC.

Social Validity

For social validity, the participants rated the intervention with a score between 23 (Lan) and 28 (Lei and Yang). All the participants agreed or strongly agreed that they liked the intervention, found the intervention helpful, thought the intervention was effective and efficient, and would participate in the intervention again to learn additional digital literacy skills. On the open-ended questions, all participants reported that they liked the target skills and felt confident after learning these skills, as they were able to complete these tasks independently. Lei further reported that he had subsequently completed contactless orders at his favorite restaurant and ordered online grocery deliveries at home. Although he did not have an opportunity to make an online flight reservation, he looked forward to a family vacation as his parents would let him book the flights. Yang and Lan did not have a chance to apply these skills yet. See https://osf.io/juq5b?view_only=746e92fd85ee4c1b82518ce4936c6c66 (masked for peer review) for participant social validity results. On IRP-15, both instructors rated the intervention highly (i.e., 85 and 88 out of 90), indicating they perceived the intervention as highly acceptable.

Discussion

This study examined the effects of CFC on teaching multiple digital literacy tasks to learners with developmental disabilities. The results provided additional support for the use of CFC in teaching chained tasks. Previously, Chazin et al. (2017) demonstrated the effectiveness of CFC in teaching an adult with autism to follow recipes. Our study further established a functional relation between CFC and improved performance across four sets of digital transaction tasks in three adolescents with developmental disabilities. Specifically, during the baseline phase, our participants performed a maximum of two steps across the target skills. However, their performance immediately improved once CFC was introduced, and all participants acquired all four skills after the intervention. Their high-level performance of the skills was also maintained for at least one week after the intervention.

Previous research has targeted a range of digital literacy skills, including the use of Calendar, email, and Google Maps applications (Balint-Langel et al., 2020; Cihak et al., 2014; Yuan et al., 2019). This study extended digital literacy instruction to include transactional tasks. Given the increasing prevalence of digital transactions in daily life, proficiency in these skills is becoming essential (Van Dijk & Deursen, 2014). For example, an estimated 85% of the population in China relies on digital platforms and applications for daily transactional needs (China Business Industry Research Institute, 2023). Proficiency in these skills may be particularly beneficial for individuals with developmental disabilities as it helps circumvent some of the challenges associated with traditional in-person transactions, such as verbal communication difficulties and the complexities of calculating purchase totals and change (Goo et al., 2016). Our social validity results also supported addressing digital transactions during instruction. Our participants reported finding these skills valuable and indicated increased confidence in managing daily activities independently, such as ordering food at restaurants, shopping for groceries, and booking flights. Future research should consider addressing additional digital transaction skills to further support the independence of these learners in their everyday activities.

In teaching these digital transaction tasks, we observed that two of our participants met the intervention termination criterion before completing the intervention for all clusters for some skills. This early conclusion of the intervention phase was likely due to a combination of our CFC arrangement and measurement. First, after teaching the target cluster, our instructors were required to complete the steps in the remaining clusters in front of the participants. Even though our participants were not prompted through the remaining clusters (e.g., Chazin et al., 2017), it appears that the mere exposure to the instructor demonstrations allowed Lei and Yang to acquire the nontarget steps through observation. Similar findings have also been reported in some previous studies, where learners with developmental disabilities acquired chained tasks through observation (Griffen et al., 1992; Wolery et al., 1991). For example, Griffen et al. (1992) found that their participants were able to perform food preparation steps with over 85% accuracy solely by observing their peer. As such, providing opportunities for learners to observe demonstrations of nontarget steps may be efficient and could help facilitate their acquisition of these chained tasks, including those that require using digital platforms.

It is important to note that previous research has supported the efficiency of either instructor-led or learner-led completion of nontarget steps when teaching chained tasks (Chazin et al., 2017; Spooner et al., 1986), as both provide learners with exposure to the entire task (Bancroft et al., 2011). While the relative efficiency between the two approaches remains unclear (Cooper et al., 2020), it is possible that some behavioral requisites are necessary for the instructor-led approach to be effective. In our study, Lan still required intervention for all clusters despite the instructor demonstrations. Anecdotally, we observed that Lei and Yang were attentive and continuously watched the instructor demonstrations across the tasks, while Lan was often distracted and looked around during the demonstrations. As attention is likely a necessary condition for demonstrations to be effective, practitioners choosing to use instructor-led completion of nontarget steps should ensure student attention during the demonstrations. Nevertheless, as we did not collect specific attention data, future research should consider examining the relation between attention and digital task acquisition with instructor-led completion in a CFC procedure.

Second, our inclusion of continuous performance probes facilitated the timely detection of participants' mastery performance. Specifically, instead of requiring the participants to complete the intervention for all steps before concluding (e.g., Balint-Langel et al., 2022; Yuan et al., 2019), we conducted continuous probes following each intervention session to provide opportunities for the participants to independently perform all steps in a skill. Their performance during these probes was used to inform the conclusion of the intervention phase. Consequently, it was possible to conclude the intervention phase for a participant without completing the intervention for all clusters, provided their performance met the termination criterion. Due to observational learning, Lei and Yang's performance reached the termination criterion after receiving intervention for only one or two clusters.

Similar observations were also noted in Lambert et al. (2016), where researchers intermittently probed participants' performance when implementing a forward-chaining procedure. The intervention phase concluded when a participant correctly performed all steps in the target task across three consecutive probes, irrespective of whether the intervention had been delivered for every step. The authors also noted earlier conclusions of the intervention phase than initially anticipated. Compared to intermittent probes (e.g., Chazin et al., 2017; Lambert et al., 2016), continuous probes could allow for an ongoing evaluation of learners' performance (Horner & Baer, 1978) to facilitate prompt decision-making on discontinuing interventions once a skill is mastered. Consequently, it could decrease the number of unnecessary intervention sessions, allowing for the reallocation of time and attention towards other critical skills.

Besides the effectiveness of CFC, we also assessed the perceptions of both participants and instructors for the use of CFC for teaching digital literacy tasks. All participants reported enjoying the intervention, as they acquired multiple digital literacy skills through CFC. Our instructors also viewed CFC positively and considered it an acceptable intervention procedure. They highlighted its ease of implementation, suggesting that CFC is not only effective but also user-friendly. This ease of implementation was corroborated by instructors' rapid mastery of the CFC procedures during initial training and their high procedural fidelity throughout the intervention phase. Moreover, the instructors found CFC to be time-efficient, with each session lasting no longer than 5 min. The brief sessions made it possible to conduct the intervention during short recesses, making CFC a practical option for school settings.

Finally, it is important to emphasize that digital transactions inherently involve financial management. As such, developing personal financial skills should be an important instructional component for adolescents with developmental disabilities. Additionally, we recommend establishing a system of communication between learners with developmental disabilities, particularly those under the age of 18, and their guardians regarding appropriate usage of the financial transaction applications. If applications incorporate transaction monitoring features, we recommend that these features be enabled. All applications used in this study could be configured to send immediate text notifications to guardians if a payment confirmation is initiated. The guardian is then required to approve the payment, thereby adding an additional layer of security. Guardians should consider activating these features to mitigate risks associated with digital monetary transactions.

Limitations

Our study has several limitations. First, our participants exhibited relatively high levels of functional skills. Consequently, the effectiveness of the CFC procedure remains unclear for learners with lower skill levels. In addition, all participants had access to and prior experience with digital devices and some applications. As such, future research should also assess the intervention effects on participants with limited exposure to digital platforms and applications.

Second, our instructors provided digital devices for teaching and probing the target skills. Although one participant reported having completed online grocery shopping and contactless restaurant ordering using his phone outside of the experimental setting, we did not systematically assess whether participants generalized the learned skills to their personal devices or across different devices (e.g., iPads). Similarly, we did not conduct generalization probes for contactless ordering using QR codes from different restaurants. It is recommended that future replications include generalization probes to evaluate the participants' ability to transfer skills across a range of digital devices, platforms, and media (e.g., QR codes) and use multiple-exemplar training (Cooper et al., 2020) in cases where challenges in generalization are observed.

Conclusion

As digital technologies grow increasingly integral to daily life, incorporating digital literacy skills into the educational curriculum for learners with developmental disabilities is becoming essential. The results of our study supported the effectiveness of CFC in teaching various digital literacy skills to learners with developmental disabilities. Importantly, instructors in this study considered CFC to be user-friendly and easy to use. When arranging CFC, it may be beneficial to include ongoing assessments and provide learners with opportunities to experience nontarget clusters, such as instructor demonstrations in this study. Such strategies facilitate intervention efficiency by accelerating learners' acquisition of digital tasks and enabling timely decisions on the mastery of these skills.

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Figure 1

Number of Steps Performed Independently by Lei, Yang, and Lan across Probes

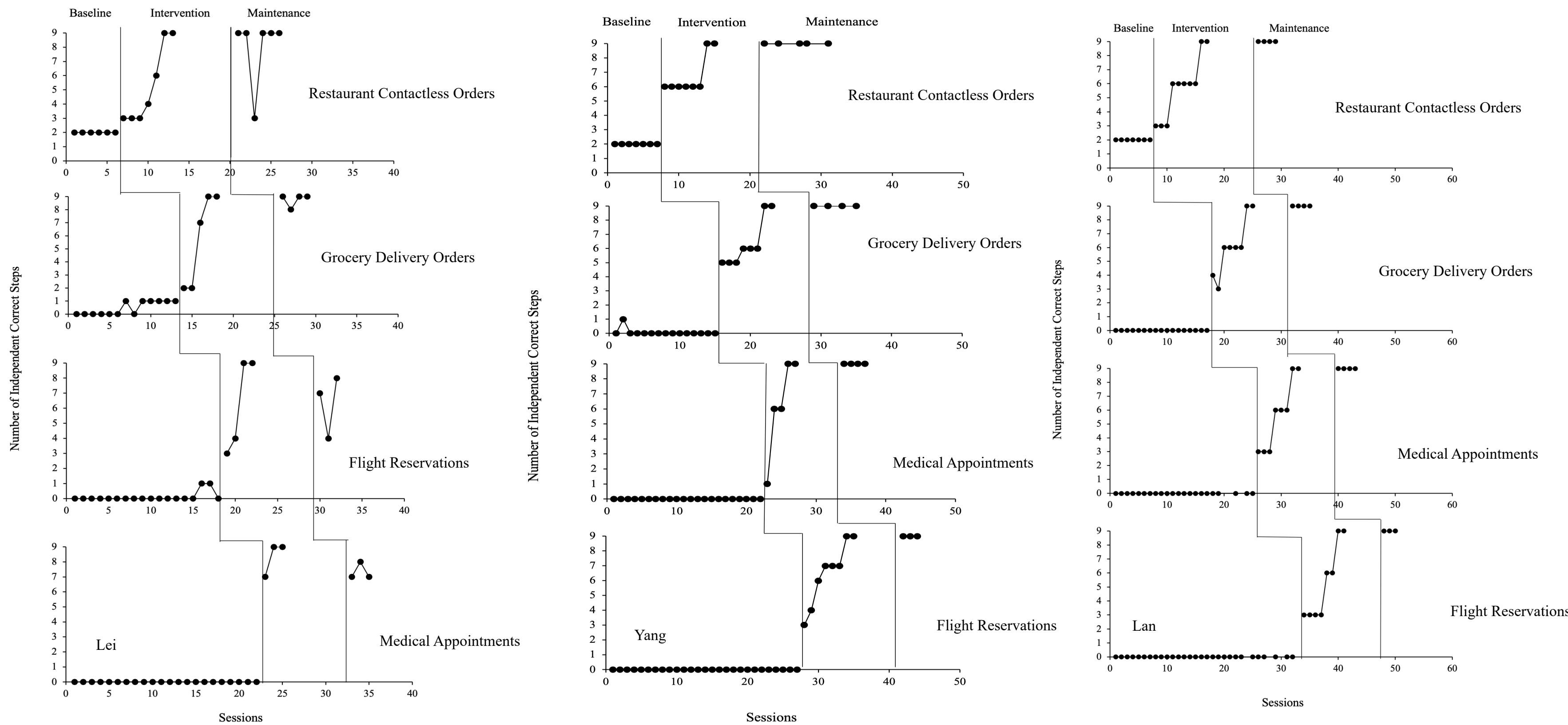

Table 1

Clusters and Steps for Four Digital Literacy Skills

Cluster	Steps	Restaurant Contactless Order	Grocery Delivery Order	Flight Reservations	Medical Appointments
1	1	Tap the Camera app	Tap the Meituan Grocery Shopping app	Tap the Ctrip app	Tap Alipay—Medical Health
	2	Scan the QR code	Scroll and browse through the items	Select the departure and arrival cities in the designated spaces, as specified on the notecard.	Press “appointment”
	3	Press the link provided by the QR code to access the digital menu	Locate and select all the items listed on the notecard	Select the date provided on the notecard	Locate and select the medical specialization as indicated on the notecard
2	4	Locate and select “pick up” service option	Add the selected items to the cart	Select a flight	Select a hospital
	5	Scroll and browse the menu	Select the saved delivery address	Select the “Economy Class” option	Select the date provided on the notecard
	6	Locate and select all the items listed on the notecard	Select a delivery time	Select from saved passenger details	Select an appointment time
3	7	Add the selected items to the cart	Press confirm items	Choose a seat	Select from the saved patient profiles
	8	Press confirm items	Select a saved payment method	Select “no” to opt out additional services	Confirm appointment details
	9	Press confirm payment	Press confirm payment	Press confirm payment	Press confirm appointment registration fee payment

Table 2

Total Number of Intervention Sessions Received

Participant	Cluster 1	Cluster 2	Cluster 3	Total Sessions
Restaurant Contactless Ordering				
Lei	3	3	1	7
Yang	3	3	2	8
Lan	5	3	3	10
Grocery Delivery Order				
Lei	3	2	*	5
Yang	3	3	2	8
Lan	3	3	2	8
Flight Reservations				
Lei	3	*	*	3
Yang	3	3	2	8
Lan	3	3	2	8
Medical Appointments				
Lei	3	1	*	4
Yang	3	2	*	5
Lan	3	3	2	8

Note. * no intervention took place for the cluster