Education and Training in Developmental Disabilities, 2009, 44(4), 493–508

Acquisition and Generalization of Chained Tasks Taught with Computer Based Video Instruction to Children with Autism

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Abstract: Three elementary aged students with autism participated in an evaluation of computer based video instruction that targeted functional life skills. The effects of the software were analyzed in the context of a multiple probe design across and replicated across participants. This study represents a departure from more traditional video based instruction for individuals with autism because it combines video modeling as well as computer based simulation training in absence of any in-vivo instruction. All instruction took place on the computer and student's performance in vivo was the primary dependent measure. The participants each mastered all the skills they were taught via the computer and generalized this to the natural environment. They maintained the skills after a two-week follow up.

Learning functional life skills is the cornerstone of many Individualized Education Plans for students with autism. A focus on functional skill instruction allows students the opportunity to learn valuable skills that lead to greater independence and autonomy (Brown, 1979). One of the key features of special education services is the ability of educators and parents to focus instruction and curriculum on those areas where a student needs the greatest amount of assistance to increase their independence. In the classroom, proving student with frequent enough practice, sufficient guided repetition, and opportunities to use a wide range of materials to promote generalization can be a challenge when a teacher has a group of learners with heterogeneous needs who all require intensive instruction. One solution to this logistical challenge is to staff more paraprofessionals or teacher's aides in the classroom to provide more individualized attention to students. Another solution is to plan ways for students to independently engage in learning activities that do not require direct teacher supervision.

Learning activities centered on functional skills and supported by video or computer based video instruction (CBVI) have a small but growing body of literature support and may be one way to address students' needs for individualized instruction. The use of CBVI takes many forms but relies heavily on the growing body of evidence that suggests video can be a powerful teaching tool (Ayres & Langone, 2005). For example, Charlop-Christy, Le, and Freeman (2000) used video modeling to effectively teach hygiene skills (among other pre-academic and social skils). Alberto, Cihak, and Gama (2005) used video as an instructional tool to teach the use of an ATM machine to middle school aged students. Similarly, Sigafoos et al. (2005) employed video modeling to teach microwave use to adults with developmental disabilities. Even when students are taught to access video independently (on video tape or DVD), adult interaction is still integral to the instruction. The role of the adult may not be as a teacher per se, but their role is important to the instructional arrangement because they often set up the instructional setting for the video or aide the student in moving from video to *in-vivo* practice.

CBVI allows greater student independence during instructional activities because the video interactions are mediated by computer which provides prompting (often in the form of video) and an opportunity for the student to practice aspects of the target behavior. In

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this way, the instruction becomes more of an active simulation. In 2004, Simpson, Langone, and Ayres used CBVI to effectively deliver social skills instruction to young students with autism in teaching the students to appropriately engage in social protocols like turn taking and waiting for a turn. Mechling, Pridgen, and Cronin (2005) used CBVI to teach verbal responses to questions that a student would encounter in fast food restaurant. This particular intervention required teacher involvement (prompting and error correction) however, it provides an example of how as technology improves, there is greater potential for students to engage in more independent learning activities. In 2007, Mechling and Ortega-Hurndon used CBVI to teach three complex chained tasks to young adults with developmental disabilities. Similar to the methodology used in Mechling et al. (2005), computer controlled the delivery of video and the teacher assisted with prompting. Ayres, Langone, Boon, and Norman (2006) used CBVI to teach purchasing skills to middle school aged students with intellectual disabilities. In this case, all instruction and prompting were delivered by the computer and students worked independently during this portion of instruction. Participants still engaged in related purchasing skill instruction with a teacher though. Mitchell, Parsons, and Leanoard (2007) present one of the most technologically advanced examples of combining video and computer interaction for students with autism. They used a virtual reality environment to instruct teenaged students how to interact in a café (order food, sit at a table etc). In the cases listed above, teachers were an integral part of facilitating the interactions of the student with the technology and video. With one of the potential values of CBVI being independent student usage, further efforts are needed to examine how students can engage in technology based instruction with their teachers playing a more limited role.

The current study focused on teaching chained tasks with CBVI without direct teacher support. Advances in technology have revolutionized the types of simulations that can be used to supplement or augment instruction. Taking note of that, Browning, White, Nave, and Barkins (1986) cautioned about the importance of similarities of stimuli between natural and contrived training environments, researchers have continued to look for ways to improve simulations in various ways. For example, Cihak, Alberto, Kessler, and Taber (2004) documented the superior efficiency of combing in-vivo instruction with simulation instruction over in-vivo or simulated instruction alone for teaching fax machine, ATM, debit machine, and copy machine use. This implies that students benefit greatly from the repeated practice and extension that simulation training affords but they also need the *in-vivo* instruction to ensure efficient generalization.

This investigation was built around the rationale that CBVI is a powerful intervention that can present students a range of multiple exemplars and provide instructional prompting and feedback. Further, if students are able to engage in a behavior that is topographically related to the criterion behavior (the behavior expected in-vivo), the behavior may generalize to the natural environment without additional in-vivo instruction. This would allow teachers the ability to provide individualize instructional opportunities to students for functional skills while maximizing time and reducing cost on instructional materials (e.g. food, consumable products) or travel (to appropriate in-vivo locations in the community or school).

The fundamental research question addressed in this investigation is whether students acquire a functional skill (making soup, making a sandwich and setting the table) using CBVI and then generalize this skill to an *in-vivo* setting without additional instruction.

Method

Participants

This study was approved by school system, private, and university IRBs. Three participants were recruited through the local school system as well with the assistance of the Autism Society of America in a medium sized southern city to take part in this study. All three participants were diagnosed with autism by the TEACCH program in North Carolina and had autism special education eligibilities. In addition to having autism, participants also had to: consent to participate, have parental permission to participate, be elementary school aged, have sufficient fine motor skills to complete the target tasks, use a mouse to move the cursor and click on icons, and attend to a computer screen for at least 10 minutes. Lastly, all potential participants were screened and to be included in this study, students had to be performing below 60% independent (averaged across skills) on the tasks targeted by intervention. This liberal criterion meant that one student (Stephen) was allowed to participate despite demonstrating above 60% independence for one of the target skills.

Depending on the school system, different standardized test information was available to the researchers and not all existing information was made available. Therefore caution is warranted relative to the generality of findings to others with autism diagnoses. In the descriptions below we have attempted to detail as much as possible about the students. The first student, Stephan was a 9 year 2 month old male student who enjoyed using the computer. He showed stereotypical behavior when excited or after successfully completing tasks by flapping his hands and rocking. School records indicated that Stephen was performing significantly below grade level in academic areas and that he exhibited characteristics of ADHD. The second student, Natalie, was 9 years and 6 months old at the beginning of the study. She had difficulty paying attention to task for long periods of time and she was especially distracted by other student behavior and noises. The Bayley Scales of Infant Development II (Bayley, 1993) indicated that she had an IQ of 53. Her adaptive behavior was evaluated with the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984), which showed standard scores of 43 for daily living, 52 for socialization, 55 for communication with a composite of 55. Like Stephan, she was highly distractible and would occasionally walk away from in-vivo probes. During the game, she wore headphones to reduce distractions. The third student, Ray, was a quiet, soft spoken 7 year 7 month old boy who would respond to greetings verbally but only after being reminded. He was very sensitive to sensory simulation and gagged if he got mustard or mayonnaise on his fingers during testing. Ray would exhibit signs of frustration and anxiety (whining, making faces, and not responding) when presented with difficult tasks. He enjoyed using the computer and could turn on the computer and log in to his favorite games. He had a history of refusing to respond to standardized assessment tests. The only test scores available for Ray were from the Preschool Language Scale 3rd Edition (Zimmerman, Steiner, & Pond, 1992) that showed standard scores of 68 for auditory comprehension, 52 for expressive communication with a composite score of 56 for language.

Setting and Instructional Arrangement

The study took place in multiple locations and included both home and classroom environments. Ray received CBVI in his home on a Windows computer. Natalie and Stephen received CBVI in their respective classrooms on a Mac laptop with an attached mouse. In-vivo probes took place in the school for Natalie and Stephen and in the home for Ray.

The arrangement of CBVI setting and in-vivo setting for Ray was in his home kitchen and dining room. For Natalie and Stephen CBVI and in-vivo setting were in different areas of their schools including at the classroom snack area (all 3 skills), in the cafeteria (all 3 skills), and at a picnic table outside (sandwich and setting the table).

Materials

Materials for the *in-vivo* probes varied depending on the task. For preparing soup, students were provided an individual serving sized 8oz microwavable container of soup (Campbell's or Progresso and different kinds such as chicken and stars, vegetable, etc.) situated approximately 1 ft from a microwave. Each container had a metal lid (with sharp edges) that was removed prior to instruction. For making sandwiches, students were provided a cafeteria tray with two slices of bread, meat (turkey, chicken, bologna, or salami), cheese (Swiss, American, baby Swiss, or provolone), and a condiment (mayonnaise or mustard) in a preopened single serving package. These materials were situated on a tray to the left of the food preparation area. After intervention and once students demonstrated mastery of making a sandwich, a full bottle of the condiments was used from which students would have to squeeze an appropriate amount. During training, a pre-opened package was used to reduce the chance that fine motor difficulty would prevent the student from opening the package and not completing the task. Finally, for setting the table, students' materials were positioned to the left of the child in random order. Materials included with a plate, fork, spoon, knife, napkin, and cup. The specific materials varied but included paper, plastic, and ceramic plates; plastic and metal flatware; cloth and paper napkins (folded in triangles or rectangles; and glass, Styrofoam and plastic cups.

During CBVI, students sat at a computer and used a two button mouse to interact with the software program called *I Can!- Daily Living and Community Skills* (Sandbox Learning Company, unpublished) software was developed by Sandbox Learning Company (owned by the second and third authors). The software included video models and required the student to manipulate images on the screen that simulated the natural environment. The instructional procedures and interaction are detailed in the procedures section.

The images that the student saw during CBVI consisted of video images filmed from a 1st person perspective (c.f. Ayres & Langone, 2007) which are depicted in the left column of Figure 1. Videos showed a narrated step-by-step walk-through of each target skill. Items used in the filming making a sandwich included two different types of bread (wheat and white), two types of cheese (Swiss and cheddar), two condiments (mustard and mayonnaise) and two types of meat (turkey and bologna). The video for making soup used two different but similar microwaves and three different types of soup. The materials filmed for the table setting sequences included white ceramic and white Styrofoam plates, plastic and stainless steel silverware, a white Styrofoam cup and a blue plastic cup, and white and orange napkins. These were combined in various combinations for each skill to produce five video examples of each task being completed. The longest video was 1:10 minutes (setting the table). The average video length was 50s.

In addition to video models, students saw professionally illustrated materials designed to mirror the stimuli they depicted in the videos (see right column of Figure 1). These materials (e.g. a slice of bread) were drawn to facilitate programming the computer game and allow the programmers maximal control over manipulating movement of the images. Every video image had an illustrated counterpart that was used during the interactive instructional portion of the program. The students manipulated these materials to mirror in-vivo actions. This will be described in the procedures section.

Response Definitions

In-vivo. All three target behaviors were task analyzed (see Table 1) and during *in-vivo* probes, students were presented the task in a total task format (Alberto & Troutman, 2003) whereby they had the opportunity to respond correctly or incorrectly for each individual step of the task analysis regardless of whether or not they correctly responded to earlier steps of the task analysis. A correct response occurred when a student began the response within 5s of the task direction (e.g. "Please set the table) or within 5s of completing the previous step (e.g. beginning to place a piece of meat on a slice of bread with in 5s of placing the bread on the plate) and the student the student had to complete the step within 5s of starting the step. Any other response was scored as incorrect. This included not beginning a response soon enough after the task request or previous step completion (latency error or no response), failing to complete the step within 5s of beginning the step (duration error), or engaging in a topographically incorrect behavior given the step on the task analysis (topography error).

In cases where the student made any error (latency, duration, topography), the researcher stopped the student, blocked the student's view of the task materials, and corrected or completed the step without allowing the student to see what was being done. The rationale behind this procedure was two fold. First, the step was completed or corrected to allow the student the opportunity to respond correctly to subsequent steps of the task analysis rather than terminating the session and scoring all steps after the error as incorrect.

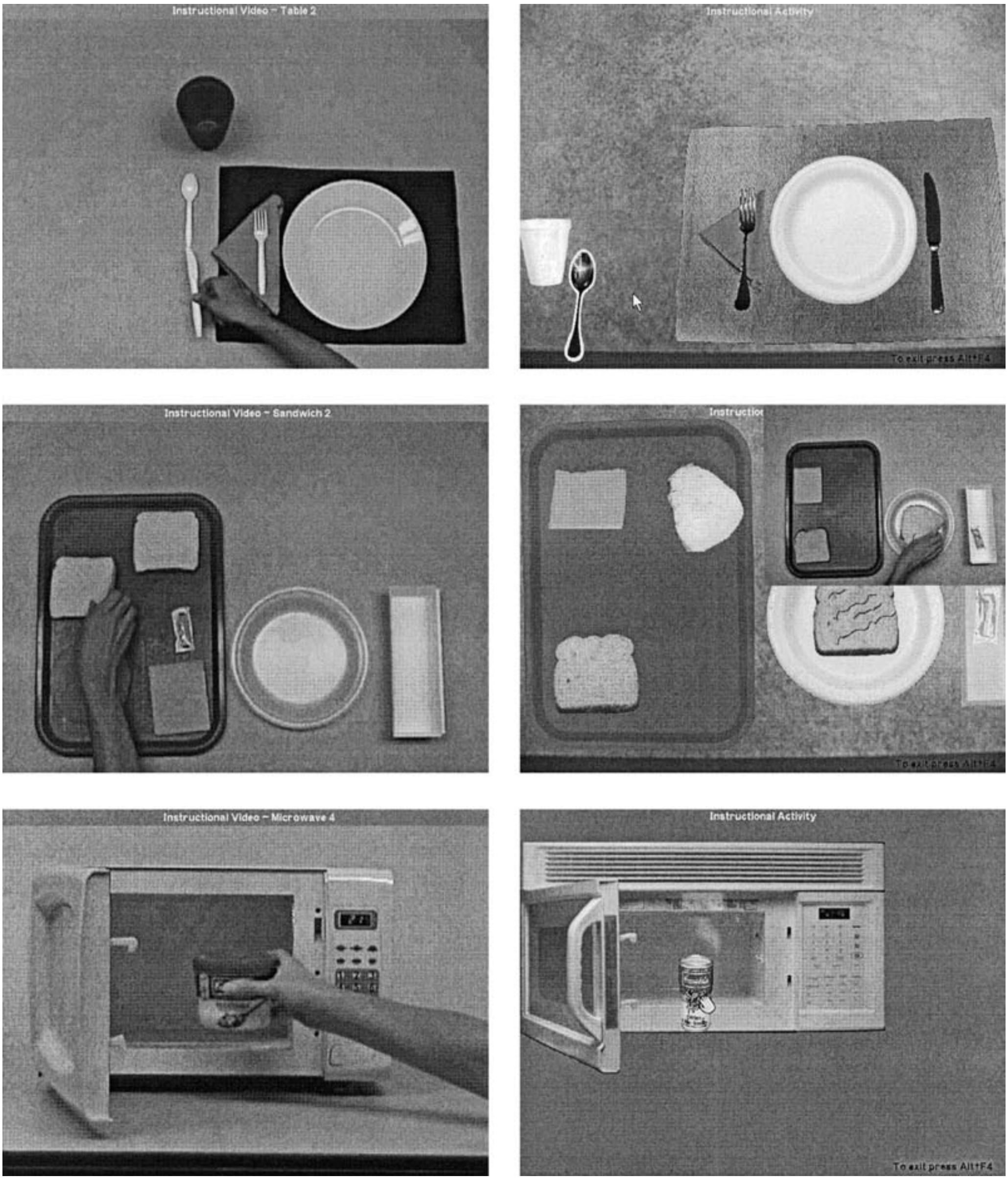

Figure 1. Screen captures of the instructional software. Images on the left side show screen images of the video models. Images on the right column show clips of different parts of the interactive software.

Second, the completion of one step and the arrangement of the stimuli are the S^D for the subsequent steps; therefore, in order to evaluate student knowledge of the subsequent steps, the stimuli had to be properly placed. This total task presentation provides a conservative estimate of baseline behavior because it allows measurement of student performance on all steps.

It is important to note the difference in latency parameters between *in-vivo* and CBVI. With *in-vivo* the latency for a correct response was 5s whereas on the computer, the latency for responses (and prompting) was set at 10s.

TABLE 1

Task Analysis of Target Skills

Setting the Table	*Making Soup*	*Making a Sandwich*
1. Pick up the plate	1. Open the microwave	1. Pick up a piece of bread
2. Put the plate on the mat	2. Get the soup	2. Put the bread on the plate
3. Pick up the napkin	3. Put the soup in the microwave	3. Pick up the condiment
4. Put the napkin to the left of the plate	4. Close the microwave door	4. Spread the condiment on the bread
5. Pick up the fork	5. Press "Stop/Clear"	5. Put the package in the trash
6. Put the fork on the napkin	6. Press "Time"	6. Pick up the meat
7. Pick up the knife	7. Press "1"	7. Put the meat on the condiment
8. Put the knife to the right of the plate	8. Press "3"	8. Pick up the cheese
9. Pick up the soon	9. Press "0"	9. Put the cheese on the meat
10. Put the spoon to the right of the knife	10. Press "Start"	10. Pick up the bread
11. Pick up the cup		11. Put the bread on the cheese
12. Put the cup to above the knife and spoon		

This was a function of software coding in this prototype where coordination of the programming to allow recording and multiple "events" to take place simultaneously on the computer made a 5s latency too short for student response. Based on our pilot testing with a 5s latency, students did not have a reasonable amount of time to identify the appropriate target to "click" and then initiate moving the mouse toward the target. We found that 10s allowed a much more reasonable time.

Computer Based Video Instruction. During CBVI, four responses were scored. Independent correct responses were scored if the student completed the correct step of the task analysis within 10s of the task direction (for the initial step) or within 10s of completing the previous step. Prompted corrects were scored when students did not respond within 10s of the task direction or completion of the previous step but responded correctly after the computer delivered a prompt. Three types of prompted corrects were possible: verbal, verbal plus model, verbal plus stimulus prompt. To have a prompted correct that was verbal plus model or verbal plus stimulus prompt the student would have to have not responded at all to the less intrusive levels of prompting. These prompt levels and their application are defined below in the section detailing the instructional methodology. Only independent corrects were counted toward meeting the mastery criteria. The program recorded responses and reported the total percent independent correct after the student completed the session.

General Procedures

In-vivo probes. Students were brought to the testing area (part of the classroom, school kitchen, or home kitchen), one of the researchers (second author) pointed at the materials for the task and gave the task direction (e.g. "Make the soup"). Students were allowed 5s to begin the response. If they failed to begin the response, the researcher shielded the student from viewing the correct response and completed the step on the task analysis for the student and then repeated the task direction. This was an attempt to prevent the student from acquiring the skill by watching the researcher model the response. In some instances, this shielding would not wholly keep the participant from seeing what occurred. For example, several steps of the task analyses required the student to pick up an object. In these instances, the researcher would place her body or clipboard between the student and the materials, pick up the correct material and place it in the student's hand.

If students responded incorrectly or exceeded the allowable duration for the response, the researcher interrupted the response, placed the materials in the correct place for the next step of the task sequence and repeated the task direction. We believed that these efforts were the most prudent way to allow students a complete opportunity to demonstrate how to perform as many steps of the task analysis as possible while recognizing the risk that students might "learn" from the intervention of the researcher. After students completed the entire task, they were allowed to consume whatever food they made if they wanted. Sessions for individual skills lasted approximately 10 min (shorter once students mastered the skills) and all three skills were probed in succession on the same day.

CBVI procedures. Pilot testing of the software with other students with autism revealed that the computer interface was intuitive and that the instructions in the program (e.g. "Now we are going to watch a video, when the video finishes press the arrow button"; or "Now it is your turn, use the mouse to ______.") were sufficient to train students to use the software. Because of this previous testing, no additional training was planned or needed. The teacher or parent assisted the student with logging into the computer program. Once in the program, the student viewed two narrated video models of the target task being completed. After the first video ended, the second video exemplar played. Figure 1 shows screen captures of videos for each skill in the left hand column.

Once the student completed viewing the video models, the program asked them to complete the skill in a computer simulation. Figure 1 shows screen captures of the interactive simulation screens for each task. The computer displayed an image of all materials on the screen and then issued a task direction (e.g. "Make a sandwich"). Students responded by using the mouse to click on items, move items across the screen, and then click on locations to drop or place items. For example, part of the in-vivo task analysis for making a sandwich consisted of these steps: pick up the bread, place the bread on the plate, pick up the meat, place the meat on the bread. On the computer, these steps were identical. The student had to click on the bread to pick it up, move the bread to the place, and place the bread on the plate by clicking on the plate. The clicking response on the bread to pick it up was one step of the TA and then clicking the plate to place the bread on the plate was another step of the TA. Each of these was prompted as needed in a modified system of least prompts (SLP) instructional arrangement (Wolery, Ault, & Doyle, 1992).

Students were allowed 10s to respond using the mouse, if they did not respond, or began an incorrect response (e.g. clicked on the wrong item to pick up), the computer stopped them and delivered the next level in the prompt hierarchy. The SLP procedure consisted of levels:

1. Independent: student begins a response and finishes the response within 10s of the previous step or task direction.
2. Verbal: computer provides an auditory response prompt telling the student what to do (e.g. "Put the bread on the plate").
3. Model prompt: computer shows a visual response prompt in the form of a video model where a live actor completes the step (identical to the pre-session video models). The middle image in the right column of figure one displays the model prompt being delivered.
4. Stimulus Prompt: analogous to a "partial physical" prompt in terms of level of intrusion, the stimulus prompt created a bright yellow "halo" on the location where the student needed to click. The image in the top right of Figure 1 shows the spoon being highlighted.
5. "Full Physical": the computer controlled the images on the screen and completed the step for the student.

If students responded correctly before any prompting was required, the response for that step of the TA was scored as independent. If the student did not respond until after a prompt, the highest level of prompt required for the student to respond correctly was scored. If the student made an error, the computer prompted them and allowed them to complete the step, the response was scored based on the highest level of prompt required and a notion was made that the student made an error on that step before completing the step. All sessions were scored and recorded by the computer.

No programmed reinforcement was provided for correct responses during CBVI. A reinforcer game was available non-contingently on student performance after the student completed the simulation. A teacher, or a parent (for Ray in the home), supervised all CBVI sessions and did not provide any feedback to the student. They were present only to monitor the performance of the computer program and to keep students on task. During the course of the study, students generally displayed eagerness to work on the program and no attention problems were noted. Students usually engaged in two sessions per day with each session lasting approximately 5 min total. Inter-session intervals varied based on school and home schedules.

Experimental Design

CBVI was evaluated in the context of a multiple probe design across behaviors and replicated across students. The sequence of target behaviors was counterbalanced across participants. Pre/post in-vivo probes were used to evaluate generalization and were the principle measure of interest. Pre/Intervention probes functioned as the baseline measure. All students were evaluated in-vivo on all target skills prior to receiving instruction on the computer. Once their data were stable across at least three sessions, each student began computer-based intervention on their first skill. Once a student responded independently to 90% or more of the steps of the task analysis during CBVI for his or her target skill on at least three occasions (consecutive sessions at 90% were not required), the researcher tested for generalization with in-vivo probes on all skills and the student began intervention on their next skill. This continued until each student had received intervention on all target skills. The criterion for moving to in-vivo testing was set at 90% independent on three separate occasions for multiple reasons. First, we wanted to evaluate in-vivo performance as soon as possible but yet allow adequate acquisition time on the computer and second we wanted students to have an opportunity to engage in all skills (if possible) as quickly as experimentally possible and using a 90% criterion seemed like a reasonable compromise.

Reliability

The primary observer scored student responses during the in-vivo probes. All in-vivo sessions were video taped to allow for collection of reliability and procedural fidelity data. Interobserver agreement (IOA) data were gathered for student responses as well as procedural fidelity. For in-vivo sessions, data were collected by an observer in real time. A second observer viewed video of at least 20% sessions for each student (mean of 27.69% of all sessions) on each skill before and after intervention and scored student behavior as well as procedural fidelity. IOA was calculated by dividing the number of agreements on student responses by the sum of the agreements and disagreements and this number was multiplied by 100. Interobserver agreement for these averaged 98% with a range of 96.2-100%. The disagreements on student performance were always a matter of differences in counting response time. For example, one observer saw the student begin the response within the specified time frame where as the other observer scored the behavior as incorrect because the behavior was on started within the allotted time.

Procedural fidelity was calculated by scoring researcher behavior for all critical steps of the *in-vivo* probe interaction. These included 1) setting out the appropriate materials, 2) providing the student with a verbal instruction to begin the target task. Then for each step of the task analysis, the researchers behavior was scored for whether they 3) responded correctly to the student action whether they had to interrupt an incorrect response or allow the participant to condition, and 4) whether or not they adhered to the latency limit before moving the student to the next step. Because these last two components were scored for each step of the task analysis, the total number of steps varied based on the skill. The number of correctly performed researcher responses was divided by the sum of appropriate and inappropriate responses and multiplied by 100. Procedural fidelity was 96.6%, calculated by dividing the total number of procedural steps followed by the total number of procedural steps scripted to be followed and then multiplying by 100. The procedural steps that were not followed were always related to latency intervals and the researcher allowing 1-2 additional seconds for a student to initiate a response.

During intervention, the computer collected all data on student responses. Prior to deploying the program, it was extensively tested and reviewed by the software development team and the researchers. No procedural or scoring errors were reported during this evaluation. The teacher, researcher or parent completed a protocol checklist after each session to record any irregularities in computer function during intervention. However, with this prototype software, the program did not log and save student data for each session keyed to students' names and dates.

Results

Figures 2 through 4 show student performance data for *in-vivo* probes. All students demonstrated improvement during *in-vivo* probes following mastery of the target skill on the computer. The percent of non-overlapping data (PND) from pre-intervention to post-intervention in-vivo for Stephan and Ray was 0% for all skills. The PND for Natalie was 16% for making a sandwich and 0% on setting the table.

Stephen

Stephen showed low levels of accurate responding during *in-vivo* probes for setting the table with a mean percentage correct of 11% (See Figure 2). After he reached criterion on the computer simulation in six sessions, he scored 100% correct on in-vivo probes for three consecutive sessions after which his performance dipped slightly to 92% correct before rebounding to 100% and back to 92%. Two weeks after intervention he responded at 100% correct for three consecutive sessions. Stephen demonstrated slightly higher abilities with making a sandwich. Prior to CBVI, he averaged 65% of steps correct. Once he met the 90% criteria in CBVI in 11 sessions, he demonstrated complete independence during *in-vivo* probes and maintained 100% accuracy at a two week follow up probe. With micro-waving soup, he showed stable responding in-vivo prior to intervention where his mean performance was 39% correct. In ten sessions of CBVI he met criterion and generalized his performance to *in-vivo* probes where he responded correctly for 100% of the steps across three sessions and then maintained at 90% correct at a two week follow up.

Natalie

Natalie's first skill was making a sandwich. Prior to intervention, she responded at low levels averaging 34% correct (See Figure 3). The only step she consistently got correct was putting the final piece of bread on the sandwich. After she initially met criteria on CBVI in nine sessions, she demonstrated higher independent performance in-vivo by responding correctly for but was not completing the task independently. The decision was made to return to intervention until she met criterion again and she also received probes on the remaining skills and began intervention on setting the table. Once Natalie reached criterion on making a sandwich for the second time (eight additional sessions) she was probed *in-vivo* again and showed more consistently high performance than previous *in-vivo* probes but she was not responding at 100%. Again she returned to intervention for four sessions and then back to *in-vivo* where she again responded better than during baseline but not at 100%. She consistently and correctly responded for the final four steps of the task analysis. Her errors were always with the first four steps. For setting the table, Natalie's performance was low and stable with a mean of 19% independent during *in-vivo* probes. Her errors were inconsistent across sessions. Upon beginning intervention, she responded slowly at first and ultimately required 20 CBVI sessions to meet criterion. She engaged in one additional CBVI session beyond criteria. In post intervention (and maintenance probes) she generalized her performance to the natural setting with a mean of 79% of steps correct. Natalie did not have enough time to begin CBVI for making soup because the school year ended, however, her performance data remained low and stable throughout the intervention.

Ray

The evaluation of performance with the software was intended to be conducted in the

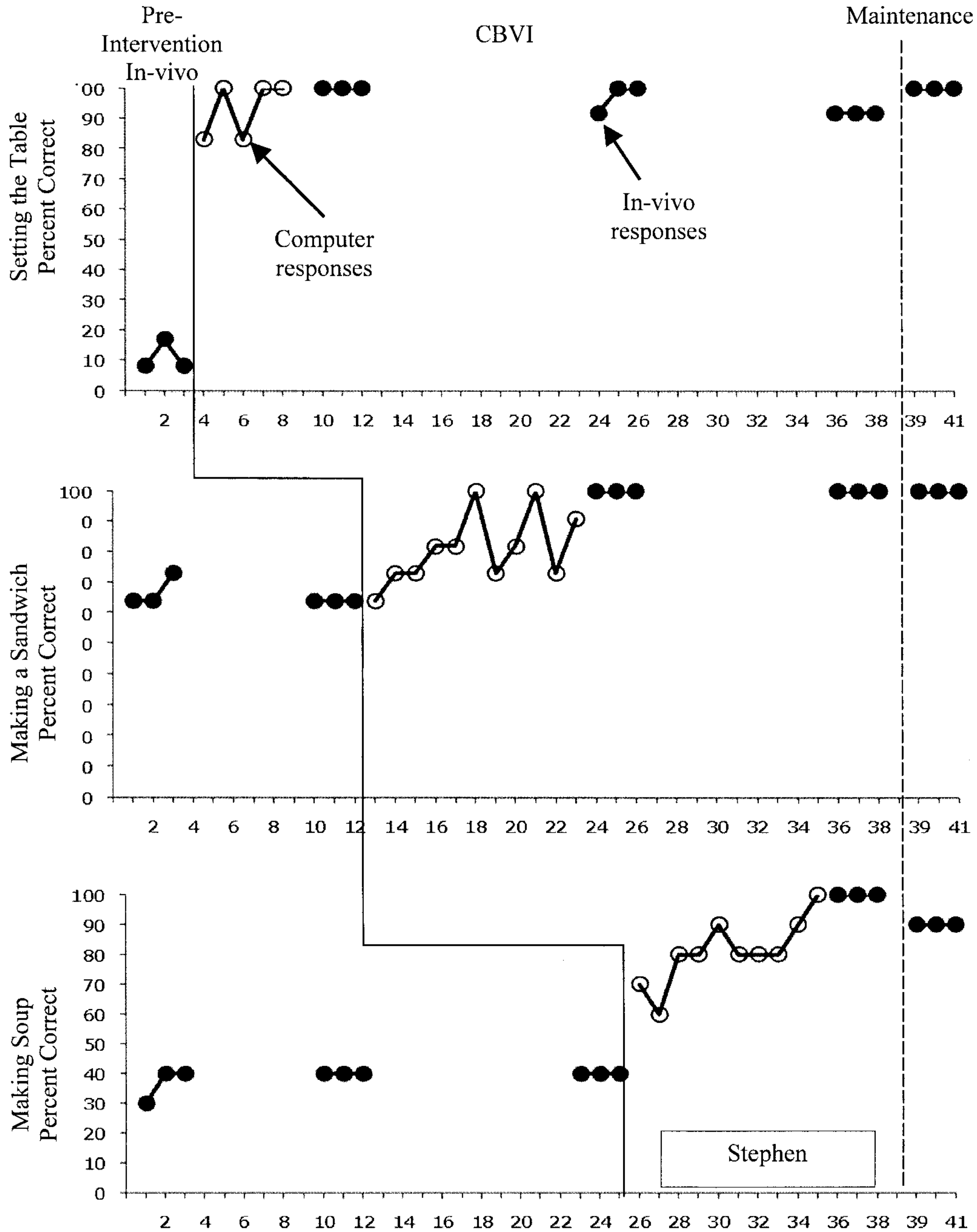

Figure 2. Response data for Stephen. Closed circles represent responses in-vivo and open circles represent responses on the computer.

context of a multiple probe design (like with Stephen and Natalie), however, it was discovered through the session logs on Ray's computer that he likely gained access to all three instructional programs prior to demonstrating mastery on the first skill. In addition, reviews of the logs revealed that Ray accessed the program three additional times for his

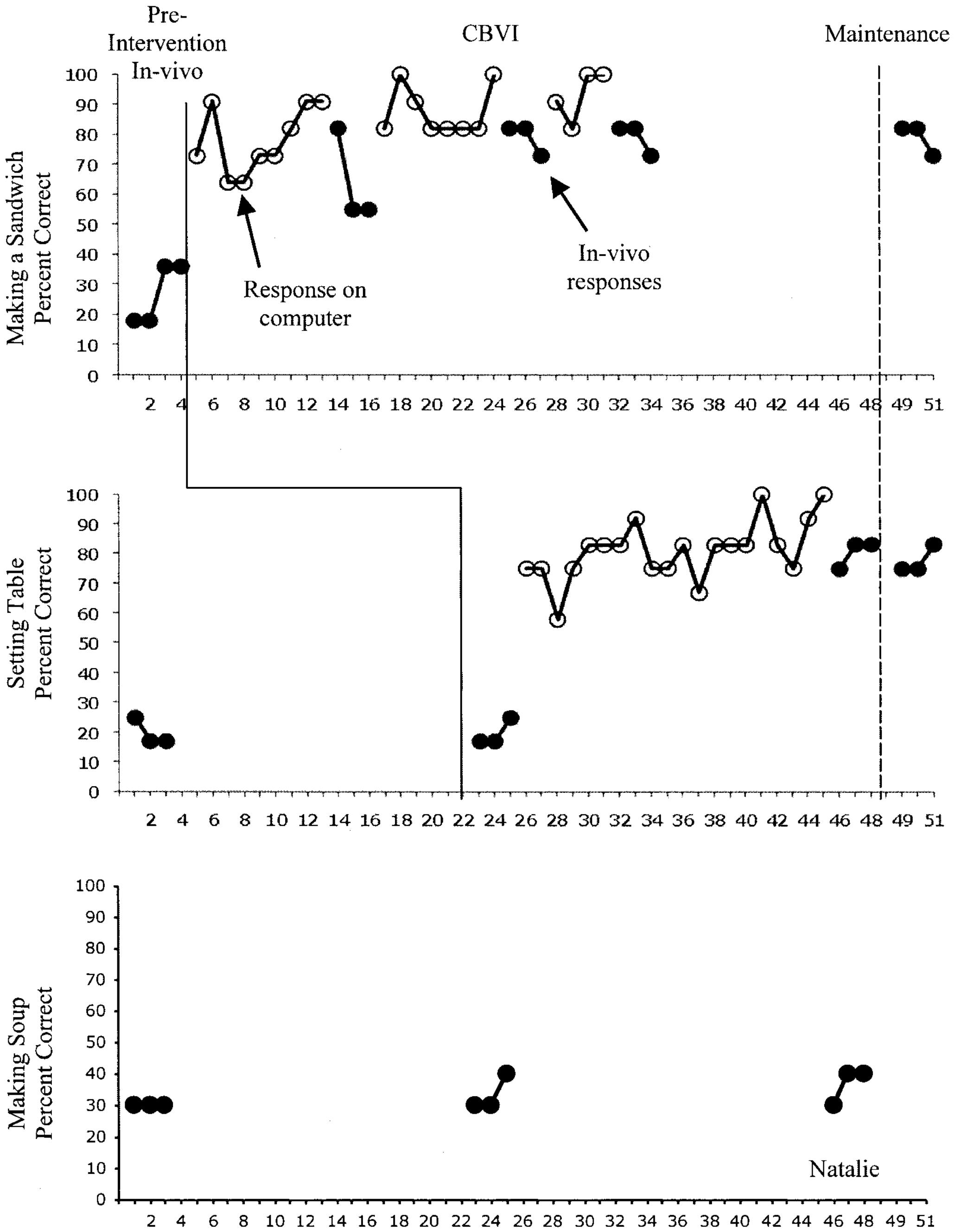

Figure 3. Response data for Natalie. Closed circles represent responses in-vivo and open circles represent responses on the computer.

first skill (microwaving soup) after he had demonstrated mastery. Therefore his graph (see Figure 4) essentially reflects three concurrent AB designs because we believed this would be the most conservative way to present his data because he could not have access the

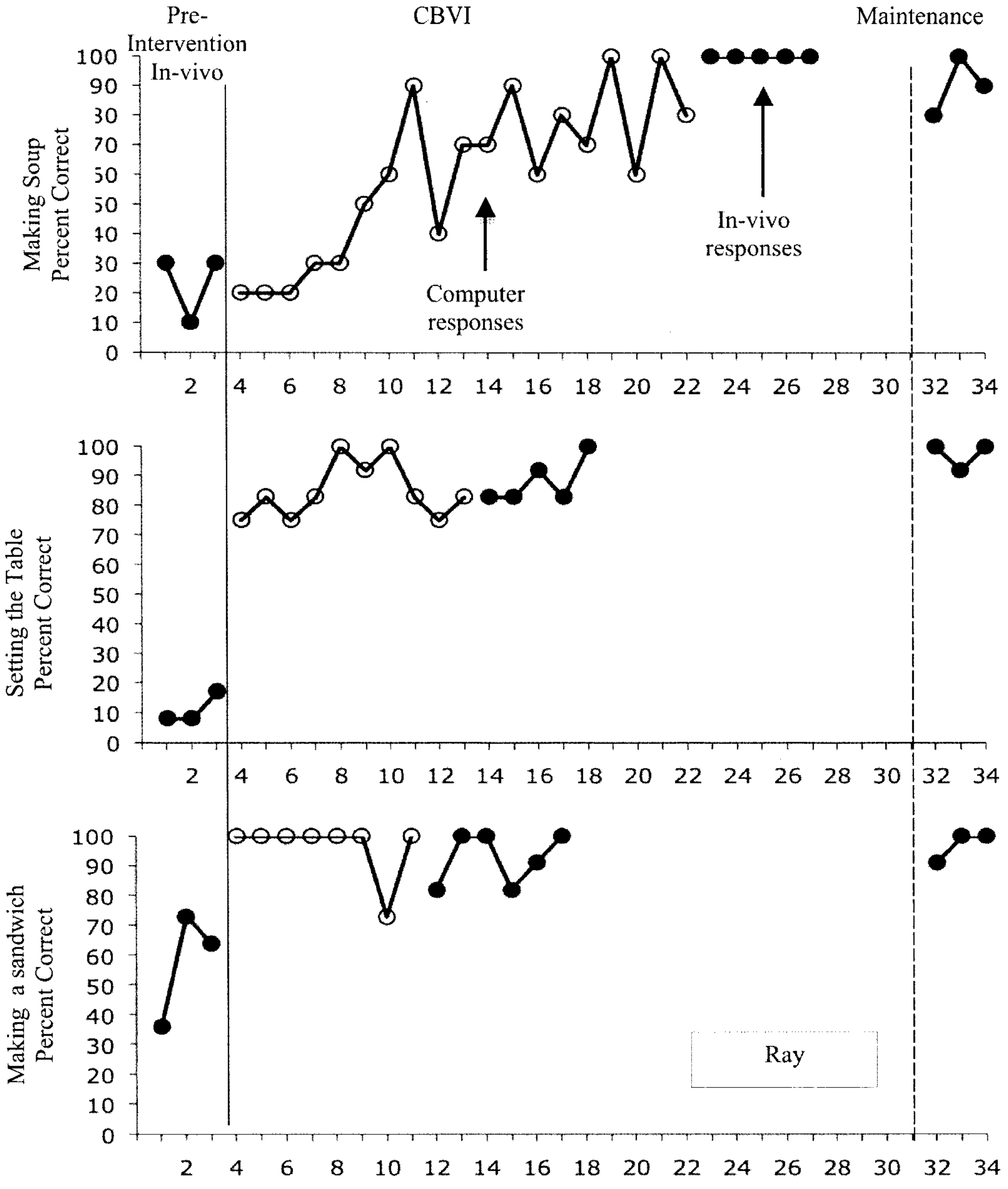

Figure 4. Response data for Ray. Closed circles represent responses in-vivo and open circles represent responses on the computer.

software until after he completed initial baseline testing *in-vivo*. After he saw how to log into the software during the first session, he could then have accessed the program at any time and on multiple times during the same day. His data are displayed as if he accessed the software for all skills immediately after having access to it.

Ray showed low levels of independent performance for micro-waving soup with a mean of 23% correct during pre-intervention probes. Ray required 19 CBVI sessions to master micro-waving soup after which he demonstrated independent performance during the first six post intervention in-vivo probes. After 11 sessions on CBVI for making soup, Ray's performance had stagnated, he was probed for his performance on the remaining skills, with the intention of beginning intervention on setting the table. At this time, because of the high degree of independent performance, it was discovered that Ray had accessed the remaining skills on the computer. The computer tracked his activity however and this showed that after 11 sessions of accessing CBVI for setting the table, and 10 for making a sandwich, Ray had achieved mastery on the computer. During pre-intervention probes for setting the table, Ray had averaged 11% correct responses and during post intervention he demonstrated a mean of 93%; achieving 100% accuracy during several sessions. Ray's pre-intervention ability to make a sandwich was higher relative to the other target skills. His pre-intervention performance ranged from 36 to 73% correct with a mean of 58%. He averaged 93% correct during post intervention with several sessions at 100% correct. During in-vivo probes, Ray would regularly repeat the verbal prompts from the software verbatim.

Social Validity

A social validity survey was given to parents, teachers, teaching assistants, speech therapists, and occupational therapists working with the participants. Half of the surveys returned were from parents, and half were from service providers. A 5-point Likert Scale was used (1 = strongly disagree; 5 = strongly agree) for individuals to respond to attitudinal questions about the goals and procedures of the study. Parents and professionals felt elementary school rather than pre-school, middle school, or high school was the time to learn these skills (4.4 average). Parents and professionals would use a version of this game to teach other functional skills for independence, work, or leisure (4.8, 4.4, and 4.6 average, respectively). Professionals were asked additional questions about the game but only four responses out of the six surveys were completed since they were not involved in using this instruction. Overall, professionals felt the students enjoyed the game (average 4.8), but they did not feel it reduced the time they would spend teaching making a sandwich, setting the table, or using a microwave (2.5, 2.8, 2.5, respectively).

Judging the social validity of the study outcomes came from informal feedback from parents. One saw their child microwave something and set the table. Another reported that their child used the microwave and made a sandwich. One saw the child complete all of the skills. The parents were not asked to involve the children in these skills at home so they were not directly tested in this environment. In an email one parent wrote, "he has talked about setting the table since then. He told me just last night that I was putting the napkins on the wrong side of the plate." Anecdotal reports from parents and teachers as well as observations of students confirmed that they enjoyed using the game. All participants wanted to work on the game and all participants tried to access the other skills in the game before they mastered the target skills on which they were working.

Discussion

To consider using a computer game to teach a functional life skill, seems, on the surface, impractical and counterintuitive. Results of this study demonstrated that it can be accomplished and that the student will generalize the skill to the natural environment. This begs the question as to why one would use computer technology to teach these skills when they might be best taught in-vivo using the natural materials.

Using technology to teach functional skills in this way has distinct advantages that are important considerations for instruction. First, technology is "recyclable" in that once the lesson is developed (scheduled, program, individualized), the teacher does not have to prepare for the lesson in the same way every time. Similarly, with a lesson that is tightly structured and delivered reliably through technology, the teacher does not have to worry about procedural variations that other staff may introduce as a child is acquiring a skill. For example, if a teacher is teaching a student to wash clothes in a washing machine and teaches the student to load the clothes, turn on the water, wait for the water to reach the top, and then put in the powdered detergent but another professional is teaching the student to turn the water on in the washing machine, put in the soap and then load the clothes, the student may fail to acquire the skill as quickly as he or she would have if they were initially taught a single correct way to complete the task.

Beyond the computer's ability to deliver consistent instruction ad nauseum, it also provides the opportunity for independent learning. The teacher is freed to work 1:1 or in small groups with other students; perhaps other students who are trying to generalize what they learned on the computer. In terms of generalization, computer and video technology allow for a wide range of examples to be inserted into a lesson beyond what a teacher could reasonably assemble for use in the classroom. For example, in the current study, five different place settings combinations were used to teach setting the table and these were depicted in different settings and on different tables. Technology can bring that all into one place and allow the teacher to control the degree of variability in an attempt to prompt stimulus generalization. If this sort of technology proves to be successful in replications, it is reasonable to assume, if adopted, students would be able to spend more time in the community working on social skill related tasks that are more difficult to program on a computer and less time focused on repeated trials of functional skills.

Limitations

This study attempted to control for threats to internal validity by using a multiple probe design across behaviors and then replicating that across participants. The logistics of this design made it difficult for one of the students, Natalie, to complete all of her target skills; yet, intra and intersubject replication of effect were still demonstrated. More narrowly, to interpret these results, one must be cautious of the accelerating baseline data for Natalie on making a sandwich and, to a lesser extent on setting the table. Ray also exhibited some variable data with some baselines showing slight accelerations.

In terms of research design, Stephen's results document the most convincing evidence that the software was an effective instructional tool with three demonstrations of effect. To a lesser extent, Natalie's mastery of two of the skills she had time to do show promise. Ray's results have to be approached with the greatest caution since the three AB designs, though illustrating acquisition, fail to achieve the experimental control offered by the evaluation on Stephen's data. However, Ray's violation of the procedural protocols and accessing skills that were to remain in baseline may yield one of the most valuable findings of the study. Ray's exploration of the software and eagerness to engage with the activities may have led to him learn the target skills (the experimental design does not permit this conclusion to be drawn though) and be motivational but beyond this, his initiative demonstrates the ease with which systematically designed software can be used by a student without a great deal of adult supervision. The design could have been tightened more by requiring a criterion level of 90% or 100% over three consecutive sessions rather than three sessions. Admittedly, the decision to use the more relaxed criteria (90% independent or better across three sessions) was one of expedience than experimental rigor but the results still indicated that once students were able to meet the criteria, they were able to generalize the skill to the natural environment.

Other limitations that impact the external validity of this study include the availability of the software to teachers. Currently this study evaluated proprietary software to answer research questions about the possibility of teaching functional skills with CBVI. However, in the future, when such software is more widely available, teaches will be able to incorporate this into their instruction. Until that time, this study does demonstrate that interactive CBVI can lead to positive outcomes and teachers can incorporate some of these techniques into simple authoring tools like IntelliStudio and even PowerPoint.

Another limitation that should be considered is that, from an instructional standpoint, strictly defining the order of steps for making a sandwich may seem arbitrary and in some ways limits the generality of these results. In other words, one can make a sandwich by placing a slice of bread on a plate, then meat, then condiments, then cheese and then the last slice of bread. This is certainly a socially valid way to construct a sandwich. However, for the purposes of this study, we were interested in evaluating whether such tight stimulus control could be achieved on the computer and then generalized to the natural setting. Therefore the sequence of all steps in all skills became critical. One should note that no student, regardless of sequencing preference was able to perform any of the skills in baseline to the same level of mastery that they did following intervention. While sequence errors were evident during pre-intervention probes, many of the student errors were latency or duration errors. This indicates that they would not have been able to perform the skills fluently if at all without intervention. Lastly, had the software been able to track daily student data by session and step and log that information, we may have been able to make data based decisions that could have led to faster acquisition.

Future Directions

While this study demonstrated the impact of CBVI on the acquisition and generalization of functional skills for three students with autism, future investigations could consider a broader range of skills. Within CBVI, no consistent evidence base exists for what prompting strategy is the best. For example, Mechling and Ortega-Hurndon (2007) used a constant time delay and this study used a modified system of least prompts. Future research can examine the relative efficiency of these two procedures within the delivery model of CBVI. Further research is also warranted for the evaluation of how students interact with the software. This study required to students to complete mouse clicking and moving operations that were mirrored on the screen as genuine movement. With new input computer devices becoming available (e.g. Nintendo Wii) that inexpensively allow a user to interact with a game using gross and fine motor movements in topographically similar ways one would use in-vivo, the possibility of allowing a student to actually rehearse the motor movements required for a task increases and may impact acquisition.

Using technology to teach, specifically, CBVI, is not substitute for teacher directed in-vivo instruction. However, if researchers are able to consistently document the efficacy of CBVI to teach generalized functional skills to students with autism and intellectual disabilities, these can become powerful supplements to traditional instruction and all the classroom teacher greater freedom to spend individual time with students.

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Received: 19 June 2008
Initial Acceptance: 23 August 2008
Final Acceptance: 15 December 2008