Fun to Develop Embodied Skill: How games help the Blind to Understand Pointing

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ABSTRACT
We discuss how gaming can be used as a training strategy for students who are blind or visually impaired (SBVI) to develop embodied skill in use of haptic assistive technology. The technology takes the form of a haptic glove that is designed to give SBVI access to the pointing behavior of teachers in mathematics/science instruction that is performed in conjunction with speech and the use of instructional graphics. Our initial studies show that significant 'embodied skill' was required to afford fluent multimodal communication between the instructor and student. We developed a gaming strategy, employing flow theory to enhance the fun and engagement of the SBVI to promote extensive perceptual training. Our results showed significant improvement and interaction gains as the game-play progressed over multiple sessions. Results also indicate that skills developed through game play were persistent, and transferable to complex multimodal situated discourse conditions.

Categories and Subject Descriptors
H.5 [Information Interfaces and Presentation]: Haptic I/O

General Terms
Multimodal Discourse, Gaming, Embodied Skill, Assistive Technology

1. INTRODUCTION
SBVI are typically one to three years behind their seeing counterparts [24]. However, they are capable of learning spatial reasoning and more broadly, mathematics [11, 13]. This leads us to conclude that the reason for this deficit must lie either in the paucity of learning material or in the communication of that material to the SBVI. Students have to fuse three information streams: the spoken speech stream, the tactile rendering of some graphic that accompanies the instruction, and the deictic gestures of the instructor that situates the speech with the graphic both temporally and spatially (i.e., pointing that synchronizes with the vocal utterance). Of the three information sources, giving the student who is blind access to the teacher’s gestural actions poses the most significant research challenge. Raised line drawings are relatively inexpensive to produce, readily available, can be quickly and easily explored by those who are blind [22], and can be used during instruction. The problem is that a student who is blind cannot resolve the teacher’s deictic references towards the instructional material as she lectures [7].

To make the student who is blind attend the teacher’s pointing, we adopt a typical sensory-replacement approach [1, 18] by which the visual information is replaced by a real-time tactile signal that informs the student who is blind of the pointing locus of the instructor. We developed a system capable of tracking the teacher’s pointing and conveying the direction, through use of a haptic glove, the student should move her ‘reading hand’ over her raised line version of the figure in order to coincide with the point the teacher is indicating.

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Figure 1: System setup
In this paper we briefly introduce our system and discuss
the use of the system in deixis-laden teach/student-like interactions. Information regarding additional research with the glove’s development will be briefly discussed and the reader will be directed to previous publications for details in these areas. Our first teacher/student interaction with the system was in the form of a charade game (similar to a word-find puzzle). This game is similar to a class in that a guide leads a follower who is blind on a discovery quest (solving charades). The joint activity is mediated by our system. In the first round of the charade studies, conversations failed to engage in fluid discourse. We posit that the SBVI was forced into a high cognitively demanding multi-task/multi-modal activity: engaging into a deixis laden conversation with the guide and trying to solve a problem while navigating over her embossed document. To solve this problem of cognitive load, the haptic aided navigation must turn from controlled to automated and one way of achieving this is through an “extensive perceptual experience” ([23] p. 169). In other words, the navigation skill should become embodied so that more cognitive resources can be devoted to understanding the lecture. To promote such experience, we created an “arcade-like” game that demands extensive navigation using the glove. The game was developed to engage the players in a satisfying activity (flow theory) which would encourage active and prolonged gaming sessions among the participants. By playing the game, they were able to develop and embody the navigation skill. After each participant played the game at least three times, a second round of the charade game was performed. The results from the second charade game showed great improvement in discourse fluency when compared to the first round of the charade studies. Results indicate that in the second round of the charade study, the system “disappeared” from participants’ conscious interaction. The studies reported here show that it is possible to have a fluid mediated interaction between a guide and a follower who is blind when the subject matter elicits pointing to a graphic or table. These studies and findings are detailed in the following sections.

2. SYSTEM DESIGN AND EARLY STUDIES

Figure 1 shows the configuration of our system. The instructor (on the right) teaches using visible graphical material in the form of a poster, chart, or projection on the whiteboard. A scaled-down raised-line version of the graphical material (with Braille characters replacing visible lettering) sits in a frame on the student’s desk. Cameras capture live video of both the instructor’s deixic behavior and the student’s reading hand. A vision-based tracking approach is employed to extract the Point-of-Instructional-Focus (PIF) and the Point-of-Tactile-Access (PTA). The PIF is extracted by tracking the teacher’s pointing hand, and the (PTA) is extracted by tracking the student’s reading activity. A Disparity-Vector (DV) is computed to determine the direction the student has to move her reading hand to access the PIF on her raised line graphic. This vector is conveyed to the student via a haptic glove (shown as an inset in figure 1). The glove uses an array of vibrating cell phone motors to communicate the DV to the student. A camera in an iMac captures the instructor’s embodied behavior. The iMac screen serves a second purpose of providing feedback to the instructor. The screen shows the realtime video image of the instructor with her PIF highlighted. The student’s PTA is highlighted, as well, as a colored circle. The system, therefore, provides a two-way ‘attention awareness’ to facilitate discourse grounding. This design has been detailed in [16] where we discuss our design rationale and alternatives.

We went through four cycles of research and development until we arrived at the glove displayed in figure 1. In the first generation of gloves, we had actuators assembled in three different configurations (round, rectangle and square). We tested all three configurations on the tasks described bellow. The round configuration yielded poorer results than the other two. The subsequent models were more robust, easier to maintain and produced more salient signals. The square configuration was the preferred one because it affords the maximum distance between actuators. We shall briefly summarize the tasks and other findings (all statistically significant) reported on the previous publication [15] when the gloves were worn by twenty five participants.

We devised three perception-related tasks. In the first task, a random signal (North, Northeast, etc) was sent through the glove and participants were required to tap on the arrow corresponding to the direction perceived as quickly and accurately as possible (figure 2a). The mean hit rates were: 79.16%, 78.12% and 39.06% for the square, rectangle and round configurations respectively. We also found that a well fitting glove increased performance rates no matter which configuration was used. Specifically, a participant who rated the glove as a “good fit” had significantly faster response times (around 250ms) and better signal discrimination.

Figure 2: Perception related tasks from previous studies

The second task was designed to test if the vibration on the palm would somehow impair tactile reading. Participants successfully read the information from the board displayed on figure 2b while the glove was vibrating (hit rate above 90% for all three configurations) and no loss of sensitivity was reported. On the third task, stories were told to the participants. A typical sentence in the stories would be: My friend lives in a [missing information]. The missing information (the number of bedrooms) should be acquired from reading the number embossed on tactile board (figure 2b). The haptic glove helped the participants to navigate to the number while they were listening to the story. Participants correctly answered 80.35% (on average) questions related to the stories. To give the answers, participants had to use information acquired from both hearing the story and tactile exploration of the numbers presented on the board.

3. PHRASE CHARADE STUDIES

Our earlier studies focused on the subject’s ability to follow directions and read while listening in a passive way. Mul-
timodal discourse and instruction, however, involves more than passive ability. We needed to determine if a student can engage fluidly in the dynamics of a continuous multimodal discourse stream while simultaneously entertaining cognitive problem-solving and learning activities. In other words, we needed to test the system in a setting where the instructor, to accomplish her instructional goal, had to use pointing. To make it similar to a classroom setting, students were required not only to follow the deixis-laden instruction, but to also use the information they were given to solve a problem. For that, we devised a game we call the phrase charade game that probes the capacity for such active engagement. For reasons that will become evident, the study was performed twice. We shall call this the first charade and second charade experiments.

3.1 Charade Game and Study Design

The charade game is played in pairs: A sighted guide and a follower who is blind are configured as shown in Figure 3. The guide helps the follower to solve the charade by employing speech and deixis. The puzzle is presented on the guide’s whiteboard as a rectangular grid of letters (figure 3a), and on the follower’s desktop as a concomitant braille grid (figure 3b). Our haptic glove system was deployed to facilitate the dialogue. Words that make up a ‘clue phrase’ are hidden in the grid as horizontal, vertical, or diagonal letter chains that can run in any direction. The cognitive activity of the discourse dynamic is represented by a ‘catch phrase’ that the followers have to discover from the clue phrase. For instance, in the puzzle depicted in Figure 3a, we have the clue phrase “Twinkle twinkle little star”, which is associated with the familial catch phrase “Blink blink small sun”. The guide is aware of the catch phrase, but cannot tell the follower the referent catch phrase “Twinkle twinkle little star”. The guide helps the follower to solve the charade by employing speech and deixis. Words that make up a ‘clue phrase’ are hidden in the grid as horizontal, vertical, or diagonal letter chains that can run in any direction. The cognitive activity of the discourse dynamic is represented by a ‘catch phrase’ that the followers have to discover from the clue phrase. For instance, in the puzzle depicted in Figure 3a, we have the clue phrase “Blink blink small sun”, which is associated with the familiar catch phrase “Twinkle twinkle little star”. The guide is aware of the catch phrase, but cannot tell the follower the answer directly.

Figure 3: Phrase Charade Game Setup: (a). Visible letter matrix (b). Braille letter matrix

We took care to ensure that the catch phrases were familiar to the anticipated student participants. We began with a list of 50 catch phrases from a phrase book. We narrowed this to a list of 12 most generally familiar four-word-long phrases using a survey of college students and staff members in our department. Table 1 shows the eight most popular phrases. These were then used in the studies reported here.

3.1.1 Why the charade and not math instruction

The charade game was intended as a pre-study and training exercise for participants. We anticipated the same students who participated in the charade experiments would also be apart of our final study using mathematics instruction. If this was indeed the case, then the charade game offered us the chance to meet the participants and to introduce the students to the haptic glove. This also allowed us to work with a fewer number of students, which is important for our study because of the limited number of SBVI at Name Withheld for Blind Review University (xxU). The use of the charade game, instead of a mathematics curriculum, ensured no contamination of the future mathematics instruction. That is, students who would later participate in the mathematics experiments would not be introduced to any mathematics instruction using the system before the actual experiment.

3.1.2 Similarities between the charade game and instruction

In the figure 3a, one can see that the words are written in different directions. They are written in a descending left to right diagonal as the word “Blink”, or in backwards as in “sun”. We borrowed this from the traditional word finding games. It can be seen as a precursor of the mathematics graphs and charts that will be used in the future instruction experiments. When lecturing, teachers can access graphs in a variety of ways, depending on the situation or on their instructional objectives. This random writing direction in the charade is a way of trying not to make the pointing unpredictable for the follower, although we must acknowledge that any given word can be written in only one direction.

In word puzzles, letters go in one direction to form a bigger chunk of information - a word. During the charade experiment the guide, pointing at the “S” in the word sun, says: “... it starts here and goes in this direction ...”. Similarly, one can imagine a situation where the teacher is presenting a sine wave (figure 4). She can say: “... It is a perfect wave ... it goes diagonally up, in a curve ... (points at “A”, “B”, “C”). ” The successive pointing is slowly revealing the form of the curve, just as the letters put one after other reveals the word.

Figure 4: Introducing a sine wave

Other important resemblance is the fact that the guide, aware of the solution, leads the student through a discovery quest. In this sense, the dialog in the charade experiment is similar to the one expected instructional settings. This offers us an unique opportunity to observe what interactive strategies guide and follower will develop as they explore the
new affordances the system brings. Furthermore, we needed to identify and address the impediments that could arise from this new form of communication. The phrase charade embodies the core objective of our research which is to enable the students who are blind to comprehend multimodal instructional discourse by resolving the teacher’s deictic references.

3.2 First Charade Study

Four xxU (Name-Withheld for Blind Review) undergraduates who are blind responded to our recruitment efforts and participated in the first charade study: Two females (N and M) and two males (R and G) to play the role of followers. Two sighted graduate students with teaching experience were recruited to serve as guides. Each guide worked with a male and female follower.

Each guide-follower pair was given instruction on the technology and game. They were permitted to familiarize themselves with the technology and charade by playing a practice game. One pair of catch/clue phrase was randomly selected among the top four most popular (Table 1) and used for the practice. Each pair then played the three remaining catch/clue phrase games. Data was collected and recorded for these games.

3.2.1 Data Coding and Analysis

We recorded the exchange and coded the speech, gesture, braille reading activity and the synchronous activity using the MacVisSTA [17] system. The discourse was coded in terms of ‘reference chains’ at three levels: Object level, Meta level and Para level [12]. In object level, conversants are discussing about their joint project [14] – taking direct actions to solve the charade. Whereas in meta level, the subject is the discourse itself. Turns related with discourse repair were also coded as meta level. Para level utterances relate to the individual experience and references to people and objects vividly in the speaker’s environment. Words of encouragement like: “There you go,” “take your time”, etc. were coded as belonging to the para level thread. This coding allows us to understand the joint problem solving activity of the participants, the fluency of the discourse (whether there was excessive meta-level conversation to repair the discourse), and the degree to which the discourse is focused on the problem or on the technology itself. A usability post-questionnaire was also designed.

3.2.2 Study Results

While the participants were able to complete the study, we found the discourse rather cumbersome. In all, a third of the discourse was spent on conversational turns coded as either belonging to Meta or Para level reference chains. Research shows that when conversants feel that the technology is “getting in the way” of their interaction, they are likely to quit using it [20]. Hence, we judged the system to have “getting in the way” of their interaction, they are likely to quit using it [20]. Hence, we judged the system to have

4. EMBODIED SKILL

The acquisition of embodied skill may be conceptualized as the automatizing of tasks that were previously under conscious control. The difference, according to Wickens ([23] p. 175), is that the controlled task demands attentional resources whereas the automatic one does not. According to the same author, “extensive perceptual experience” and consistency of responses are necessary ingredients for a task to become automatic ([23] p. 169). Extensive training also helps to eliminate decrements in sensitivity [8]. Furthermore, training ameliorates task performance by improving tactile discrimination increasing activation of the somatosensory cortical areas representing the stimulated body part [9]. Such training can be achieved by game playing as long as it is engaging.

5. DESIGNING FOR FLOW EXPERIENCE

As explained in the previous section, the skill training game is meant to be played by the student who is blind as a training tool. The game playing strategy to help people with disabilities to acquire new skills has been used before [10] (among others). However, we are taking this approach to a new level: We want the skill embodied.

The game is designed to produce a set of graduated challenges that engages the subject at successive levels of difficulty as their level of skill improves. To aid in this design, we employed the “Flow” concept of “Optimal Experience” developed by Csikszentmihalyi [6]. Csikszentmihalyi’s model has been adapted to the design of computer games [5]. Flow is a feeling of “complete and energized focus in an activity, with a high level of enjoyment and fulfillment” [6]. When we are in the “flow zone”, we are so engaged and focused that we lose “track of time and worries” [5]. In other words, we are in the “zone” when we perform an activity that give us pleasure and, at the same time, demands our attention. Csikszentmihalyi lists the components of the Flow:

- A challenging activity requiring skill;
- A merging of action and awareness;
- Clear goals;
- Direct, immediate feedback;
- Concentration on the task at hand;
- A sense of control;
- A loss of self-consciousness; and
- An altered sense of time.

Csikszentmihalyi’s model does not require that an activity exhibit all eight components to enable the flow experience. The goal of our skill training game design was to provide a set of challenging tasks, graduated to improve the participant’s skill in the use of our haptic glove. We employ Csikszentmihalyi’s model of ‘challenge’ where he states: “Enjoyment appears at the boundary between boredom and anxiety; when the challenges are just balanced with the person’s capacity to act.” ([6], p. 52). Hence, our design objectives were to provide a set of clear goals with direct and immediate feedback. The task had to be tightly associated with our overall purpose of promoting the development of embodied skill in the use of the glove. In doing so, we seek to merge the actions of the player with the awareness of the pragmatic goal (shared by our subjects) that our system will eventually aid them in learning, by providing clear near-term goals that they can achieve, provide timely feedback of their level of skill improvement, require some degree of commitment and concentration to play, and provide the subject with a sense that they are in control of the game.

5.1 Designing Challenging Activity

We modeled our game in a fantasy context patterned loosely on the television and movie series: “Mission Impossible”. Table 2 shows the game setup that is read to the player using Text-to-Speech when the game is started. We
make extensive use of speech and sound effects as a means to enable engagement by providing a multimodal experience. The subject has to move her hand over a 'gameboard' under the guidance of the haptic glove system. When her hand comes within some level-defined distance from the target, the 'bomb' is disarmed. Target’s coordinates are randomly assigned.

Table 2: Game instructions for the first phase

| This is Agent Smith of the Agency of Impossible Missions (AIM). Your services are needed at this time. Dr. Evil has stolen all of the launch codes of our nuclear arsenal. With such codes he can destroy any city in the world. Your mission, if you decide to accept it, is to disarm the launch sequences as they are detected. The first launch sequence detected is for New York City. You have 2 minutes to find the codes and disarm them. Go! |

The challenge and the goals are clear. In this situation, the goals are not only to find the targets, or to play the game per se. It is about helping in the construction of a technology that might be useful in the education of SBVI, in general. This kind of feeling lasts longer and is more rewarding than the immediate and temporary satisfaction of a regular game play, and provides the student with a broader awareness of how the game will improve the technology available to students who are blind (Csikszentmihalyi’s second Flow component).

The direct and immediate feedback is provided by the tracking and the haptic glove. The need for concentration is clear: There is a goal to be accomplished within a time frame, the player has to focus on the task or she will fail. The player can quit the game at any time by pressing any key on the keyboard. She can also pause the game by moving her hand out of the tracking area. This was meant to give the player a sense of control.

Since the game is inspired on the Mission Impossible movie series after the “Go” command, the movie’s theme song starts playing. The music tempo is paced according to the game level. For instance, when the player reaches level two, the background music tempo is increased by 50%. On level three, the tempo is 75% faster than that at level one. The idea is based on the work of Brodsky’s [4]. He studied the effects of altering the tempo of background music on simulated driving and found that as the tempo of the music increases, so does the simulated driving speed. In more advanced levels the player is required to navigate faster, so this change in tempo functions as an extra stimulus.

The game comprises three levels. Each level lasts 2 minutes. The player must find the codes and disarm a number of warheads at each level within that time. In level one, ten targets must be found within the 2-minute timeframe. In levels two and three the number of targets to be found within the same time frame are 20 and 40 respectively, and the required distance of the hand from the target point decreases successively. Figure 5 shows target sizes and distances from the hand on levels one and two.

When the player gets to the target the system emits a sound of a ‘small detonation’ indicating the destruction of the target device. Together with the Mission Impossible theme music, this audio feedback is designed to enhance the sense of immersion in the game.

The faster the player navigates, the more points she earns. The program records the highest score each player accumulates, along with the most advanced level attained. To add a degree of competition, the system speaks the names and scores of the top three players before articulating the game instructions. This is to increase the competition and also to function as a stimulus.

5.2 The Mission Impossible Game Trials

We wanted the game to become an attraction for the community of SBVI on campus and mitigate our shortage of participants. Therefore, the game was used as both a recruiting and training tool. Trained participants will be needed in future research activities related to this project. After this game study, we wanted to repeat the charade study with the participants who played the game and to compare their performance against the data reported earlier. Furthermore, we wanted them to participate in a capstone mathematics instruction experiment. To satisfy these pragmatic concerns, it was critical that we provided flexibility of schedule for our subjects. To achieve this, we developed a strategy of deploying a game arcade to which the subjects can go at their convenience. The program and all the required equipment were stationed in a room reserved especially for this purpose. All the student needed to do was schedule a time that worked for both her and her ‘tutor’ (who also collected the experiment data). Each participant was required to play the game for three one-hour long sessions on three different days. However, if any participant really felt challenged by the game and wanted to come back a fourth or fifth time, she was allowed to.

In total, we had five participants, three females (A, N and O) and two males (R and G). N, R and G also participated on the first charade experiment.

5.3 The gamers’ experience

The participants were requested to answer a post-questionnaire after their third trial. At that point, the study was “officially” over, although the participants could schedule more sessions, if they wish. R was the only one who returned after answering the questions. He had four more sessions (because he enjoyed the game, and wanted to earn the highest score). Data from these were also collected by the computer program. For consistency, we include only his questionnaire completed at the end of his third session in our results.

We proposed fifteen statements to the participants and asked them to rate their level of agreement with them. The rating ranged from 1 (totally disagree) to 5 (totally agree), 3 being neutral or no opinion. Participants were also urged to comment on the statement being presented. All strongly agreed that they would perform better if they had played more. All but one either agreed or strongly agreed that they had to stay very alert to get the targets on time. This is a good indicator of engagement. R told us that if this game were in the market, he would buy it. All strongly agreed that
they had fun playing the game and that they would like to return and finish it. “Finishing” means getting over all the three levels of the game. Our engagement argument also found evidence in the fact that all participants considered that they got so absorbed by the game that they lost track of time and strongly agreed that they had full control of their character to accomplish the mission. However, none of them forgot that they were wearing a glove.

We also had a set of questions related to challenge and boredom. We wanted to evaluate if the different game levels kept them challenged and not bored. The idea is that as the subjects get more skillful, they might find the game boring and that is the time to progress to the next game level. Three participants did not find level 1 challenging. This is what we expected. Level 1 was designed as the “warm-up” level to bring all subjects to a baseline of proficiency. For some of the participants, this was the very first time they had contact with the haptic glove. Half of the participants found level 2 challenging whereas all of those who made the third level, strongly agreed that it is challenging. As for boredom, level 1 were considered not boring by 4 of the 5 participants and that was the unanimous opinion for levels 2 and 3. We also asked for how long they could keep playing without getting bored, the possible answers ranged from 1 (5 minutes) to 4 (30 minutes) and 5 (45 minutes or more): All but one agreed that they could play 45 more minutes or more beyond the time they just played, without feeling bored. The only person who gave a different answer (30 min), O, had just played a more than 54 minutes without interruption – she was trying to break the overall record.

5.4 Data Analysis

The quantitative data, automatically collected every time the game was played, consisted of 1) the elapsed time since the game began; 2) x and y coordinates of the player’s tracked finger, 3) the x and y coordinate of the target. The data analyzed here are from game play at level two. We feel these data hold the most value for an overall comparison because each participant reached this level and found it challenging.

We begin our discussion examining the techniques used by the participants to locate a target. For each target a map was produced to show the direction each participant took to go from their starting point to the target. This data was then categorized into groups. The techniques that emerged from the data were: Direct (navigation straight to the target – figure 6a); overshoot (the subject passes by the target and returns – figure 6b); stair step (subject follows the directional signals strictly – figure 6c); Unknown (technique does not fit into any of the previous categories – figure 6d) and Lost (figure 6e).

As expected, the Direct technique yielded significantly shorter times to target than all the others (paired Student’s t, p-value < 0.0001). However, it was not the most used (table 3).

We wondered if participants had migrated from a less to a more effective technique as the trials progressed. Table 3 shows techniques and their usage from trials one through three for game level 2. One can observe that number of times the participants got lost remained roughly the same, while increases in Direct and Stair Step techniques can be observed along with a decrease in Overshoot. This was translated to shorter times to target where a significant improve-

<table>
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<th>Trial</th>
<th>Direct Speed</th>
<th>Overshoot Speed</th>
<th>Stair Step Speed</th>
<th>Unknown Speed</th>
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</table>

When we analyze individual data, we see that despite the fact N was the one who most used the Direct technique (46.32% of the time), she was significantly the slowest gamer (paired Student’s t, p-value < 0.0001). Interestingly, N was the game’s top scorer during all her 3 trials. This was due to our flexible scheduling. Only after she was done with her trials, competition heated up and boosted the gains. Other significant speed differences were found, please refer to table 4 for intervals and ranking.

The fastest three (O, A, and R) were able to drastically increase their navigation speed (45%, 45%, and 62% increase, respectively). They were also those who achieved level 3 and the most competitive. R asked our team members to e-mail him in case some had broken his record. A’s last trial lasted almost one and half hours as she wanted to make sure that she was the top scorer.

6. REVISITING THE PHRASE CHARADE

Our skill training game results show performance gains in game play. However, we needed to know whether the
gains were transferable to the lecture-like task scenario. To answer this, we asked our participants to redo the charade experiment. We conducted this second charade study in the late Spring of 2009. This time, we used catch phrases ranked from 5-8 (Table 1) and the experimental procedure remained absolutely the same.

Among those who participated in the second charade study, three participants (R, N, and G) were also present in the first charade. We had one dropout since the first charade: M. M decided not to participate in the following studies (game and 2nd charade) because she has other disabilities which cause loss of sensation on her palm, which caused her to have difficulty with using the glove. On the other hand, we had two new participants joining our studies starting from the game (A, O). Therefore, we shall first compare the pre and post game performances of R, N and G. We report our analysis of the overall performance times, general discourse content, and game experience from the post-charade questionnaires.

6.1 Performance Gains and Task Focus

We compared the overall completion times of the phrase charade performed by our three subjects from the Spring of 2007 against that of our second phrase charade study. Each participant solved three charades in each of our studies, giving us 9 sets of results in our 2007 study, and potentially 15 sets of results from our 2009 study. One dataset from a repeat subject in the second charade had to be excluded because of a system malfunction during that study. This yields 8 sets of data from the repeat participants and 6 from the new participants in the 2009 study.

The performance times were markedly increased in second charade. For our repeat subjects, the new average completion time was 238.50 seconds as opposed to 443.88 seconds from the 2007 study. This is a 1.86-fold time difference. A paired Student’s t test at a 95% confidence interval show the obvious significance of this result (paired Student’s t, p-value=0.0020). When we include all 5 subjects in the 2009 study, we have an average completion time of 251.92 seconds. Our observations of the discourse content in the 2009 study showed virtually no references to the technology in the 2009 study. Almost all the speech was dedicated to solving the charade. In other words, the average of conversational turns devoted to problem was 96.68% among the repeat subjects. In the first charade trial, the average was 66.7%, and significantly different (Paired Student’s t test (p-value < 0.0001). When we include all participants, we have an average of 97.14% of the turns dedicated to problem solving. Figure 7 shows the percentages of problem solving (object level) turns of the two charade studies (before and after playing the game).

Together, these results show that there is indeed transference in skill from our skill training game to the phrase charade discourse-oriented game.

7. CONCLUSION AND FUTURE WORK

We have presented our work on supporting instructional discourse where the verbal component is situated within a graphical presentation with deixis. We overviewed our system design and the results of our perception-action tests that indicated that the technology was able to provide direction in conjunction with speech and fingertips reading. When we applied the system to a real discourse situation with heavier cognitive requirements represented by our phrase charade game with our participants who are blind, we found that the discourse was laborious, and that there was inordinate attention paid to the technology, and insufficient resources were dedicated to the substance of the discourse.

We posited that the use of the assistive technology must become fully embodied and automatic before it can support dynamic fluent instructional discourse. We advance the idea of employing a skill training game, to encourage the development of the level of skill necessary. We employed principles of GameFlow theory to develop the game, and to test it in a self-regulated game arcade format. The results of our skill training game studies suggest that this strategy is effective in encouraging skill development within a framework of fun. The game kept our participants motivated, and the manipulation of the level of challenge in the form of game levels scaffolded the development of embodied skill in the use of the assistive technology.

We performed a second phrase charade study to determine if the skill acquired by our skill training game would transfer into a discourse environment. The results of our second charade study show an almost two-fold increase in speed over our first charade study before the skill training game. Furthermore, commitment of discourse to discussing the technology practically disappeared. The assistive technology was no longer the focus, and the problem at hand (the charade) and the dynamics of regular discourse maintenance dominated.

The speed of interaction and the capacity of our technology to assist communication between a seeing instructor and SBVI are critical in the eventual use of such technology in the classroom. This is made even more critical by the prevailing model of inclusive classrooms, where people with disabilities attend the same class as those who do not. It has been argued that inclusive classrooms are beneficial for both disabled [7] and non-disabled students [19]. Furthermore, such inclusive instruction is required by law Disabilities Education Act Amendments (IDEA, 1997), and the No Child Left Behind Act (NCLB, 2001). A court ruling [21] had also reinforced the non-segregational approach. Therefore, the discussion is not if inclusive classrooms are good or not, it is how to make them work. The reduction of the gap between
special and regular students requires both inclusion of those with special-needs and effective educational methods for all students [3]. One of the most promising practices for helping students with disabilities succeed in the classroom is the use of technology [2].

Our continuing research with this technology is to investigate the scaling up of its use in real classroom scenarios with the communication of real mathematics and science curricula. We foresee that such technology will require rethinking of how teachers need to be retrained for inclusive education, and how curricula will have to be adapted to the technology.

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9. REFERENCES