Exploring Engagement Opportunities for Autistic Children: Using AAC as a Controller in a Wizard-of-Oz Coloring Game

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Autistic children face significant challenges in vocal communication and social interaction, often leading to social isolation. There is evidence that Augmentative and Alternative Communication (AAC) offers support to mitigate these challenges, enabling them to communicate with non-vocal means through forms of AAC, such as speech-generation devices (SGDs). However, the adoption and use of SGDs are hindered by several factors, including the large amount of practice required to learn to use SGDs and the limited options for highly engaging social learning contexts. Our study introduces the novel approach of using SGDs as game controller for digital and interactive games. With three design goals guiding our work, we conducted a Wizard-of-Oz formative case study with five participants aged 3-5 years, who were learning to use their SGD. We simulated a digital coloring game, integrating the speech-generated output of the participant's SGD to function as the game's controller. From this case study, we observed that all participants engaged with the game using their SGD for at least one turn, and two participants also engaged in emerging joint attention responses with the game and game's facilitator. This paper discusses these findings and contributes directions for future research, with suggestions for the design of future SGD-controlled games and exploration of social connection and collaboration between autistic children who use AAC and their caregivers, siblings, and peers.

CCS Concepts: • **Human-centered computing → Empirical studies in interaction design**; **Usability testing**.

Additional Key Words and Phrases: Augmentative and Alternative Communication, Gamification, Autism Spectrum Disorder

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1 INTRODUCTION

Autistic children[1] often have difficulty communicating vocally and engaging socially with others [5]. These difficulties may lead to social isolation from peers and members of their family [19]. To mitigate these social and communication challenges, autistic children sometimes require Augmentative and Alternative Communication (AAC) as a form of communication, which provides a way to communicate as an alternative to vocal speech [44, 69]. AAC encompasses a wide range of communication methods, including both low technological and high technological options. Low technological AAC includes forms of communication that do not require electronic devices [33]. Examples include picture boards and communication books. These methods rely on symbols or pictures to facilitate communication. High technological AAC involves electronic devices, ranging from simple button-based devices to complex computer systems [33]. These include speech-generating devices (SGDs), specialized devices, and apps implemented on commodity hardware, such as tablets. SGDs often use a grid display, where symbols, pictures, or words (icons) are organized within a grid format and users select to construct messages. Grid displays range from a field of one to hundreds of icons (see Figure 2 for an example).

AAC is particularly relevant for autistic children for several reasons. Many autistic children have difficulties with verbal communication and struggle with social skills [5]. Some autistic children may be non-verbal or have limited speech, making expressing their needs, thoughts, and feelings challenging. AAC can provide structured ways for them to engage in social interactions [44]. AAC tools such as SGDs can be tailored to the individual's needs and abilities, providing a personalized way for autistic children to communicate [21]. AAC can also reduce frustration from the inability to communicate effectively and help autistic children become more independent in communication, reducing their reliance on caregivers to interpret their needs and desires [18, 39, 44]. AAC plays a vital role in supporting autistic children by providing them with tools to communicate, participate in social and educational activities, and more fully express themselves.

Despite the well-documented benefits of AAC, integrating it into daily routines often requires significant time and practice—a challenge for both caregivers and therapists [18, 39]. This difficulty can restrict AAC's use to only supporting functional communication, rather than enabling rich, socially engaging experiences for autistic children, their caregivers, and peers. In supporting functional communication alone, this represents a missed opportunity to fully harness AAC's potential. In this paper, we propose re-purposing existing SGDs as game controllers. By leveraging the inherently motivating nature of play, this approach not only has the potential to foster deeper user engagement but also creates valuable opportunities for users to practice SGD use. Over time, it may facilitate meaningful social interaction through multi-player games involving peers or caregivers, thereby broadening the scope of AAC to support both communication, social connection, and collaboration.

In examining previous research on gamification and AAC, studies have shown acceptance with therapists and caregivers of autistic children in using gamification to support in learning prerequisite skills for using SGDs, such as learning to press icons on a screen and orienting the child's attention to the device [8, 18, 71]. However, these studies did not contain games that responded to the *speech-generated output* of a device. The use of SGD as an *interactive game controller*, to our knowledge, has not been studied before with those who use AAC. SGD as the game controller can serve as a tool to support the communication partnership between the child, their caregivers, siblings, peers, and therapists, within a *socially situated practice*, while playing the game.

[1]In this paper, we will be using identity-first language; however, it is important to acknowledge that language preferences may vary among individuals who identify as autistic [63, 65].

To explore the use of the speech-generated output of SGD to control a game, we conducted an exploratory Wizard-of-Oz case study [34, 46], with five autistic children. These were children who were 3-5 years of age, who use AAC, and participated within a University clinic setting. We incorporated a piggyback prototype using pre-existing digital platforms [30]. To observe our participants' engagement with the game and SGD, we designed a coloring game using Microsoft's Paint 3D and open-access coloring pages from Crayola. The first author, acting as the 'game,' responded to the speech-generated output of the participant's SGD by coloring items in the picture when the participant selected the color on their SGD. Participants accessed the game using Zoom's web conference platform with the shared screen feature enabled to view the game, and were asked to 'control' the game using their SGD.

The main contribution of this work is to explore the novel use of the SGD as a game controller, providing insights for future design considerations of AAC-controlled games and for future work in exploring the use of such games to enhance social connection and collaboration between autistic children and their caregivers, siblings, peers, and therapists. With this study, we propose three design goals for future work in AAC-controlled games: 1) **Use Existing SGDs** by ensuring the design does not require a new device or application as new devices and applications can be costly and often require additional training [17]; 2) **Foster Playful Use of SGDs** as most SGDs are designed for functional communication, and by integrating play, users may get more practice with the device and be more likely to use it long-term [18]; and 3) **Facilitate Social Interaction** by creating opportunities for social interaction with peers, siblings, and caregivers, enhancing the social dimension of SGD use. These goals represent our vision for future AAC devices and applications. In this work, we model the use of Design Goal 1 with our piggyback prototype and Wizard-of-Oz method and begin the evaluation process using a case study for Design Goal 2 to determine its potential for engaging users. Our results also show instances of Design Goal 3 with two participants.

2 RELATED WORK

2.1 Engagement Challenges for Autistic Children Who Use AAC

Effectively addressing the engagement challenges of autistic children using AAC involves a comprehensive strategy. This includes selecting appropriate and effective communication tools and creating socially engaging environments tailored to the child's interests [38]. One way that parents and therapists engage with autistic children is by using SGDs (see Figure 2 as an example). Research indicates that SGDs are particularly effective for autistic children, facilitating more frequent and spontaneous communication compared to other AAC methods like picture exchange systems or sign language [44]. This suggests that SGDs may be more user-friendly and engaging, encouraging autistic children to communicate more often using these tools. Research has also shown that aligning activities with the child's interests, such as games, significantly enhances their interaction with others [38].

Despite the effectiveness of SGDs, particularly when paired with activities within the child's interests, there are still challenges in engaging autistic children to use AAC. Research with parents of autistic children highlights the challenges parents face in incorporating AAC into their daily routines [18, 39]. For AAC to be effective, it must not only accommodate the diverse communication styles of autistic children but also seamlessly integrate into the family's daily life [39]. Parents often spend an inordinate amount of time learning to operate and use SGDs within their child's daily routine and strongly desire to connect and engage with their children. [18, 39]. Parents also worry about the stigma that the SGD carries, as their child uses a different modality to communicate when compared with vocal peers [39].

One way to address these engagement challenges faced by autistic children who use SGDs is to incorporate gamification with the use of the SGD, allowing parents to engage with their child in preferred games, and also creating a tool for autistic children who use SGDs to connect with their vocal peers and siblings. For social engagement and communication within games, previous research explored promoting teamwork [31] and aiding in language learning [60]. Games that are *controlled by* speech generated by an SGD may increase opportunities for engaging social learning contexts. This study will explore the engagement of autistic children who use SGDs and their interaction with a coloring game that responds to SGD output.

2.2 Gamification for Autistic and AAC Users

For AAC users, previous studies have also examined the design and use of games to support users in learning how to use their SGDs. Studies have found the importance of adding visual and sound components, storytelling, and customization to game design to enhance engagement and learning [10, 51]. In addition, previous work has shown success in using immersive games and universal design teaching new skills to autistic children, indicating the potential of gamification for this population [57].

Within the design of AAC game applications, research has also highlighted the importance of incorporating user-friendly design features within AAC apps, such as including interactive elements (i.e. popping bubbles on a screen), and adding familiar characters in games [8, 71]. These features can motivate learners and facilitate interaction with peers, demonstrating the importance of a user-centric approach in AAC technology. Integrating AAC into engaging and meaningful activities, such as games, increases the motivation of the AAC user to engage with their device and with others [29]. It is important to consider all of these recommendations when designing games to incorporate with the use of AAC. For our study, we selected a game that combined visual elements (coloring the picture) with sound (verbal acknowledgement of the user's selection of the color), and selected coloring pages with familiar characters such as barnyard animals, pets, and underwater animals.

2.3 Interactive Game Controllers

Game controllers specifically designed for the game console, such as those used in PlayStation or XBox consoles are a common way to interact with games. Games with consoles designed to interact with body movements, such as Nintendo's Wii or Microsoft's Kinect are also popular [61, 64], specifically when working with those with developmental disabilities [13, 70] or with older adults [1, 12, 72]. In addition, the use of body movement as a game controller has shown to promote social engagement and movement with those in retirement communities [40] and with patients who are diagnosed with dementia [67, 68].

Voice-controlled games have existed since 1973, and their development has largely been tied to the development of hardware and software to capture and process voice input and to incorporate it within game play [2]. However, despite this long period of development, there is limited work on the use of voice-controlled games. Some research has shown that voice-controlled games can function as an accessibility feature for individuals with motor impairments [3]. Previous studies have also evaluated the use of voice control compared to fine motor control of games and found that though gamers with fine motor control performed better in the game, the voice control features caused less fatigue for gamers with motor impairments [32]. An advantage of using voice control is that it may eliminate gaming errors that sometimes occur when using fine motor movements [55]. In addition, some autistic children have challenges with fine motor skills [43], and games that respond to voice output may provide another accessibility option for engagement with games.

For this study, we propose the use of a voice-controlled game, which uses SGD output as the voice controller. Previous studies have investigated the use of voice- controlled games, particularly regarding the design patterns that are present in such games currently on the market [3]. Based on this research, one design pattern was particularly salient, the design pattern of *unscripted conversation* [3]. In an unscripted conversation design pattern, the character in the game may follow a script with questions, but the player can respond in any way. Based on keyword recognition, the game then responds to the player [3]. In our game, we incorporated this design pattern by asking the participants the colors they would like to color the animals in the pictures, providing an unscripted conversation component to the game.

3 SYSTEM OVERVIEW

3.1 Game Implementation

A primary focus of the game's implementation was to be child-centered, incorporating participant preferences within the game [15]. Since our participants did not have the communication skills necessary to communicate their preferences with researchers, we provided an initial screening form to the clinic's therapists, where we asked them about the activities they observed children engaging with more frequently in the clinic. The facilitators indicated that the children enjoyed coloring, and for this reason, we selected coloring to be the game's activity. The children recruited for our study were familiar with selecting color icons on their SGDs.

Based on the feedback from the clinic's therapists, we designed a coloring game for participants using Microsoft's Paint 3D application and digital coloring pages available for open access on Crayola's website [2]. The setup of the game followed a Wizard-of-Oz design format [46], where the first author acted as the 'wizard,' running the game and responding to the speech-generated output of the SGD. The participants did not see the 'wizard' during the interaction with the game.

3.2 Game Implementation Rationale

The purpose of this study was not to study a coloring game, but rather, use the coloring game *as an example of a game* that could be integrated with SGDs, in order to promote the independent use of SGDs in a socially situated practice between the child who used the SGD, their peers, family members, and anyone else within their social network. We used the Wizard-of-Oz method to present the game to participants so that we could explore the game's feasibility, without needing to develop the actual software to play the game. In addition, this format allowed for flexibility, as we were working with young children, and we could respond to unpredictable behavioral responses. With consideration to our Design Goal 1 (outlined in the introduction of this work), it is important to note that different autistic children may use different SGDs. These devices are typically proprietary in nature meaning that they cannot be augmented or tinkered with. To circumvent this barrier, we devised a lightweight piggyback-prototype which required no modification to the existing SGDs. Piggy-back prototyping is a method of quickly assembling a new system prototype from an old system [20]. Previous research has shown this method for use in proprietary social media systems [30] as well as with plugins [16]. For our implementation, we built the game from a pre-existing system of Microsoft Paint 3D, with a 'wizard,' who responded to the keywords generated from both SGD and vocal speech output.

When reflecting on Design Goal 2, we also considered that the participants might attempt to use the screen as a touchscreen to color the image in the game, rather than control the game with their SGD voice-generated output. Touchscreen coloring as a feature was not enabled on the game's laptop as our primary purpose was to explore the connection between the use of the SGD as a

[2]https://www.crayola.com/featured/free-coloring-pages

game controller and engagement. For this reason, we only allowed vocal speech or SGD output to control the game. We allowed these communication modalities to function as the game controller to provide flexibility for participants who communicated with vocal speech as well as a SGD, while fostering engagement both with the SGD and the game.

3.3 Game Play

During the game process, in-person 'game facilitators,' familiar people and therapists assigned to work with the child in the clinic, supported the participant while playing the game. This Wizard- of-Oz Coloring Game involved four steps (see Figure 1). With the assistance of the game facilitator, the child logged into the Zoom session with the first author acting as the 'wizard.' Game facilitators were allowed to redirect participants to the SGD to select the color and to point to the game screen when the color changed, but were instructed to provide minimal prompts to the child outside of this rule. This was to show the child that the SGD was controlling the game. The researcher turned their camera off, with one side of the Zoom screen showing only the child on the video and the coloring page so that the researcher could observe and record how the participant and game facilitator were interacting with the game. With the researcher not visible on the screen, the child could interact with the 'game' rather than the researcher. The researcher also turned their microphone and speaker on to communicate with the participant and hear commands from the child's SGD. On the participant side, their microphone and speaker were on to enable communication with 'the game.'

The researcher started the game, asking the child to select a color using their SGD to color the animal on the screen. The child selected the color on their SGD, and it generated an output sound of the color selected. Finally, the researcher moved the paintbrush and colored the picture in the game based on the child's selected color.

4 WIZARD-OF-OZ FORMATIVE CASE STUDY

4.1 Ethics Statement

An Institutional Review Board approved the study. Due to the fact that our participants were children under the age of 18, we followed the informed consent process approved by the Institutional Review Board, where the participant's legal guardian consented to their inclusion in the study. However, we also included assent procedures [23] within our study, asking participants if they wanted to play the game with us before starting. If they moved towards the game, we started the game. As soon as the child moved away or indicated they were done playing the game, we ended the game session. Since the 'wizard' was operating remotely from a laptop, we required game facilitators to be present with the child. We also made our system portable, so that it could be incorporated within the typical clinic routine, familiar to the children.

4.2 Methods

4.2.1 Participants. We recruited five participants for the case study who participated in a University clinic. We used convenience sampling [35] to recruit our participants from one clinic where autistic children attended several days per week to learn to use their SGDs. We used this strategy for recruitment, as autistic children who use AAC can be a hard-to-reach population [59], requiring an extensive professional network and legal guardian consent. We also recruited participants specifically who indicated a preference for coloring, through previous observations by clinic therapists, as an activity they were observed to spend time with in the clinic setting. The purpose of this study was to be an exploratory multiple case study, and one that did not require a large sample size, as is standard for these types of studies [62]. Participants ranged in age from 3-5 years,

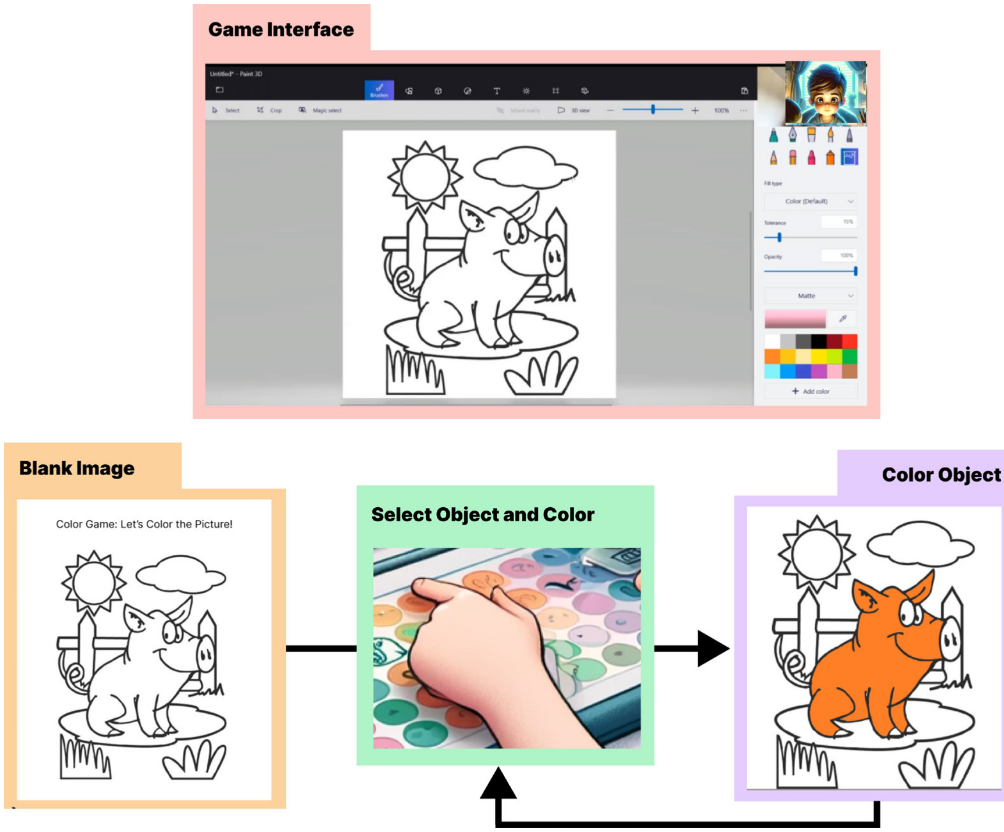

Fig. 1. System Overview Setup: Game Interface: The child logs in to the zoom session with the Microsoft Paint 3D picture. Blank Image: The researcher, acting as the game starts the script "Let's play a game! What color should we color the pig?" Select Object and Color: The child selects the color on their SGD, and the SGD broadcasts the sound of the word (eg."orange"). Color Object: The researcher colors the pig in that color. The game continues with additional selection of colors per object.

and all were diagnosed with Autism Spectrum Disorder, as shown in Table 1. All participants used SGDs to communicate, and were able to select at least one icon on a page using their SGD. Though participants demonstrated a range of proficiency with their SGD and speech capacity, at the time of the study none of the participants were using either speech or their SGD to fully meet their daily communication needs. All were using speech with low frequency and with a small number of words, and all communicated primarily through pre-linguistic means (e.g., pointing to things they wanted, pushing away things they didn't want, facial expressions, using nonspecific vocalizations). All participants used the SGD Proloquo2Go by Assistiveware (see Fig. 2). Participant information is shown in Table 1.

4.2.2 Setting. We used the web conference platform Zoom to complete our study. Participants accessed Zoom through a laptop set up within the University clinic on a table, in an open area within the clinic. Participants also had their SGD present. The laptop was not a touchscreen-enabled laptop. This was so that only the voice output of the SGD could control the game, and a participant did not accidentally color the image using the touchscreen of the laptop. We enabled the Zoom

Fig. 2. Setting. Image of a participant logged in to the game and using an SGD with a grid display to play the color game.

screen share function, with the coloring page displayed on the screen in Microsoft Paint 3D, as well as audio and video recording functions (see Figure 2). In addition, we had an alternate video recording from another video recording device positioned toward the child and laptop screen to capture data that would not be collected from the Zoom recording, thus providing more information for future data analysis. For example, if the child chose to keep their AAC device lower than the laptop camera, the alternate video recording could capture this video instead of the Zoom video recording. Only the Zoom camera was used to help the 'wizard' operate the game. The second camera's recording was not accessed by the 'wizard' during game play.

4.2.3 Wizard-of-Oz Procedure. Participants accessed the game through the Zoom video conferencing web platform with the shared screen feature enabled. The 'wizard's' computer shared the digital coloring pages on Microsoft's Paint 3D program. The coloring pages were selected from the 'Plants and Animals' page, and we selected the first three pictures that showed common animals: barnyard, pets, and undersea creatures. These categories of animals were chosen due to higher levels of preference with these animals and children at this age group [7].

Once the game facilitator logged the participant in to the Zoom web conference, the game began. The 'wizard' then began the game script as follows:

Hi, do you want to play a game? [Wait for child to indicate 'yes']
Let's go to your color page! [Pause for navigation.]
We are going to color the picture! [Pause for 5 seconds.]
Use your talker to tell me what color to color each animal!
What color should we color the pig?

For example, when the participant selected the color 'pink' on their SGD the speech generated output said *Pink*. The first author then moved the paintbrush and selected pink on the Zoom screen, coloring the picture of the pig pink on the screen (Figure 1). When moving to the next image in the picture, the 'wizard' stated to the participant the next image to color, and asked what color to color the image (following the game script above). These game turns repeated until all the images on the page were colored. The 'wizard' asked the participant if they wanted to keep playing, and if they indicated yes, the 'wizard' pulled up the next coloring page. The 'wizard' followed this procedure until the participant indicated they were finished playing by saying "All done" using their SGD or by moving away from the screen.

4.2.4 Data Collection. Data were collected via the Zoom audio and video recording as well as with a second camera present in the room collecting video and audio data. We collected data using both viewpoints, so that we could get a good vantage point of the child's interaction and engagement with the game. This allowed us to also reflect that a typical game would not be able to 'see' the player, and these observations would provide valuable information for designing future games for follow up studies.

Though there has not been an established definition of engagement in early childhood literature, some studies define engagement through behavioral observations [58], using duration of interaction as a form of measurement [49]. For this study, we defined two behavioral dimensions for observation with our participants: 1) engagement with the game, defined as the length of time the participant was in front of the computer interacting with the game and 2) engagement with the SGD, defined as the length of time the participant interacted with the SGD through eye gaze or selection. Engagement onset was counted in seconds from the time the participant had their body oriented towards the computer or SGD with the offset when the participant looked or moved away from the computer or SGD. We also counted the number of turns the participant engaged with the game, and recorded any joint attention responses (where the participant made eye contact or oriented their body towards the game facilitator and to the game) [52].

In our data collection process, as previously noted, we had two cameras recording: the Zoom camera angle, which can be described as the 'Game View,' providing us with the vantage point of what an automated gaming system would 'see' when the player was playing the game; and the second camera recording the player from behind, defined as the 'Room View.' This participant observation data collection strategy [37] provided insights into user behaviors and experiences while the participant was interacting with the game. This approach was essential for us to collect data, and to the proprietary nature of existing SGDs, we could not modify SGDs to gather data. By using this approach, we sought to capture user interactions with the SGD that might not be readily captured by the 'Game View.'

4.2.5 Data Analysis. Since our participants had limited communication to provide us with feedback on their user experience, data analysis for our case study involved an iterative and ethnographic approach, consisting of behavioral observations to gather information [6]. The first author maintained a journal to document observations and evolving thoughts about user experiences. Additionally, discussions were held with the University clinic's behavior analyst and speech and language pathologist during the data analysis process to gain further insights into the child's experience and to

Table 1. Participant Information. From our observations of participants, *Proficiency with AAC* is defined as the following: Beginning: the participant can select one icon on a single page; Emerging: the participant can select multiple icons on a page; the participant can navigate or scroll between two pages or fields. From our observations of participants, *Speech Capacity* is defined as follows: Non-vocal where the child did not emit any vocal words or word approximations; Partial vocal where the child emitted vocalizations but they were word approximations; and Vocal where the child emitted one or more full vocal words. *Pictures* are the number of pictures colored during the game. *Game* is defined as the seconds spent engaged in the game. *AAC* is defined as the seconds spent engaged with their SGD.

Id	Age	Gender	Proficiency with AAC	Speech Capacity	Pictures	Game	AAC
P1	4	F	Emerging	Non-vocal	2	360	360
P2	4	M	Beginning	Partial Vocal	2	46	141
P3	4	M	Beginning	Partial Vocal	1	20	5
P4	5	M	Beginning	Non-Vocal	1	13	7
P5	3	M	Emerging	Vocal	1	56	56

contextualize observations. Serving as the 'wizard' the first author also engaged in a process of iterative sense-making during the data analysis process to develop a deeper understanding of each child's individual experience and to understand commonalities across participants. The other authors also reviewed the video recordings independently, jotting down observations. The first, second, and fifth author met to share observations, with weekly meetings occurring from December 2023-February, 2024. Furthermore, these regular meetings were held by the authors to reflect on potential biases or alternative explanations as part of the data analysis process. The data analysis process was iterative, and used this ethnographic approach to qualitatively code the observations. Thus, calculating inter-rater reliability would not be suitable [48].

5 RESULTS

In this section, we present the results as a case study with five participants interacting with the Wizard-of-Oz SGD-controlled coloring game within a clinic setting. We first share our observations of each participant's experience with the game, reflecting on the experience through the vantage points of the *game view* and *room view* videos. Next, we synthesize our observations into three themes: engagement with the game, engagement with the SGD, and game play opportunities for social interaction and collaboration. A summary of engagement results can be found in Table 1.

5.1 Participant Observations

5.1.1 P1. P1 was a 4 year old female who had emerging proficiency with AAC and was largely non-vocal (did not emit vocal words or word approximations). She was able to navigate her SGD, scrolling between two pages of icons, selecting an icon from a field of multiple icons on a page.

From the Game View video, the participant started the Zoom session with the shared screen feature enabled of the Microsoft 3D paint game. For the participant's initial selection, the 'game' was not able to hear the audio, and the facilitator vocally repeated the color the participant selected from the device. Once the initial object was colored, the participant moved forward in the game and continued pressing colors on their SGD to complete two coloring pages. We observed 5-second pauses between the question from the game *What color do you want to color the picture?* and the selection of colors from the SGD. When the game script advanced to a new picture, the child continued to press colors. The game facilitator stated that the child wanted to color the previous picture in its entirety, including the background. At this point, the 'wizard' went back to the original picture so that the child could color the background of the image, before moving on to the second page. The game facilitator later shared after the game's conclusion that they knew they wanted to color the background based on previous experience with the participant and coloring. Following this observation, we can infer that an automated gaming system would switch pictures once all of the objects were colored, leaving the background uncolored. However, with this participant, the game, operated by the first author as the 'wizard,' manually facilitated the continuation of coloring the current picture until all the white spaces in the background were filled. This should be a design consideration and challenge for future game design, as a child may become frustrated if they want the entire picture colored, including the background.

From the Room View video, there was more to see compared to the Game View presented. We observed that the participant initially wanted to use the screen as a touch screen; however, once they saw the connection between pressing an icon on their SGD and seeing the colors on the screen, they continued to select colors on their SGD, coloring the two different pictures. When transitioning from the second to the third picture, the game loaded a new image and the 'wizard' asked the participant to choose a color. The participant did not respond and was prompted by the game's facilitator, to choose a color. The participant, visibly frustrated, used their SGD to say, "all done," resulting in the termination of the game session.

During the game, the participant navigated between two pages on their SGD, each with a field of 12 options. The participant engaged with both the game and the SGD for 360 seconds each and colored two pages. For this participant, once the initial connection occurred between the selection of an icon from the SGD as a means to control the game, they consistently looked to the game, then to their device to select the color, and then back to the game for 13 turns. They also engaged in one joint attention response with the game facilitator (eye gaze from device to the game facilitator) when they needed help with the game, and the game was not responding to the initial touch screen selection.

5.1.2 P2. P2 was a 4 year old male who had beginning proficiency with AAC. He was partially vocal, vocalizing some approximation of words during our session. His SGD had a single page with 4 icons of colors as choices.

In the Game View video for this participant, the session started with the participant being partially visible on the video, and making a vocal sound resembling "een," which led the game to color the first object in the picture green. There was a long pause before the next selection of the SGD by the participant. We reflected that it was a challenge for the 'wizard' to understand what the child was doing without being able to see the participant, and the game continued to follow the script, repeating the prompt of *What color do you want to color the pig?* three times until the child selected a color from the SGD. Following the next selection, the game continued to respond to the color choices made by the participant using their SGD, coloring objects on the screen accordingly based on the audio input from the SGD. The 'wizard' noted that they could not see the participant on the video camera, and needed to rely on the audio output of the SGD to move forward in the game. This is similar to how an automated, rather than 'wizard,' SGD-controlled game would respond.

In the Room View video, again, we observed a different experience of the participant than from the Game View. The participant interacted with the game by attempting to press buttons on the laptop and using the screen as a touchscreen, which resulted in accidentally closing the game on the screen. The facilitator intervened by reloading the game onto the screen. After being redirected to select a color using the SGD by the facilitator, the participant proceeded to select colors on the device without looking at the game screen. It was observed that the participant was not looking at the game screen; however, it appeared as though they were responding to the audio of the game script as they would wait for the game to ask the question of *What color...?* and then would respond by selecting a color. The engagement times were recorded as 46 seconds with the game and 141 seconds with the SGD, during which the participant colored two pictures. They engaged with the game for seven turns. They did not have any joint attention responses with the game's facilitator.

5.1.3 P3. P3 was a 4 year old male who also had beginning proficiency with his SGD. He was partially vocal, and had some vocal word approximations during the observation. His SGD also contained a field of 4 colors.

From the Game View video, the participant took some time to interact with the game, and 50 seconds elapsed before they selected a single color on the SGD to color in the picture presented on the screen. After this selection, the facilitator shared that they walked away, and the game ended. For this participant, it was again a challenge for the 'wizard' to understand if they were attending to the prompt of *What color do you want to color the pig?* so the game repeated the prompt 5 times before they selected a color on the SGD.

The Room View video revealed that the participant stared at screen making mouth movements and some vocal sounds, looking around the room. For this participant, the SGD showed a field of 4 colors. The participant's engagement with the game was brief, looking at the game screen for 20 seconds and interacting with the SGD for 5 seconds to make a color selection. They made a single color selection to color one object in the picture, for one turn. Despite this brief engagement, it was noted to the researchers by the game's facilitator that this duration of engagement was the longest the participant had sat and attended compared to other clinic activities. Reflecting on this experience, we noted the participant needed a more explicit connection between selecting the color from the SGD and the game's response, indicating a need for the facilitator to model the use of the device and then point to the corresponding action in the game. The participant did not have any joint attention responses with the game's facilitator.

5.1.4 P4. P4 was a 5 year old male who had beginning proficiency with his SGD. He was non-vocal and did not vocalize during the session. His SGD had a field of 4 icons representing the colors red, green, blue, and yellow.

For the Game View video, we observed the child interact with the SGD by first selecting two colors simultaneously, which presented a challenge for the 'wizard,' acting as the game, in isolating a single color's audio to color the picture. As a result, the game repeated the question, *What color do you want to color the pig?* regarding color choice when this overlap occurred. The child selected 'orange' on their SGD, and the game colored the pig in the picture orange. As the 'wizard,' operating the game, we noted that we could see that the child moved away from the game and ended the game. For an automated gaming system, this would be a challenge to identify that the child was finished playing, and the game would continue to loop the prompt of *What color do you want to color the[insert name of object]?*, if the child moved away and did not close the application.

For the Room View video, the child selected two colors simultaneously on their SGD. After the child was prompted to select one color instead of two, they selected 'orange' and then smiled at the screen when the pig was colored. Although there was a field of 4 colors available on the SGD, the child then desired a different color than what was present. They could not find the color on the field of 4, and then attempted to select it by touching the color on the game screen. This attempt was unsuccessful, leading to frustration, vocalized by yelling and walking away from the game. The child was engaged with the game for 13 seconds and with the SGD for 7 seconds. They engaged with two turns in the game. They did not engage with joint attention responses with the game facilitator. Reflecting from this vantage point, it is possible that this participant would need more than four choices on their SGD to be visible when playing a color game.

5.1.5 P5. P5 was a 3 year old male who had emerging proficiency with his SGD. He was vocal and vocalized words and word approximations as he selected icons on his SGD. His SGD contained a field of 4 icons of colors; however, he was able to scroll and move the field up and down to select from a display of new colors.

In the Game View video, the 'wizard,' operating as the game, initially could not hear the child's vocal speech command to color the pig red. The facilitator intervened by repeating the color out loud, prompting the game to color the pig as requested. After coloring the pig, the child continued to use vocal speech and also select colors on their SGD to complete coloring the first picture. The game responded to both the vocal speech selection and SGD output as the purpose of the game was to respond to both types of speech. When the game transitioned to the second picture, the 'wizard' again could not hear the child's color selection. The facilitator had to repeat the color choice, but in the delay, the game facilitator noted that the child had walked away from the game which was not visible to the 'wizard' operating the game.

From the Room View video, the child was seated a table, and it was noted that other clinic children and therapists were present in the room off-camera. It was observed that the child had access to a field of four colors on their SGD and was actively scrolling between fields to select colors from different fields of 4 icons. The child used vocal speech and identified colors before making selections on the device. Their full attention was on the game once the first object was colored. However, the child walked away from the game, when the game *lagged* and did not immediately color the picture with their color selection. The child was engaged with both the game and the SGD for 56 seconds each, coloring one picture with 5 turns of the game. This participant engaged in two joint attention responses with the game's facilitator, and one joint attention response with another child in the room when different colors appeared on the screen. Reflecting on this vantage point, to keep children engaged, game lags will need to be minimal between the selection of color from the SGD and coloring of the picture, and auditory issues with voice control of the game within noisy environments will need to be solved.

5.2 Case Study Synthesis

5.2.1 Engagement with the Game. We observed that emerging AAC users had a higher duration of engagement with the game. P3 and P4 spent more time engaged with the game than their SGD, looking at the screen and attempting to use the screen as a touchscreen to color the picture. P1, P2, and P5 all colored 2 pages of the game, while P3 and P4 colored 1 page before indicating they were finished playing by walking away or selecting "all done" on their SGD.

Vocal speech capacity did not seem to impact the engagement with the game for our participants, as P1 spent the longest time with the game and did not make any vocal word approximations. Once the initial connection was made between the SGD generation to control the coloring of the game, P1 and P5 consistently looked to the game, then to their device to select the color, and then back to the game for several turns.

5.2.2 Engagement with the SGD. We observed that for emerging AAC users, we again had a higher duration of engagement with their SGDs, with P1 engaging with their application for 360 seconds and P5 engaging with their SGD for 56 seconds; both of these participants spent an equal amount of time engaged with the game and the SGD. P3 and P4 spent the least time with their SGD (5 and 7 seconds, respectively). P2 spent more time engaging with their SGD (141 seconds) than with the game (46 seconds). It should also be noted that P2, did respond to the game questions by selecting colors on their SGDs in response to game questions; however, their full attention was on their SGD rather than the game. This is an interesting finding as they were hearing and responding to the game instructions but not looking at the screen to see the color change.

For P5, our only vocal participant, we observed that they often vocally stated the color and then selected it on their SGD. The game responded to both the vocal selection and SGD-generated output, and this participant used both communication modalities consistently to interact with the game.

5.2.3 Game Play Interaction and Social Collaboration. All of the participants engaged with the game for at least one turn (Design Goal 2). P1 initially showed an inclination to use the screen as a touch interface; however, once the connection between using the application as the controller occurred, they consistently used their SGD to color the images. P1 also displayed a preference for coloring every object in the entire picture. The game attempted to move to another picture without coloring all of the objects, and this led to frustration when the game progressed to a new image without completing the coloring of the entire picture.

We observed that two of our participants (P1 and P5), engaged in joint attention responses between the game and the game's facilitator, who was a familiar therapist within their clinic setting (Design Goal 3). P1 looked to the facilitator when they needed help to navigate to an icon to interact with the game. P5 also engaged in one joint attention response with a peer off of the camera screen when the color showed on the screen, and two joint attention responses with the game's facilitator when the game shifted to a new coloring page. This indicated emerging social collaboration between the participants, therapist, and peers during game play.

Observations also revealed situations where there was a need for social collaboration between the participant and game facilitator. P3 was observed making mouth movements and looking around the room, and P4 smiled when the pig was colored on the screen after they selected their first color, but showed frustration when they could not find the desired color shown in a field of four on their SGD and walked away from the game. These instances demonstrate a need for more collaboration from the game facilitator to show the connection between the SGD as the game controller and the game, and a natural learning opportunity to teach the child to navigate the fields of the SGD.

6 DISCUSSION

6.1 Design Implications for AAC Voice Controlled Games

It is important to note that all participants engaged with both their SGD and the game for a brief duration, and all of the participants engaged with the game for at least one turn. For autistic children who are beginning communicators, even brief moments of engagement can be considered a success, as the executive functioning skills needed for engagement and joint attention between SGD and the game can be a challenge for this population [14]. Based on this finding, games may require better modifications to suit these early-stage communicators' needs and capabilities. Simplifying the game interface with fewer elements on the screen, incorporating more movement with child-friendly characters or avatars, and integrating more sounds could enhance attention and engagement for beginning communicators. In addition, it is necessary to trial the game design with autistic children who have more established language skills, SGD use, and joint attention capabilities to determine if they may be a more suitable audience for these types of games. We observed frustration for some participants when the images were not completely colored (P1), when a color appeared as an option in the game but not on their field of view for the SGD (P4), and when there were lags in game responses (P5), indicating a need for flexibility and quick responsiveness of future gaming systems. For two of our participants (P2 and P3), having more guidance connecting the SGD as the game controller would be beneficial to address challenges with playing the game. These findings align with previous research suggesting that before engaging with an activity, the learner must engage with *events of instruction* [25], indicating a need for scaffolding activities before initiating the game. Existing literature using gamification to teach prerequisite skills for AAC supports the use of a pre-game tutorial phase aimed at capturing the learner's attention and assessing prerequisite skills, such as attending to the game screen and navigation of their SGD [71].

Within game design research, game tutorials reveal mixed results regarding their efficacy regarding gaming performance [4, 11]. However, research in this field has shown that game tutorials, depending on the game type [36] or game's complexity [4, 11], may increase player time with a game, and guidance from in-game tutorials provide positive effects on learning to play the game and user flow for gamers [50, 54]. Researchers have also noted that within actual games, there can be several design features (such as *The Personal Advisor*, where a within-game agent can provide visual cues and advice for the player) that support the learning of the game for players outside of a standard tutorial [56].

Notably, neurotypical adult gamers are the primary population of study for most game tutorial studies, and not autistic children, who may require direct instruction before learning a skill [27]. Autistic children sometimes have a low frustration tolerance [47] and may hyper-focus on particular stimuli in their environment [45], both of which are considerations for game designers for this population. In particular, games that contain multi-sensory stimuli and features leading to frustration for a neurotypical gamer may be amplified and lead to game abandonment for autistic gamers. It is important that future SGD-controlled games are developed using a co-design process [53] with autistic children, their therapists, and their caregivers, when developing future iterations of the game as well as game tutorials.

Research within game design has also shown that players learn game mechanics by exploring different components of games [4], and may experience higher levels of enjoyment if these tutorials are modeled within the context of the game [24]. Game tutorials that are fun and engaging may also increase user adoption in playing the actual game [73]. In addition, observing others play games can be helpful for gamers [41], and pre-game tutorials incorporating exploration and models of game play, as well as game facilitator guides for parents and game partners, may support autistic children who use SGDs to learn SGD-controlled games within a social and collaborative context. From this study, we learned that using a piggyback prototyping method [16, 20, 30] was helpful for gathering information on the use of games and SGDs for autistic children. This method allowed us to incorporate the speech generation from different SGDs as well as vocal input with an already existing digital platform, saving us time and resources (Design Goal 1). If we had to develop a *from scratch* prototype with direct connectivity to an SGD to explore this idea with our participants, it would have presented challenges in navigating proprietary SGD software. In addition, using the Wizard-of-Oz method also allowed for flexibility within the game-play, so if the child exhibited frustration, rather than continue with the script presentation, the 'game' moved on to the following picture.

With that said, during game-play, we identified moments where the 'wizard' responded to the child differently than in an automated game system (e.g., instances when the audio was difficult to hear through Zoom and the facilitator repeated the speech-generated output), which is a key observation for the future design of SGD-controlled games. For our study, we had two cameras recording participants, the Zoom recording, and an in-room recording of the child's interaction with their SGD and the game. When analyzing the results, there were moments where the in-room camera showed a different angle of the child interacting with the SGD and occasionally picked up on more auditory output from the device than the Zoom recording. Ultimately, the Zoom recording vantage point is what an automated game would 'see' while interacting with someone playing the game. Challenges identified from these recordings (audio capture, tracking the child's attention to both the game and the device) provide insights for future design considerations, such as adding an external microphone, as well as eye-gaze tracking software to incorporate within future AAC voice-controlled gaming systems.

6.2 SGD-Controlled Games for Supporting Social Connection and Collaboration

Previous research studies have noted children's frustration and lack of motivation in using AAC, often stemming from a disinterest in using a SGD as a communication tool [39]. We observed two instances of this with our participants, with P3 taking 50 seconds to interact with their SGD, and P4 visibly showing frustration when they could not find the color they wanted on their grid display for the SGD. Personalization of games to match individual interests, paired with SGD integration, may increase the frequency of independent SGD use.

In addition to their potential to provide increased opportunities for independent practice in AAC, games controlled by SGD output could also offer a new context for social interaction (Design Goal 3). Though participants in the current study interacted with the game individually, we did observe two participants demonstrating the emergent use of joint attention during the game (P1 and P5) with the game's facilitators [52]. By allowing vocal speech and SGD output to control the game, this also sets up the opportunity for collaboration with AAC users and people who do not use AAC. One notable concern among parents is the stigma associated with AAC, when their children use AAC to communicate in primarily vocal settings [39], and the integration of AAC within games may motivate vocal peers to engage with autistic children who use AAC, thus facilitating social interaction and inclusion [66].

By transforming the learning of the SGD from a passive to a shared experience, games can enhance engagement and social practice with the device and with others, including parents, siblings, and peers, particularly when engaging in play activities [18]. This is particularly relevant considering *Broffenbrenner's Family Systems Theory*, which emphasizes the inter-connectedness of children and families within larger social systems [9, 39]. Games, therefore, can be designed to integrate seamlessly across these nested systems, encouraging participation from all members of the child's social network.

Within the child's social network at home, parents of children using SGDs often face the challenge of dedicating significant time and effort to learning and integrating SGDs into family routines, compounded by a general lack of external social support and training for SGD use [18, 39]. This situation is further exacerbated when children lack regular access to therapy services or inclusive peer settings that could provide highly engaging social settings for AAC use [18, 39]. Games, in this context, offer a plug and play solution, potentially reducing the time and effort required by parents while simultaneously promoting social engagement with AAC activities. This approach aligns with recent research suggesting that games can be an effective practice tool outside therapy sessions, enhancing communication through play [18]. Gamification of AAC may foster connectivity and shared communication experiences between parents and their children, as well as between siblings, a desire strongly expressed by parents [39].

Within their larger social network, gamification may improve the engagement between autistic children, their SGDs, and with others as a collaborative tool. One research study noted that autistic children and young adults reported that the social interactions within multi-player or team player video games were their primary source of social connection [22]. Furthermore, previous research has shown that incorporating neurotypical, vocal peers in game-play with autistic children who use AAC, can increase contextually appropriate communication within the game, particularly between the AAC user and their peers [66]. Games that require teamwork or cooperative play can help children practice social skills like turn-taking, sharing, and collaboration towards common goals [66]. SGDs as game controllers may be customized to prompt users to interact, perhaps by requiring players to press buttons in sequence or communicate choices.

7 LIMITATIONS AND FUTURE WORK

The primary purpose of this case study was exploratory: to gather insights regarding the interaction of participants playing a coloring game, using their SGD as the game's controller. The use of SGDs as an *interactive game controller*, to our knowledge, has not been studied before with young autistic children, and thus, we needed insights gained from this study to guide future work in designing SGD-controlled games for children with autism. It is important to note that the purpose of this study was not to show generalization across age groups, nor was it meant to show any long-term effects or changes in the participants following the study, and the brief engagement periods demonstrated by participants are not an indicator of long-term effectiveness of the game.

Within AAC research, studies often focus on a single site with few participants[26, 28, 42]. In addition, we chose this research design and method due to the following challenges: we needed to find young autistic children who use SGDs, a population that requires: 1) legal guardian approval to participate in research; and 2) one that requires an extensive professional network to find. Due to these challenges, our sample came from children already participating in a clinic setting within one geographic area, which is a limitation. Despite this limitation, the case study provided us with valuable information regarding the design of future studies for testing the game with a larger sample of participants of different age ranges from different geographic areas with different SGD proficiency levels, across several sessions so that we can study the effects of SGD-controlled games longitudinally.

This study used a Wizard-of-Oz method to test the game, which allowed for potentially more pauses or disruptions within the game's flow than an automatic system. To facilitate the Zoom recordings, we also used a laptop to play the game, and some participants tried to use the screen as a touch screen to play the game, when initially taking their first turn. Future studies should examine the use of a larger second screen as part of the game setup so that the user only sees the larger screen of the game and the SGD while playing the game. The sessions also took place in a clinic that had other children playing, so the noise level in the room sometimes made it challenging for the researcher to hear the SGD output. Future designs should look at universal microphone connectivity between the SGD and game.

Future studies should also examine adding additional prerequisite 'game tutorials' to teach the requirements for game play to the child prior to starting the game. These games can contain activities as levels or milestones presented as pre-game modules, following the research on *events of instruction* [25] with the following milestones:

- Game Milestone 1: Attention to big screen and game. The child directs their eye gaze to the big screen showing the game, by following movement of icons such as bubbles on a screen. This can be detected using eye gaze software.
- Game Milestone 2: Attention to SGD. The child selects icons on their SGD, responding to instructions from the 'mini-game' (i.e. "touch red," "touch orange"). The game detects the selection based on the audio output of the SGD.
- Game Milestone 3: Practice with eye gaze to the game and selecting icons on their SGD. The child looks at the screen first, receives the instruction 'touch red,' and then selects the red icon on their SGD. The game tracks both movements with eye gaze detection and audio detection.

It is also important to observe the application of this work when evaluating engagement with AAC game play and additional groups of people. Examples of these additional game studies include:

- Studying the use of SGD game play with children who are more advanced communicators on the autism spectrum.

- Studying the use of art or coloring games with children who have significant motor impairments, including those who use SGDs. Children who do not have the motor skills necessary to draw often require others to create artwork for them. SGD Art Games could provide an opportunity for inclusion for that population.
- Studying the effects of games that respond to SGD output and engagement with multiple people within a larger collaboration system, evaluating multi-player use of SGD games, specifically with caregivers, peers, and siblings.

8 CONCLUSION

Overall, by using a Wizard-of-Oz coloring game guided by our three design goals, we gained valuable insights regarding how autistic children who use AAC may interact with a game that responds to SGD output as the game's controller. These include the impact the level of proficiency the child has with the SGD, the importance of preparatory activities for children at different stages of SGD familiarity, and ideas for future design iterations of an SGD-controlled game. As part of our study, we also observed with two participants, moments of social connection and collaboration through game play. These findings emphasize the need to explore new gaming approaches for autistic children who use AAC. The observed variability in engagement also suggests a need for adaptable and personalized features within such games. In the future, we plan to conduct more in-depth studies on gaming prototypes for autistic children who use AAC.

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REFERENCES

[1] Maayan Agmon, Cynthia K Perry, Elizabeth Phelan, George Demiris, and Huong Q Nguyen. 2011. A pilot study of Wii Fit exergames to improve balance in older adults. *Journal of geriatric physical therapy* 34, 4 (2011), 161–167.

[2] Fraser Allison, Marcus Carter, and Martin Gibbs. 2020. Word play: a history of voice interaction in digital games. *Games and Culture* 15, 2 (2020), 91–113.

[3] Fraser Allison, Marcus Carter, Martin Gibbs, and Wally Smith. 2018. Design patterns for voice interaction in games. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*. 5–17.

[4] Erik Andersen, Eleanor O'rourke, Yun-En Liu, Rich Snider, Jeff Lowdermilk, David Truong, Seth Cooper, and Zoran Popovic. 2012. The impact of tutorials on games of varying complexity. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 59–68.

[5] American Psychiatric Association. 2013. *Diagnostic and statistical manual of mental disorders (5th ed.)*. American Psychiatric Association.

[6] Jeanette Blomberg and Mark Burrel. 2009. An ethnographic approach to design. In *Human-computer interaction*. CRC Press, 87–110.

[7] Marta Borgi and Francesca Cirulli. 2015. Attitudes toward animals among kindergarten children: species preferences. *Anthrozoös* 28, 1 (2015), 45–59.

[8] Jamie B Boster and John W McCarthy. 2018. Designing augmentative and alternative communication applications: The results of focus groups with speech-language pathologists and parents of children with autism spectrum disorder. *Disability and Rehabilitation: Assistive Technology* 13, 4 (2018), 353–365.

[9] Urie Bronfenbrenner. 2013. Ecology of the family as a context for human development: Research perspectives. *Adolescents and Their Families* (2013), 1–20.

[10] Murilo C Camargo, Rodolfo M Barros, Jacques D Brancher, Vanessa TO Barros, and Matheus Santana. 2019. Designing gamified interventions for autism spectrum disorder: a systematic review. In *Entertainment Computing and Serious Games: First IFIP TC 14 Joint International Conference, ICEC-JCSG 2019, Arequipa, Peru, November 11–15, 2019, Proceedings 1*. Springer, 341–352.

[11] Shuangyuan Cao and Fang Liu. 2022. Learning to play: understanding in-game tutorials with a pilot study on implicit tutorials. *Heliyon* 8, 11 (2022).

[12] Ying-Yu Chao, Yvonne K Scherer, and Carolyn A Montgomery. 2015. Effects of using Nintendo Wii™ exergames in older adults: a review of the literature. *Journal of aging and health* 27, 3 (2015), 379–402.

[13] I-Ching Chung, Chien-Yu Huang, Shyh-Ching Yeh, Wei-Chi Chiang, and Mei-Hui Tseng. 2014. Developing kinect games integrated with virtual reality on activities of daily living for children with developmental delay. In *Advanced Technologies, Embedded and Multimedia for Human-centric Computing: HumanCom and EMC 2013*. Springer, 1091–1097.

[14] Blythe A Corbett, Laura J Constantine, Robert Hendren, David Rocke, and Sally Ozonoff. 2009. Examining executive functioning in children with autism spectrum disorder, attention deficit hyperactivity disorder and typical development. *Psychiatry research* 166, 2-3 (2009), 210–222.

[15] Flannery Hope Currin, Cassidy Kilcoin, Kerry Peterman, Kyle Rector, and Juan Pablo Hourcade. 2024. Opportunities and Challenges in Using Tangible, Teleoperated Voice Agents in Kid-Driven Moments in Play Among Families with Neurodivergent Children. *Proceedings of the ACM on Human-Computer Interaction* 8, CSCW1 (2024), 1–25.

[16] Catherine Delcourt, Zhixin Jin, Sofia Kobayashi, Quan Gu, and Christine Bassem. 2023. Demonstration of A Figma Plugin to Simulate A Large-Scale Network for Prototyping Social Systems. In *Adjunct Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology*. 1–3.

[17] Yao Du, Sarah Choe, Jennifer Vega, Yusa Liu, Adrienne Trujillo, et al. 2022. Listening to stakeholders involved in speech-language therapy for children with communication disorders: content analysis of Apple app store reviews. *JMIR pediatrics and parenting* 5, 1 (2022), e28661.

[18] Yao Du, Kathryn Lubniewski, Lori Price, Grace Breslin, Paula Thomson, Natashka Jinadasa, and Nikita Soni. 2023. "They Can't Believe They're a Tiger": Insights from pediatric speech-language pathologists mobile app users and app designers. *International Journal of Language & Communication Disorders* (2023).

[19] Ana D Dueñas, Joshua B Plavnick, and Howard Goldstein. 2021. Effects of a multicomponent peer mediated intervention on social communication of preschoolers with autism spectrum disorder. *Exceptional Children* 87, 2 (2021), 236–257.

[20] Daniel A Epstein, Fannie Liu, Andrés Monroy-Hernández, and Dennis Wang. 2022. Revisiting Piggyback Prototyping: Examining Benefits and Tradeoffs in Extending Existing Social Computing Systems. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2 (2022), 1–28.

[21] Walia Farzana, Farhana Sarker, Tom Chau, and Khondaker A Mamun. 2021. Technological evolvement in AAC modalities to Foster communications of verbally challenged ASD children: A systematic review. *IEEE Access* (2021).

[22] Erinn H Finke, Benjamin D Hickerson, and Jennifer MD Kremkow. 2018. "To be quite honest, if it wasn't for videogames I wouldn't have a social life at all": Motivations of young adults with autism spectrum disorder for playing videogames as leisure. *American Journal of Speech-Language Pathology* 27, 2 (2018), 672–689.

[23] Jaime Flowers and Jillian Dawes. 2023. Dignity and respect: Why therapeutic assent matters. *Behavior analysis in practice* 16, 4 (2023), 913–920.

[24] Julian Frommel, Kim Fahlbusch, Julia Brich, and Michael Weber. 2017. The effects of context-sensitive tutorials in virtual reality games. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*. 367–375.

[25] Robert M Gagne, Walter W Wager, Katharine C Golas, John M Keller, and James D Russell. 2005. Principles of instructional design.

[26] Jennifer B Ganz, Theresa L Earles-Vollrath, Amy K Heath, Richard I Parker, Mandy J Rispoli, and Jaime B Duran. 2012. A meta-analysis of single case research studies on aided augmentative and alternative communication systems with individuals with autism spectrum disorders. *Journal of autism and developmental disorders* 42 (2012), 60–74.

[27] Jennifer B Ganz and Margaret M Flores. 2009. The effectiveness of direct instruction for teaching language to children with autism spectrum disorders: Identifying materials. *Journal of Autism and Developmental Disorders* 39 (2009), 75–83.

[28] Jay B Ganz, James E Pustejovsky, Joe Reichle, Kimberly J Vannest, Margaret Foster, April N Haas, Lauren M Pierson, Sanikan Wattanawongwan, Armando Bernal, Man Chen, et al. 2023. Considering instructional contexts in AAC interventions for people with ASD and/or IDD experiencing complex communicative needs: A single-case design meta-analysis. *Review Journal of Autism and Developmental Disorders* 10, 4 (2023), 615–629.

[29] Suzanne Gough and Nicola Dutton. 2018. The novel use of LEGO®-based therapy to develop communicative competence in children who use augmentative and alternative communication (AAC) systems. In *The 9th Annual Conference of Association for Simulated Practice in Healthcare*.

[30] Catherine Grevet and Eric Gilbert. 2015. Piggyback prototyping: Using existing, large-scale social computing systems to prototype new ones. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. 4047–4056.

[31] Carl Gutwin, Mutasem Barjawi, and David Pinelle. 2016. The emergence of high-speed interaction and coordination in a (formerly) turn-based groupware game. In *Proceedings of the 2016 ACM International Conference on Supporting Group Work*. 277–286.

[32] Susumu Harada, Jacob O Wobbrock, and James A Landay. 2011. Voice games: investigation into the use of non-speech voice input for making computer games more accessible. In *Human-Computer Interaction–INTERACT 2011: 13th IFIP TC 13 International Conference, Lisbon, Portugal, September 5-9, 2011, Proceedings, Part I 13*. Springer, 11–29.

[33] Christine Holyfield and Elizabeth Lorah. 2023. Effects of high-tech versus low-tech AAC on indices of happiness for school-aged children with multiple disabilities. *Journal of Developmental and Physical Disabilities* 35, 2 (2023), 209–225.

[34] Christine Holyfield, Stephen MacNeil, Nicolette Caldwell, Tara O'Neill Zimmerman, Elizabeth Lorah, Eduard Dragut, and Slobodan Vucetic. 2024. Leveraging Communication Partner Speech to Automate Augmented Input for Children on the Autism Spectrum Who Are Minimally Verbal: Prototype Development and Preliminary Efficacy Investigation. *American Journal of Speech-Language Pathology* 33, 3 (2024), 1174–1192.

[35] Justin Jager, Diane L Putnick, and Marc H Bornstein. 2017. II. More than just convenient: The scientific merits of homogeneous convenience samples. *Monographs of the Society for Research in Child Development* 82, 2 (2017), 13–30.

[36] Dominic Kao, Alejandra J Magana, and Christos Mousas. 2021. Evaluating tutorial-based instructions for controllers in virtual reality games. *Proceedings of the ACM on Human-Computer Interaction* 5, CHI PLAY (2021), 1–28.

[37] Barbara B Kawulich et al. 2005. Participant observation as a data collection method. In *Forum qualitative sozial-forschung/forum: Qualitative social research*, Vol. 6.

[38] Lynn K Koegel, Ty W Vernon, Robert L Koegel, Brittany L Koegel, and Anne W Paullin. 2012. Improving social engagement and initiations between children with autism spectrum disorder and their peers in inclusive settings. *Journal of Positive Behavior Interventions* 14, 4 (2012), 220–227.

[39] Emily Laubscher, Lauramarie Pope, and Janice Light. 2023. "You Just Want to Be Able to Communicate With Your Child": Parents' Perspectives on Communication and AAC Use for Beginning Communicators on the Autism Spectrum. *American Journal of Speech-Language Pathology* (2023), 1–20.

[40] Lina Lee, Johanna Okerlund, Mary Lou Maher, and Thomas Farina. 2020. Embodied interaction design to promote creative social engagement for older adults. In *Human Aspects of IT for the Aged Population. Technologies, Design and User Experience: 6th International Conference, ITAP 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part I 22*. Springer, 164–183.

[41] Wei Li, Tovi Grossman, and George Fitzmaurice. 2014. CADament: a gamified multiplayer software tutorial system. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 3369–3378.

[42] Janice Light, Allison Barwise, Ann Marie Gardner, and Molly Flynn. 2021. Personalized early AAC intervention to build language and literacy skills: A case study of a 3-year-old with complex communication needs. *Topics in language disorders* 41, 3 (2021), 209–231.

[43] Meghann Lloyd, Megan MacDonald, and Catherine Lord. 2013. Motor skills of toddlers with autism spectrum disorders. *Autism* 17, 2 (2013), 133–146.

[44] Elizabeth R Lorah, Christine Holyfield, Jessica Miller, Brenna Griffen, and Cody Lindbloom. 2022. A systematic review of research comparing mobile technology speech-generating devices to other AAC modes with individuals with autism spectrum disorder. *Journal of Developmental and Physical Disabilities* 34, 2 (2022), 187–210.

[45] Gianluca Marsicano, Luca Casartelli, Alessandra Federici, Sara Bertoni, Lorenzo Vignali, Massimo Molteni, Andrea Facoetti, and Luca Ronconi. 2023. Prolonged neural encoding of visual information in autism. *Autism Research* (2023).

[46] David Maulsby, Saul Greenberg, and Richard Mander. 1993. Prototyping an intelligent agent through Wizard of Oz. In *Proceedings of the INTERACT'93 and CHI'93 conference on Human factors in computing systems*. 277–284.

[47] Carla A Mazefsky, John Herrington, Matthew Siegel, Angela Scarpa, Brenna B Maddox, Lawrence Scahill, and Susan W White. 2013. The role of emotion regulation in autism spectrum disorder. *Journal of the American Academy of Child & Adolescent Psychiatry* 52, 7 (2013), 679–688.

[48] Nora McDonald, Sarita Schoenebeck, and Andrea Forte. 2019. Reliability and inter-rater reliability in qualitative research: Norms and guidelines for CSCW and HCI practice. *Proceedings of the ACM on human-computer interaction* 3, CSCW (2019), 1–23.

[49] Brian W Miller. 2015. Using reading times and eye-movements to measure cognitive engagement. *Educational psychologist* 50, 1 (2015), 31–42.

[50] Raphaël Morin, Pierre-Majorique Léger, Sylvain Senecal, Marie-Christine Bastarache-Roberge, Mario Lefèbrve, and Marc Fredette. 2016. The Effect of Game Tutorial: A comparison between casual and hardcore gamers. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play companion extended abstracts*. 229–237.

[51] Siti Azreena Mubin and Matthew Wee Ann Poh. 2019. A review on gamification design framework: How they incorporated for autism children. In *2019 4th International Conference and Workshops on Recent Advances and Innovations in Engineering (ICRAIE)*. IEEE, 1–4.

[52] Kimberly A Murza, Jamie B Schwartz, Debbie L Hahs-Vaughn, and Chad Nye. 2016. Joint attention interventions for children with autism spectrum disorder: a systematic review and meta-analysis. *International journal of language & communication disorders* 51, 3 (2016), 236–251.

[53] Michelle Partogi and Nassim JafariNaimi. 2016. Fostering organizational change through co-designing collaborative media. In *Proceedings of the 2016 ACM International Conference on Supporting Group Work*. 441–444.

[54] Mario Passalacqua, Raphaël Morin, Sylvain Sénécal, Lennart E Nacke, and Pierre-Majorique Léger. 2020. Demystifying the first-time experience of mobile games: The presence of a tutorial has a positive impact on non-expert players' flow

and continuous-use intentions. *Multimodal Technologies and Interaction* 4, 3 (2020), 41.
[55] JP Piotrowski, Evangelos A Yfantis, A Campagna, Q Cornu, and GM Gallitano. 2019. Voice Interactive Games. In *2019 IEEE 10th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*. IEEE, 0780–0784.
[56] Lev Poretski and Anthony Tang. 2022. Press A to Jump: Design Strategies for Video Game Learnability. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–26.
[57] Luis Roberto Ramos Aguiar, Francisco Javier Álvarez Rodríguez, Jesús Roldán Madero Aguilar, Valeria Navarro Plascencia, Luisa María Peña Mendoza, José Rodrigo Quintero Valdez, Juan Román Vázquez Pech, Adriana Mendieta Leon, and Luis Eloy Lazcano Ortiz. 2023. Implementing Gamification for Blind and Autistic People with Tangible Interfaces, Extended Reality, and Universal Design for Learning: Two Case Studies. *Applied Sciences* 13, 5 (2023), 3159.
[58] Andrea Ritoša, Frida Åström, Eva Björck, Lisa Borglund, Elin Karlsson, Elaine McHugh, and Elisabeth Nylander. 2023. Measuring children's engagement in early childhood education and care settings: A scoping literature review. *Educational psychology review* 35, 4 (2023), 99.
[59] Georgia Robins Sadler, Hau-Chen Lee, Rod Seung-Hwan Lim, and Judith Fullerton. 2010. Recruitment of hard-to-reach population subgroups via adaptations of the snowball sampling strategy. *Nursing & health sciences* 12, 3 (2010), 369–374.
[60] Muhammad Irtaza Safi, Karla Badillo-Urquiola, Suleman Shahid, Zirak Zaheer, Momina Haider, and Hamza Mahmood. 2018. Using Native Tongue Mnemonics to Enhance English Learning. In *Proceedings of the 2018 ACM International Conference on Supporting Group Work*. 102–106.
[61] Thomas Schlömer, Benjamin Poppinga, Niels Henze, and Susanne Boll. 2008. Gesture recognition with a Wii controller. In *Proceedings of the 2nd international conference on Tangible and embedded interaction*. 11–14.
[62] Kurt Schoch et al. 2020. Case study research. *Research design and methods: An applied guide for the scholar-practitioner* 31, 1 (2020), 245–258.
[63] Ather Sharif, Aedan Liam McCall, and Kianna Roces Bolante. 2022. Should i say "disabled people" or "people with disabilities"? language preferences of disabled people between identity-and person-first language. In *Proceedings of the 24th international ACM SIGACCESS conference on computers and accessibility*. 1–18.
[64] Akihiko Shirai, Erik Geslin, and Simon Richir. 2007. WiiMedia: motion analysis methods and applications using a consumer video game controller. In *Proceedings of the 2007 ACM SIGGRAPH symposium on Video games*. 133–140.
[65] Amanda Taboas, Karla Doepke, and Corinne Zimmerman. 2023. Preferences for identity-first versus person-first language in a US sample of autism stakeholders. *Autism* 27, 2 (2023), 565–570.
[66] Nadine Trottier, Lorraine Kamp, and PAT Mirenda. 2011. Effects of peer-mediated instruction to teach use of speech-generating devices to students with autism in social game routines. *Augmentative and Alternative Communication* 27, 1 (2011), 26–39.
[67] David Unbehaun, Konstantin Aal, Daryoush Daniel Vaziri, Rainer Wieching, Peter Tolmie, and Volker Wulf. 2018. Facilitating collaboration and social experiences with videogames in dementia: Results and implications from a participatory design study. *Proceedings of the ACM on Human-Computer Interaction* 2, CSCW (2018), 1–23.
[68] David Unbehaun, Daryoush Vaziri, Konstantin Aal, Qinyu Li, Rainer Wieching, and Volker Wulf. 2018. Video-game based exergames for people with dementia and their caregivers. In *Proceedings of the 2018 ACM International Conference on Supporting Group Work*. 401–405.
[69] United States Society for Augmentative and Alternative Communication. 2022. United States Society for Augmentative and Alternative Communication (USSAAC). https://www.nidcd.nih.gov/directory/united-states-society-augmentative-and-alternative-communication-ussaac. Accessed: 2024-01-22.
[70] Sanja Vukićević, Mirjana Đorđević, Nenad Glumbić, Zorica Bogdanović, and Milica Đurić Jovičić. 2019. A demonstration project for the utility of kinect-based educational games to benefit motor skills of children with ASD. *Perceptual and motor skills* 126, 6 (2019), 1117–1144.
[71] Oliver Wendt, Natalie E Allen, Olivia Z Ejde, Sylvia C Nees, Megan N Phillips, and Daniella Lopez. 2020. Optimized User Experience Design for Augmentative and Alternative Communication via Mobile Technology: Using Gamification to Enhance Access and Learning for Users with Severe Autism. In *HCI International 2020–Late Breaking Papers: Universal Access and Inclusive Design: 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings 22*. Springer, 412–428.
[72] Chi-Min Yang, Jun Scott Chen Hsieh, Yi-Chen Chen, Shu-Yu Yang, Hao-Chiang Koong Lin, et al. 2020. Effects of Kinect exergames on balance training among community older adults: A randomized controlled trial. *Medicine* 99, 28 (2020), e21228.
[73] Xiong Zhiyong, Wang Jiani, and Jiang Lijun. 2021. How Game Tutorials in Mobile Online Games Affect User Adoption. In *2021 10th International Conference on Educational and Information Technology (ICEIT)*. IEEE, 264–268.

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