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Design and Development of a Sentence Construction Game for Deaf and Hard of Hearing (DHH) Users: A Qualitative Usability Study

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Abstract: Concerns about the writing proficiency of deaf students in the English language are well known and persistent. Many of them prefer to write concise sentences with fewer adjectives and adverbs and exhibit a variety of syntax usage errors. The purpose of this study was to evaluate the usefulness of a learning intervention created to help DHH students who struggle with sentence formation. The users played with the digital prototype and the perception of the usability of the intervention was analysed and represented using a thematic analysis. Primary insights on the usability and design of this game-based early intervention revealed that the content was well received but more gamification components must be added for the intervention to be both enjoyable and pedagogically valuable. Incorporating more gamification components, conjugating verbs, and studying the effectiveness of the intervention in addressing the difficulty of DHH students in framing sentences will be the focus of the future extension of the study.

Keywords: DHH students, sentence construction, learning intervention, gamification

1. Introduction

The educational experiences of Deaf and Hard of Hearing (DHH) students are significantly diverse and unique compared to students in general education classrooms and students from other disability groups. The Indian educational system has to be strengthened to cater their educational needs as language acquisition remains a major challenge in their life (Mohanty & Mishra, 2020). Studies reported that many DHH individuals struggle with the process of writing and different aspects of writing including phonology, morphology, lexicon, grammar and syntax (Mayer & Trezek, 2019).

Further, DHH children who have limited or no access to spoken language sounds may also find it difficult to learn the rules and patterns of a language like English, particularly because English orthography uses phonemic alphabets (Cannon & Kirby, 2013). Many students also engage in gestures right from a young age to communicate their ideas, which may also contribute to their difficulty in sentence construction during formal education.

Teachers employ a variety of resources to enhance instruction and learning in classrooms, including the use of YouTube videos, guided activities and experience-based learning. Teaching tools and artefacts, such as flashcards, diagrams and rate of speech and hearing charts are used in many classrooms. In contrast to traditional classrooms, it is frequently challenging to teach a full lesson to the students using just speech and gestures. As a result, the key issues facing educators of DHH children continue to be broadening the scope of what may be communicated to the pupils and bridging the gap between what is stated and what is understood (Mohanty & Mishra, 2020). Hence, to meet their educational demands, in addition to better teacher training programs, the teaching materials must be carefully designed. Studies have shown that early intervention helps youngsters develop their linguistic, communication, cognitive, and social abilities more successfully (Marschark et al., 2011). DHH

children who receive early intervention programmes perform better than their peers who do not in terms of language, social development, and early academic achievement (Mohanty & Mishra, 2020).

2. Literature review

A need identification study conducted by Adnyani et al., 2021 highlights the emphasis on the development of multimedia-based English learning materials in addition to highlighting the studies that have put forth the need for incorporating images, visual scaffolds, fingerspelling, etc. to enhance the learning. In another study by Chan et al., 2022, a systematic investigation on French literacy was done for Special Education Needs (SEN) and DHH students with serious games. The study also emphasizes on the improvement in the cognitive skill provided by games to such user groups. One of the major reasons pointed out with respect to poor linguistic comprehension is the lack of syntactic and semantic knowledge by an individual.

The focal question was on how to design an early intervention to improve the level of formal communication in DHH students by addressing their challenge to frame sentences involving conjugating verbs. Studies have recommended the usage of gamification approach in activities involving repetition to keep up the motivation of the user (Faiella and Ricciardi, 2015). Little evidence is available on whether the development of speech or sign language or a combination of both would be beneficial for DHH children. Hence, making an educational programme that defies homogeneity and caters to the unique educational needs of each category (age group/ grade) of students with hearing loss may hold the key to finding the solution. In this paper, we attempt to give an overview of the design and usability of a learning intervention focused on teaching elementary English sentence construction among DHH students which can be further extended to address the challenge involving sentence construction using conjugating verbs.

3. Design and Development of the intervention

The broad objective was to design an intervention that supports special needs education (formal/ informal) of DHH users. The design and development of this game-based learning intervention was carried out in three phases by a group of four researchers as part of the Human Computer Interaction course. The phases included:1) Needs Analysis, 2) Ideation and Conceptualization, and 3) Prototyping. These are elaborated as follows:

3.1 Needs Analysis

The researchers interacted with DHH students at a school with the help of the teachers and conducted a semi-structured interview with the teachers. Further, three therapists who provide early intervention to DHH students for their learning needs were also interviewed through a semi-structured interview. The discussions were capitulated in the form of a concept map providing us a peek at the interconnections in various aspects of their life and guided us towards identifying a problem, through a 5 Why analysis, that appeared important and addressable given our expertise. The key issues identified include difficulty in constructing formal sentences in any language other than sign language, difficulty in engaging in in-person conversations, difficulty in memorizing long sentences, for example, while learning topics in history as part of school curriculum, where formal long and complex sentences in English are essential. Further exploration through fishbone diagrams and empathy maps was done to get deeper insights into the problem. Additionally, a user persona was also prepared to guide the development of the intervention. Grounded on these analyses, the core problem statement was refined as “Design of an early intervention to improve the level of formal communication in DHH children by addressing their challenges to frame sentences involving conjugating verbs”.

3.2 Ideation and Conceptualization

The four group members discussed the concept map and interview data thoroughly and then utilised brainwriting technique to generate 48 ideas. These ideas were then grouped based on the major tools/ technologies they utilised. Further development of ideas and the addition of new insights and inspirations also occurred. Following this process, a Decision Matrix analysis was performed to obtain the optimal solution. Each of the four members conducted the analysis individually, based on the collectively decided factors, which were later incorporated into a single Decision Matrix via averaging. The outcome of this process was the finalisation of the idea brief – "Develop puzzles/ games (tangible/ digital) that teach English grammar and sentence construction".

Following the ideation process, the paper prototype was created to further understand the interactions associated with the elements of the puzzles. Along with the playability aspect of the game, the paper prototyping also helped in conceptualising the sequence of events, which will address the learning objective. The paper prototyping process was informed by the pedagogical references and the gameplay ideation.

3.3 Prototyping

The prototype of the puzzle was further developed using Scratch, a no-code platform suitable for creating educational tools and games. This allowed us to add many game design elements, such as rewards, levels, goals, rules, and progress. The focus of the team at this stage was to create a functional prototype. Figure 1 shows the Scratch coding environment and the user interface for the game prototype, which was then tested with users. The game's objective was to help users create sentences using blocks containing words, shaped like puzzle pieces that best describe a given image on the screen. The prototype game had two levels, which is made available on the Scratch project page *(Level-1:* https://scratch.mit.edu/projects/743654775/fullscreen/; *Level -2:* *https://scratch.mit.edu/projects/ 755127867/ fullscreen/*)

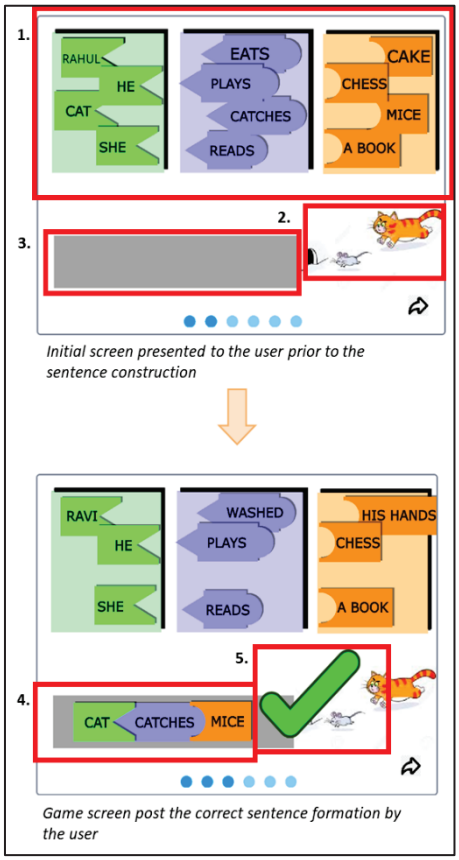

Figure 1: Screenshots of the game screen developed on Scratch

4. Gameplay and Scaffolding

In the game, the user was presented with puzzle pieces on which words were written, which were clustered together into three different bins based on the parts of speech they belonged to. In this iteration, these bins were subject, verb, and object. The content in the standard textbooks for grades 1-2 also supported such a presentation. Upon initial instruction, the user is expected to assemble the puzzle pieces to form a sentence of subject-verb-object (SVO) type (see Figure.1).

Upon successful completion of a sentence, feedback is generated by the system (see Figure 1 (4)), and the screen is refreshed for the next sentence activity. The scaffolding in the games was provided using visual elements, such as shapes and colours. Figure 2 indicates the scaffolds at different levels, i.e. for level 1, the scaffolds were provided in terms of shape and colour of the puzzle pieces, so that words corresponding to a specific part of speech will have different colour and shape. These elements will gradually fade away (colour followed by shape) as indicated in Figure 2. A progress bar indicates the remaining number of puzzles to be solved in each level.

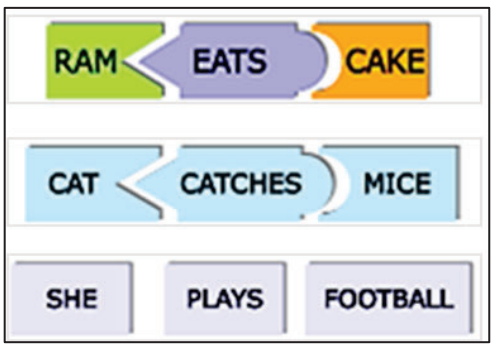

Figure 2: Scaffolds used at different levels of the game

5. Methodology (User testing)

The usability evaluation of the prototype was conducted with five users in a laboratory environment. Out of these five people, two were children (male) between the ages of 6 - 6.5 years without any hearing impairment, whereas the other three belong to the age group of 18 years and above, with severe hearing impairment to complete deafness. The variation in age group of the participants is due to our limited access to young DHH children. Users 1 and 2 helped us understand the usability challenges faced by young children while playing the game. Users 3, 4 and 5 helped us understand the challenges faced by DHH users while playing our game. We acknowledge this as a limitation to be addressed in future studies. Despite this limitation, since this was a preliminary study, data from these users helped us refine our game for young DHH users.

The two users of 6 and 6.5 years of age received instructions on how to play the puzzle in both English and Tamil. User 1 had some initial difficulty in positioning the pieces and navigating the information on the screen, but was able to complete Level 1 successfully. User 2, who had prior knowledge of puzzles, was able to quickly solve the first puzzle and successfully completed both the levels with the help of the progress bar. User 2 was able to navigate between the two levels and figured out the changes in the puzzle shape in Level 2. User 1 showed interest in moving to Level 2, but was not willing to play with the pieces due to the puzzle appearance.

The remaining three users with severe hearing impairment to complete deafness were given instructions to play the game in written format, as indicated in Figure 3. They completed both the game levels with minimal difficulty; post this study their feedback on the game was obtained by communicating with gestures and writing.

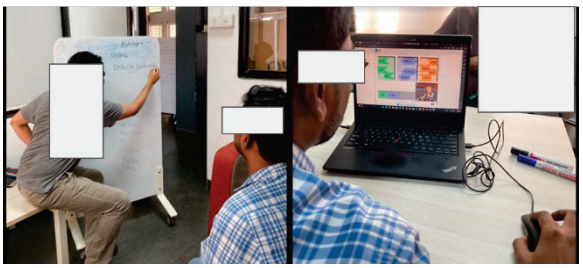

Figure 3: Interaction with DHH people with severe hearing impairment to complete deafness

6. Results and Discussion

Educational games, as visual instruments, play a crucial role in facilitating knowledge acquisition among DHH students and leveraging a strong visual approach in the creation and utilization of materials can greatly enhance the learning journey of such users. According to Bouzid et al., 2015, many of the applications developed for DHH students do not possess essential gameplay elements, such as well-defined objectives and scoring systems, which are necessary for them to be accurately classified as complete games.

The researchers tried to incorporate several gamification elements in this learning intervention and in the present study, the usability of the intervention was examined that

produced several key takeaways regarding the gamification aspects. A thematic analysis (Braun & Clarke, 2006) of the study revealed the main four themes regarding the perception of the usability of the intervention: (1) consistency of images (2) navigation within the game (3) feedback, and (4) question format. The user responses varied for themes (1) and (4) but shared more similar aspects for themes (2) and (3).

Theme 1: *Consistency of images:*- Users 1, 4 & 5 were able to map the given image to corresponding words (visual consistency) but user 2 suggested ensuring consistency in the mapping of pictures to different forms of verbs. User 3 expressed the need to increase the image size and use of animated images. User 1 expressed a confused tone while saying '*Is the boy eating a cake ?*' User 2 asked for clarification: '*Is it Rahul? A person is playing chess. Is it she ?'* The results show that more consistency in the images are required to improve the user experience of the intervention.

Theme 2: *Navigation within the game:*- The users could easily navigate between both the levels of the game. Users also found the progress bar and option to skip the questions useful. Simplicity in navigation is crucial in any online game and the results showed users appreciating the basic features incorporated in the intervention.

"The game is interesting" (User 1)
"I am going to level 2. The last one is this. I see the dot." (User 1)
"In both the games, I completed all the dots."(User 2)

Theme 3: *Feedback :*- Most of the users emphasised the need to improve the reward system, for example, incorporating animated images as suggested by user 3. Also, most users suggested incorporating better feedback techniques. The users also noted that the progress bar was helpful while playing with the intervention. Providing timely and informative feedback is crucial to keep the motivation high in users and contribute towards learning.

"*What is this tick ? Did I make everything correct ? Did I win ?*" *(User 2)*

Theme 4: *Question format :*- Users 4 & 5 suggested adding a picture and sign for each letter on the puzzle in addition to exploring other formats including fill-in-the-blanks and match-the-following (to make the intervention similar to applications like *Duolingo*). User 3 observed that the game was appropriate for classes 1-2. Users 4 & 5 suggested that the game was appropriate for classes up to grade 4. Further, user 1 & 2 could identify the difference in scaffolds used in questions in both levels.

"Oh, what to do ? You have to arrange it (puzzles in level 2). I don't want to do it." (User 1)
"This is box-box now." (User 2)

7. Conclusion and Future work

The aim of this study was to understand the usability of a learning intervention designed to address the difficulty in sentence construction among the DHH students. The users played with the digital prototype and the results of the study provided primary insights on the usability and design of this game-based early intervention. Though the content delivery of the intervention was found to be appropriate, more elements of gamification including clear and concise instructions, help functions, and control over gaming options such as speed, and difficulty need to be incorporated. This is crucial in bringing in engagement, interactivity, and active participation among the users though there still exists ambiguity in identifying what features would a learning game need to be both entertaining and pedagogically useful. Further, the intervention could be used by any novice learner with a motivation to learn the English language. Future research is proposed to focus on incorporating more features of gamification, and conjugating verbs and study the effectiveness of the intervention in addressing the challenge to frame sentences involving such forms of verbs.

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