Insights from User Testing of *Jellow*: A Communication Aid for Children with Developmental Disabilities

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Abstract The current paper reports insights from user testing of a novel pictorial, free-of-cost, desktop-based communication aid, *Jellow*, developed at the Indian Institute of Technology Bombay to enhance communication in nonverbal to minimally verbal children with developmental disabilities. We asked 7 typically developing school-age children to use the *Jellow* application to convey specific messages based on test scenarios during a structured usability evaluation. We coded for task success, time to completion, number of errors made, and number of prompts required for completing each of the ten test tasks. We also collected qualitative data on children's satisfaction with various aspects of the application and their feedback on ways to improve the application. Quantitative and qualitative feedback from this study is currently being used to develop the next version of the application that will be tested with children with disabilities.

Keywords Alternative and augmentative communication (AAC) · Children · Disability · Communication aids · Technology

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1 Introduction

1.1 *Alternative and Augmentative Communication (AAC) Systems: Types and Functions*

Alternative and augmentative communication (AAC) systems are used to either supplement (i.e. augment) or replace (i.e. provide an alternative to) existing natural speech in children with developmental disabilities such as Cerebral Palsy, Down Syndrome, Autism Spectrum Disorder, and Intellectual Disability, who frequently have expressive speech impairments [1–3]. Children who are not able to communicate effectively face difficulties interacting with others, forming long-lasting friendships, and engaging in age-appropriate play with peers, thereby losing out on critical learning opportunities. Therefore, AAC systems have been used to enhance functional communication on a temporary or permanent basis in children with disabilities [3].

Typically, AAC systems are classified as unaided i.e. not requiring any external aids, or aided i.e. systems that use low-tech or high-tech external aids for expressive communication. Unaided systems that use gestures, facial expressions, eye contact, or manual signing for communication are portable, quick to produce, and have no limits in conveying novel content; however, only individuals familiar with sign/gestural communication can comprehend them [3, 4]. Moreover, sign languages require excellent fine motor and memory skills, making them challenging for children with motor and cognitive impairments [3]. In contrast, aided systems use aids such as graphic symbols, Picture Exchange Communication Systems (PECS), or computerized Speech-Generating Devices (SGDs), also known as Voice Output Communication Aids (VOCAs) to communicate messages [5, 6]. Although low-tech aided systems are easy to learn and can be easily comprehended by a larger audience, they require the user to carry bulky picture binders/boards everywhere with them [3, 5]. However, following recent advances in the fields of electronics and computer science, high-tech devices such as SGDs or VOCAs are being increasingly used as AAC systems; in fact such systems can be easily accessed as tablet- or smart phone-based applications [7, 8]. Moreover, given their speech generating potential, they can effectively attract listeners' attention and are easy to comprehend [2].

AAC systems can aid communication in children with minimal to no speech or unintelligible speech and also teach them language skills [2, 4, 9]. Contrary to previous concerns that AAC systems would impede natural speech development, there is considerable evidence that the early use of AAC systems in fact promotes speech development in children [10, 11]. Although different AAC modes seem to be equally effective in promoting communication, individuals with disabilities may prefer aided systems to unaided systems [5, 12]. Moreover, individuals show some preference for SGDs compared to other systems [9]. Given these user preferences for high-tech systems, the current project reports on insights from usability testing of a novel, pictorial, desktop-based software application called *Jellow*, developed at the Indian Institute of Technology Bombay (IIT-B) with the aim of assisting communication in individuals learning to speak or with difficulty in speech.

1.2 Current Trends in AAC Usage in India and Indigenous AAC Systems

There are currently over 1.9 million individuals with a speech disability in India [13]. Speech impairments are either evident at birth or before 9 years of age in around 37% individuals with a speech disability [14]. Overall, over 80% of individuals with speech disabilities completely lack speech, speak only in single words, or have unintelligible speech [14]. Therefore, there is a need for a variety of assistive technologies including AAC systems for individuals with speech impairments.

Our literature review on AAC applications suggests that there are several commercially available applications of Western origin and relatively fewer indigenously developed applications. Although a majority of the AAC apps developed in Western countries are quite comprehensive, they are not necessarily adapted to the Indian context. For instance, the types of foods consumed, the types of clothes worn, the kinds of games played, etc. are considerably different in Western countries compared to India. The content of the AAC app needs to be therefore designed bearing in mind the socio-cultural and linguistic context that children will experience in their daily life while using the app as their primary mode of communication. There are currently few indigenously developed AAC applications in India. "*Avaz*," one such customizable AAC application that can be used on iPADs and certain Android tablets, allows constant tracking of the child's speech, and also provides caregiver-training modules to facilitate easy use of the application (http://www.avazapp.com/). Similarly, *Vaneeshree*, a speech synthesizer for individuals with spasticity or vocal disability has around 56 commonly used sentences in its memory and uses a cordless connection between the device and a high-power amplifier to allow the user to communicate while freely moving around the house (http://www.iitk.ac.in/infocell/Archive/dirjuly1/vanee.html). In addition, local state-supported companies such as Webel Mediatronics have developed a few other communication aids for individuals with Cerebral Palsy (CP). For example, *Pictorial* is a software tool equipped with a library of icons and associated audio clips in vernacular languages such as Bengali, Hindi, English, and Nepali (http://www.webelmediatronics.in/SystemCerebralPalsy.htm). Similarly, *Kurakani* is a 16-key pictorial VOCA developed to aid communication in individuals with CP (http://www.webelmediatronics.in/16KeyVOCA-Brochure.pdf). Lastly, *Gupshup* is a simple pictorial VOCA that comes in 1/2/4 key configurations (http://www.webelmediatronics.in/SystemCerebralPalsy.htm).

1.3 Gaps in AAC Research in India and Background of the Current Project

As discussed above, a majority of the research on AAC systems is conducted in the Western world with limited research in the Indian context [15, 16]. Insights from a mixed-methods study in two metropolitan cities in southern India suggested that rehabilitation professionals consider technology to be a powerful tool to enhance communication in individuals with disabilities [15]. However, given that a majority of the commercially available AAC apps were designed considering the socioeconomic and cultural context of developed nations, there is a dire need for the native development of low-tech and high-tech AAC devices bearing in mind the unique cultural and linguistic considerations of India [15]. These findings highlight the need for extensive research on developing indigenous AAC solutions that are inexpensive, simple to use, and adapted to the Indian context.

The work reported in this paper aims to address these need gaps and develop a novel, free-of-cost, pictorial communication aid, *Jellow*, for children with developmental disabilities. *Jellow* has a unique interface consisting of central 'category' buttons and 'expressive' side-buttons designed to broaden the language repertoire of users (see Fig. 1); moreover, it has been developed keeping in mind the socio-cultural context of India. This paper reports results from usability testing of the desktop-based prototype of *Jellow*. *Jellow* has 6 'expressive' side-buttons—"like," "don't like," "yes/want," "no/don't want," "more," and "less"—and 5 central 'category' buttons—"learning," "eating," "play," "people," and "others". A button has to be clicked to activate it. Each category button has several sub-options that can

Fig. 1 Snapshot of *Jellow's* interface

be accessed by double-clicking on it. From the home screen, there are up to a maximum of 3 hierarchical nested levels within the information architecture of *Jellow*.

2 Methods

2.1 Participants

Seven typically developing children (5 girls, 2 boys) between 5 and 10 years (Mean (SD) = 7.68(1.13)) participated in the study. Children were recruited through convenience sampling from local schools and day care centers after obtaining written parental consent as approved by the Ethics committee at IIT-B. Children with significant additional hearing, visual, orthopedic, cardiovascular, neurological, or other medical comorbidities were excluded. Since the current version of *Jellow* is in English, we excluded children who did not understand English.

2.2 Study Procedure

Two sessions were conducted at each child's home by a pediatric physical therapist. In the first session, the therapist familiarized children with *Jellow* and allowed them to freely explore it for around 20 min. The second testing session, which was conducted about 1–2 days following the initial session, involved a structured assisted usability test [17] and a short discussion to obtain qualitative feedback from children. This session was videotaped for further behavioral coding. Children were given 10 test scenarios (2 scenarios per category—"learning", "eating", "play", "people", and "others") and asked to communicate specific messages using *Jellow*, as required by the scenario. The test tasks were representative of the types of scenarios children may face in the real world while using *Jellow* as a communication aid. Exemplar scenarios included indicating food preferences for breakfast, asking for specific toys, asking for help to get ready for school, etc.

Following the usability testing, we provided children a custom-developed, 7-item, pictorial feedback questionnaire to rate their satisfaction with *Jellow* on a 5-point Likert scale. Specifically, we assessed ease of use, comprehensibility of icons, visual appeal, intuitiveness of hierarchical structure, clarity of voice, level of enjoyment, and usefulness of the application. In addition, we asked children for suggestions to improve the existing version of *Jellow*.

2.3 Behavioral Coding

We coded for task success, time to completion, number of errors committed, and number of prompts required for each of the 10 test tasks. Task success was coded as *independent* (score of 0) i.e., when the child completed the task independently without assistance or *assisted* (score of 1) i.e., when the child required therapist assistance to complete the task. The therapist assisted the child when he/she made errors during the tasks. Since the testing was with young children, we ensured that all children successfully completed all the tasks, if required, with tester assistance. Time to completion was coded per task in seconds, starting from the end of the tester's instruction to when *Jellow* spoke the required message. Next, we coded rate of errors committed for each task. An error was defined as any incorrect option chosen within the application. Last, we coded the rates of therapist-provided verbal and manual prompts per task. Verbal prompts included cues such as "look carefully" or "try somewhere else" etc. and manual prompts included physical hand-on-hand assistance to complete the task. For all outcome measures, we report category-wise summed scores obtained by summing individual scores on each of the two test tasks within a category. A higher score indicates worse performance for all our outcome measures.

2.4 Qualitative Data Analysis

For the feedback survey data, we calculated a percentage of participants who gave specific ratings (1–5) for each of the evaluated criteria. A higher score suggested greater satisfaction with *Jellow*. In addition, we also received a wealth of qualitative suggestions for improvement of the software in terms of content, icons and accompanying text, and navigation. We will report salient insights obtained from children's feedback in the next section.

3 Results

3.1 Quantitative Data

Given our small sample size, we did not conduct formal statistical testing on our data. Instead, we report means and standard deviations on all outcome measures and also discuss individual data from participants. In terms of task success, 85.7% children required assistance for tasks belonging to the "learning" and "play" categories, 71.4% required assistance for tasks in the “eating” and “others” categories, whereas none of the children required any assistance for tasks involving the “people” category.

In terms of time to completion, children required least time to complete tasks belonging to the “play” and “people” categories (Table 1 and Fig. 2). In contrast, tasks that required children to navigate to options underlying the other three categories were relatively more time-consuming.

Further, a majority of the children committed multiple errors while completing tasks that involved accessing options under the “others,” “play,” and “learning” categories (see Table 1 and Fig. 3). The least error rates were seen for a majority of the children during tasks that involved the “people” and “eating” categories.

Lastly, in terms of the rates of verbal and/or manual prompts required, children needed the least number of prompts while completing tasks that required access to options under the “people” category. Tasks belonging to all other categories required a relatively higher number of prompts as suggested by Table 1 and Fig. 4.

Table 1 Summary of outcome measures from usability testing

Outcomes mean (SD)	Learning	Eating	Play	People	Others
Time to completion (seconds)	170.6 (86.9)	148.8 (63.6)	95.6 (16.2)	34.9 (9.5)	115.8 (52.7)
Error rates (per minute)	1.6(0.9)	0.8(0.8)	1.5(1.0)	0.5(0.9)	1.8(1.6)
Prompt rates (per minute)	1.3(0.7)	0.9(0.6)	1.4(1.0)	0.2(0.5)	1.1(0.9)

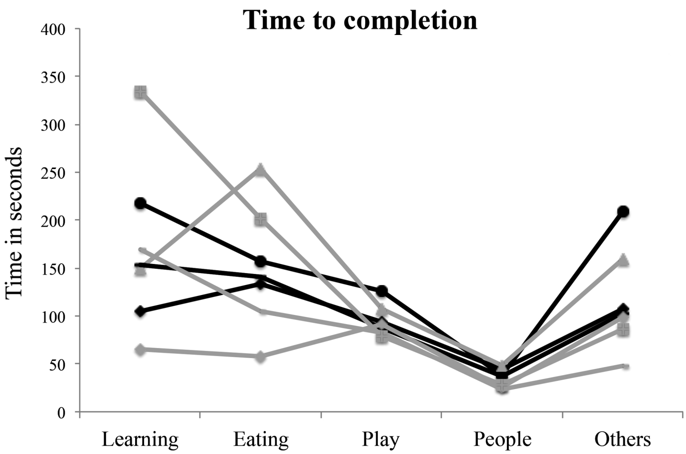

Fig. 2 Individual data on time to completion for different categories

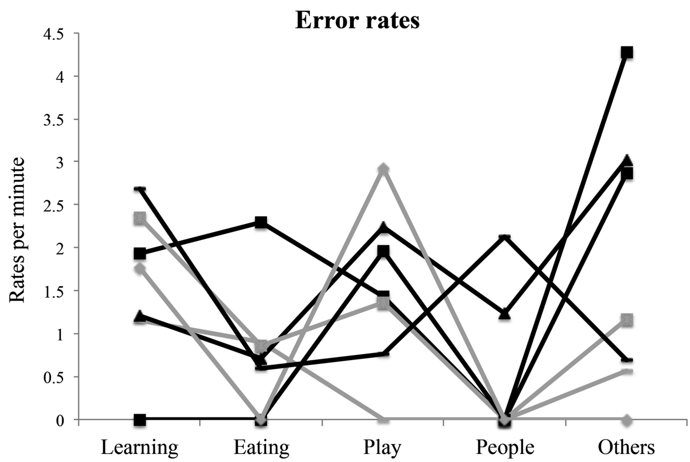

Fig. 3 Individual data on error rates for different categories

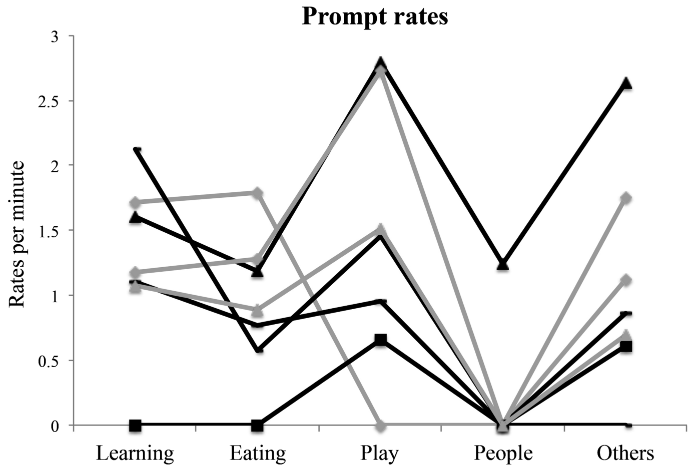

Fig. 4 Individual data on prompt rates for different categories

3.2 Qualitative Data

Our feedback survey data suggest that all children found *Jellow* very useful and enjoyable to use (see Fig. 5). They also found *Jellow's* voice clear and easy to understand. Over 80% of children found the software visually appealing and relatively easy to use. However, children had some difficulties understanding some of *Jellow's* icons and also had considerable trouble navigating through the application to reach their desired options.

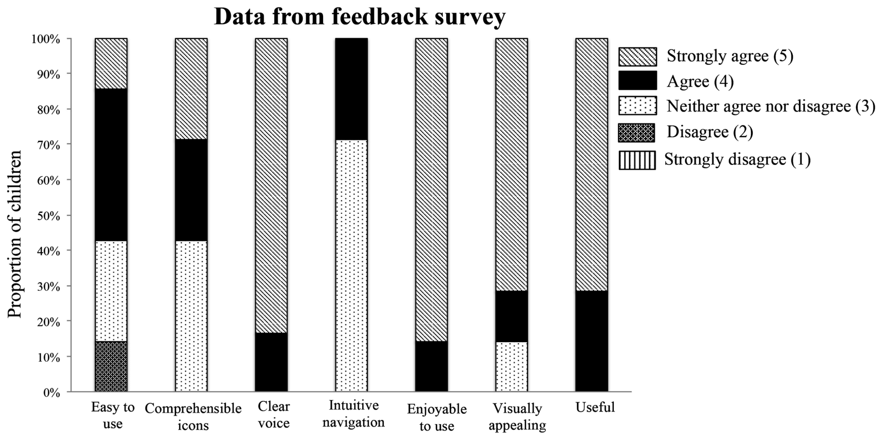

Fig. 5 Qualitative data on children's satisfaction with *Jellow*

Children also provided multiple suggestions to improve the existing version of *Jellow*. In terms of content, children recommended that we add some new categories to accommodate novel content, add new content within pre-existing categories, and simplify existing content to aid comprehension. For example, children suggested that we add a category on "greetings" to aid natural communicative exchanges. Similarly, they asked for the addition of multiple new food items within the "Eating" category, including, "idli," "dosa," "soups," "salads," and "desserts." Children suggested changing two labels, "beverages" to "drinks", and "hygiene" to "clean", to simplify comprehension of existing content. To aid use by children with varying abilities, *Jellow's* current language is very simple; moreover, the vocabulary associated with the expressive buttons remains constant irrespective of the accompanying category buttons chosen. For example, the same basic sentence structure is evident in "***I want*** lunch," "***I want*** books," or "***I want*** videogames." Children instead recommended that we develop a larger, category-wise customized verbal library involving a variety of action verbs, for example, "***I want to eat*** lunch," "***I want to read*** a book" or "***I want to play*** videogames." Currently, the "home" button takes the user to the home screen irrespective of where the user is (level 2 or level 3 of the hierarchy) within the software. To allow navigation to the preceding hierarchical level within the software children suggested that we add a "back" button. Lastly, children also had multiple suggestions to improve *Jellow's* visual appeal. For instance:

"Child 1: Doctor looks comical. (Doctor) should be totally white (wearing a white coat)"
"Child 2: The 'change footwear' picture looks more like socks, change this."
"Child 3: Change the "wafers" picture. I can't make out it is wafers. You should add a packet of wafers next to the plate with wafers."

"Child 4: The 'terrace' drawing is not clear. It looks like a slide."
"Child 5: The picture for medicine should have a medicine bottle. Medicines are always kept in a bottle, no?"

4 Discussion

4.1 Summary of Insights from Usability Testing

Our usability evaluation suggested that, on the whole, children found *Jellow* enjoyable to use. With regard to its existing content, tasks involving the "People" category were universally the easiest for children to complete, probably because this category included only a single underlying nested layer of options. Following this category, children found the "Play" category relatively easy to navigate given that it had fewer options compared to all other categories. Although the "Eating" category included several options and sub-options, children were familiar with the choices and seemed to know how they were categorized, for example, bread is a "breakfast" item versus rice is a "lunch" item, making it easier for them to find target options. In contrast, children found tasks involving the "Learning" and "Others" categories the most difficult, probably since they were unsure of the contents of these categories; therefore, they made more mistakes as they searched for desired options and took longer to find them.

Children also asked for the addition of new content within the software. Although this feedback is highly desirable in order to ensure that *Jellow* can assist children in communicating their intentions in a wide range of scenarios, it remains to be tested if a large verbal repertoire is indeed ideal for children with disabilities as they are learning to communicate. Perhaps it may be necessary to develop multiple versions of the software with incremental amounts of inbuilt speech capacity. Furthermore, multiple children recommended that we change the vocabulary of *Jellow* so that it becomes more suited to the context of usage. Lastly, our observations of the younger children in our sample suggested that they relied heavily on icons for identification of target content, given their lack of fluency in reading. Therefore, the software needs to have appealing icons that are easily comprehensible; similarly, the associated vocabulary should be as simple as possible.

4.2 Recommendations

Based on the above insights, we are currently working on improving several aspects of the existing version of the software. In terms of content, we will be adding significant novel content based on children's suggestions; however, given the grid layout of the interface that allows the display of only 9 options at a time on the screen, we will explore the option of adding a "More" button as the 9th option on the screen. When the child clicks on this option, he/she will be able to navigate to the next screen containing additional options. We also plan to incorporate an algorithm that will remember the child's most-preferred choices for any category and display them as the top options. Furthermore, to ease children's difficulties in remembering options underlying categories, we plan to incorporate a feature wherein, by hovering over a specific category icon, children will get a sneak peek at the underlying options. We will also provide a "back" button on the home screen to improve the exploration of content at different levels of *Jellow's* hierarchy. We are currently working on significantly improving the existing icons and their accompanying "word" labels to improve comprehensibility for children of different ages. We are also developing a richer verbal repertoire for the next prototype of *Jellow* to ensure that the vocabulary is adapted to the category chosen by the child.

We acknowledge that our study involved a relatively small sample size of children, thereby limiting the validity and widespread applicability of the findings; nevertheless this pilot usability study was meant to provide insights to further improve the software. We are currently working on developing an app-based version of *Jellow* that will be compatible with Android tablets and mobiles. We plan to conduct a more systematic and structured usability evaluation using a larger sample of children with developmental disabilities using this next app-based version of *Jellow* software.

5 Conclusions

The current report summarizes results of usability testing of the desktop-based prototype of *Jellow*. We are currently using insights from this study to improve the functionality and usability of *Jellow*. Following incorporation of these suggestions, we will conduct another round of usability tests with both typically developing children and children with different types of developmental disabilities to assess the ease of use of *Jellow* and its efficacy in aiding communication in children with moderate-to-severe expressive speech impairments.

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