A Communication System on Smart Phones and Tablets for Non-verbal Children with Autism

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Abstract. We designed, developed and evaluated an Augmentative and Alternative Communication (AAC) system, *AutVisComm,* for children with autism that can run on smart phones and tablets. An iterative design and development process was followed, where the prototypes were developed in close collaboration with the user group, and the usability testing was gradually expanded to larger groups. In the last evaluation stage described here, twenty-four children with autism used *AutVisComm* to learn to request the desired object. We measured their learning rates and correlated them with their behavior traits (as observed by their teachers) like joint attention, symbolic processing and imitation. We found that their ability for symbolic processing did not correlate with the learning rate, but their ability for joint attention did. This suggests that this system (and this class of AACs) helps to compensate for a lack of symbolic processing, but not for a lack of joint-attention mechanism.

1 Introduction

Autism is a developmental disorder characterized by impairments in social interaction, impairments in verbal and non-verbal communication, and presence of repetitive behaviors. Many children on the autism spectrum lack sufficient speech to meet their communication needs. Augmentative and alternative communication (AAC) systems are designed to fill this void and help these children communicate.

The most prevalent AAC technique used is Picture Exchange Communication System (PECS). PECS uses picture cards and a systematic training approach to help children with autism communicate. PECS training proceeds through six stages in a strict sequence. The first stage is *requesting,* where, using physical and verbal prompts, the child is led to learn to exchange a picture card with the communication partner in order to obtain a desired object. Subsequent stages involve helping the child to learn to make a choice, to combine pictures and make phrases, and so on. The success of PECS with children with autism has been widely reported in literature[1]. But picture cards suffer from a lack of portability and require access to pre-arranged picture cards. Attempts to improve on these two fronts led to the development of electronic communication

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aids. These, however, have traditionally been dedicated, custom-built systems for individuals with specific communication difficulties. Some of the commercially available dedicated AAC devices include Dynavox [2] and Vantage Lite [3]. These are picture-based speech generating devices where the child presses a picture on the device's display to playback an appropriate speech message. These speech messages could be either pre-recorded or synthesized using a text-to-speech conversion module.

Recent research on AAC systems has concentrated on improving the speed and richness of the messages constructed by users. BLISS2003 [4] is a communication software that allows users to construct messages using *blissymbols,* which is a graphical language that represents concepts by geometric shapes that are not necessarily iconic. BLISS2003 also features a prediction assistant that can aid faster message construction and the ability to translate bliss messages into natural language. Sibyl [5] is a text-based AAC system, which features letter prediction, word prediction and word completion to improve the speed of message construction. *How was school today?* [6] aims at helping users communicate in terms of conversational narratives. This tool uses sensors to collect data of children's activities, and uses Natural Language Generation to help them in creating narratives based on this data.

The recent proliferation of mobile touchscreen devices like smart phones and tablets offers a new platform to build AAC applications as well as new directions of research. Such devices are more affordable and easily available than the dedicated AAC systems. They are also more socially acceptable as they do not stigmatize the user and adhere to the *Design for Social Acceptance* [7] strategy to develop assistive technology. Currently available AAC applications on mainstream devices include Proloquo2Go [8] and iAugComm [9]. Though there is some anecdotal evidence available that these applications are usable, no formal evaluations have been carried out to assess their efficiency.

Our goal in this research is to design and evaluate an AAC system on a commonly available device that is effective, inexpensive, accessible, and inconspicuous. Light *et al* [10] have proposed a model in which they argue that an individual's ability to effectively use an AAC device depends on three factors: the individual's skills (motor skills, sensory issues, cognitive skills), the device architecture (display organization, selection technique etc.,) and the demands of the communication task (one-on-one communication vs group interaction). Children with autism are a heterogeneous group in terms of their skills and hence it is a challenge to design an application that would ideally suit the need for all. In order to understand the right set of features that would be appropriate for the children and their parents, we opted for a participatory design process. Other recent participatory design approaches to developing assistive systems for children with autism include vSked [11], which is a visual scheduler for classrooms containing students with mild to moderate autism; and the ECHOES project, which aims to teach social skills to children with autism through virtual agents [12].

2 Preference for AAC Platforms - A Survey

In order to find out the users' preferences for AAC platforms we started with a paper-based survey with the parents of children with autism. Twenty parents participated in this survey. Parents were given a form with two questions. The first question was which platform they would prefer for an AAC. They were provided with three options: a laptop, a tablet, a smart phone. In the second question, they were asked to give reasons for their choice. Eighteen responses were collected and analyzed. Seventy-two percent of the parents preferred using a smart phone or tablet as the communication device. The reasons provided by them were: ease of use (the touch screen), portability, cost and interest of the child. Some sample responses from the parents are:

A communication device on a tablet. Touchscreen is easier than keyboard and is portable. It is small in size and he won't attract attention using it.

I think my son can manage a touch screen. If it is a smart phone or tablet, I can carry it wherever I go.

I would prefer a communication device on a laptop. He is very interested in his father's laptop. He watches with interest what is being displayed on the screen.

Since the parents equally preferred a smart phone and a tablet, we chose to build our first prototype on a smart phone as it is more portable and affordable. In the next section, we describe the experiences we had with this prototype with a child with autism and his mother.

3 Participatory Design: Experience with Initial Prototypes

We developed several prototypes in close collaboration with a child with autism and his mother. The child was an eight-year old boy, who was non-verbal and attended a school for children with autism. He had difficulties with fine motor control, and though he had a general affinity for gadgets, he had not used any AAC device before. His mother was a college graduate and had a reasonable exposure to technology: she used a smart phone and a laptop for day-to-day communication and browsing. When we met the child and his family, the parents were trying to teach the child how to use gestures to communicate. Since the child was non-verbal, his mother acted as the proxy and provided us feedback on the prototypes of the design.

We chose to call our system *AutVisComm.* The first prototype was developed on a smart phone with a 3.2" capacitive touchscreen running Google's Android ™operating system. The vocabulary for the system contained the child's favorite food items. The mother used *AutVisComm* with the child to ask him what he wanted for breakfast that day. However the child had difficulty in choosing the target picture accurately with this form factor. Hence, in the second iteration, we ported the application to a tablet form-factor device. With a tablet, the child was able to choose the images without errors.

The mother felt that a dynamic display, where she could choose the items to be displayed on-the-fly on the screen, would help her to contextualize the AAC better. For instance, if breakfast on a day had apples and bread, she would like to present only those two choices. She felt that the presence of multiple irrelevant items on the screen distracted the child from understanding the ongoing communication. Consequently, we redesigned the application where she could construct *AutVisComm*'s display on-the-fly by choosing images from the device's camera, from the web or from the existing images in the device's memory card. Interestingly, we found that the device's camera was used only rarely. The mother's explanation was that when using the in-built camera, there were always other background items along with the object of interest, and this seemed to distract the child. So we disabled this option in the final prototype. The final prototype is as shown in Figure 1. Once the user opens the application, all the pictures available to them are displayed. Users can choose the pictures they need to construct the display. We used this prototype for further usability evaluation.

4 Usability Study with a Larger Group

At this point we expanded our user group to four children with autism. Three boys and one girl (Mean Age: 8 years; SD: 7 months), and their teacher participated in this usability study. All four children were recruited from a special school for children with autism. Informed consent was obtained from the parents. The teacher and the children used the device for one month. The teacher was initially explained how to use *AutVisComm* and configure the display. The device was used to offer choices like whether the child would like to play in the pool or in the playground.

All activities made with *AutVisComm* like configuring the display, choosing a picture etc. were logged with time-stamp. We found that the configuration time (duration between opening the application to finishing the display configuration) decreased significantly during initial sessions, and from there on remained relatively constant. This shows that teachers could learn to configure *AutVisComm* in very few sessions. Many touchscreen devices provide a tactile feedback when touching a screen element. One child had an aversion to this vibration, and hence this feature was turned off. This apart, no significant usability issues were reported from children. Also the teacher felt that it was easier for her to use *AutVisComm* than to prepare laminated picture cards for each child and keeping track of them.

Our learnings from the participatory design and usability study process are summarized below

- None of the children in the group we worked with found the texture of the device or the touch screen aversive.
- AAC with dynamic display allows caregivers to configure the same device for different children and for different contexts.
- Some children might be aversive to the vibratory feedback available in these devices
- The size of the device to use depends on the fine motor skills of the child.

5 Learning to Communicate Using *AutVisComm*

To help children learn to communicate using *AutVisComm*, we conducted training sessions for all the non-verbal children from a local school for children with autism. The inclusion criteria were the children had no functional speech or speech consisting of less than five words or word approximations. Twenty-four children took part in these sessions and informed consent was obtained from their parents. Each child had two one-on-one sessions per week. Each session lasted for about 15-20 minutes. The goal of these sessions was similar to the *requesting* stage of PECS - to help the child to learn to request his or her desired object using *AutVisComm*.

The session setup is shown in Figure 1. It involved the child, an adult communication partner (teacher), the child's preferred snack item and *AutVisComm*. The food item was beyond the reach of the child, close to the teacher. To receive the food item, the child had to request using *AutVisComm*, i.e. press the appropriate picture on the touch screen device. A single session consisted of five trials. The desired food item remained the same across all trials. In each trial, the teacher asked the child, "What do you want?" If the child responded spontaneously by touching the picture, this was considered an *independent response (IN)*. If the child did not respond spontaneously, the teacher verbally prompted the child, "Press the picture here." If the child responded to this prompt, it was considered a *verbally prompted (VP)* response. If the child did not respond even after the verbal prompt, the teacher held the child's hand and pressed the picture. This was considered *physically assisted (PA)* response.

Fig. 1. Final prototype of AutVisComm (left); communication training setup (right)

5.1 Communication Performance

The type of the child's response in each trial (IN, VP or PA) was noted. Then the numbers of IN, VP and PA responses for each child in a session were tabulated, averaged across children, and the mean PA, VP and IN responses per session were computed. Figure 2 shows the data for the first ten sessions. The graph shows that in the first session most children had to be physically assisted: the mean PA response is close to 5. As sessions progressed, the need for physical assistance became less frequent and most children started responding to the verbal prompts as indicated by the peak in mean VP response at around session 4. Further into the sessions, the need for verbal prompts also became less frequent and the children started responding spontaneously as indicated by the increasing trend of mean IN response.

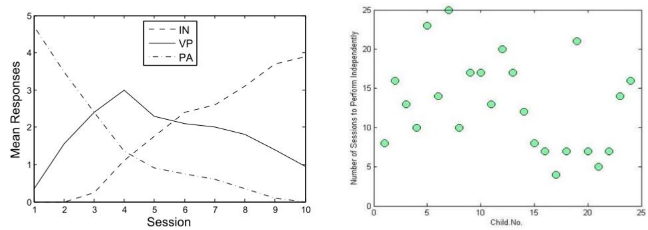

Fig. 2. Communication Performance (left). PA - child pressed the picture with physical assistance, VP - child pressed the picture after verbal prompt IN - child spontaneously pressed the picture . Individual differences in learning (right). Each dot denotes the number of sessions required by the child to achieve at least three IN response trials in a session. There are 24 dots in all one for each child.

5.2 Individual Differences in Performance

The goal of the training process was to help the children to learn to request the desired object independently. We consider the child to have learnt this when they request spontaneously (IN) without verbal or physical assistance in at least three of the five trials and this performance is sustained in at least three consecutive trials. In our analysis, we found that there was a large variance in the number of sessions required for each child to attain this performance as shown in Figure 2.

In order to understand this variance, we provided the teachers (who were not involved in the children's training sessions with AutVisComm) of the children a checklist as shown in Table 1. Two teachers rated the students using this checklist. This was a one-time rating collected at the end of the intervention. The items in the checklist were drawn from the Autism Behavior Checklist [13]. These items measure for various cognitive capacities of the children like joint attention, imitation, social skills, symbolic processing etc. The teachers were asked to rank the children on the 1–5 scale, where 1 indicates that the child always exhibits the behavior and 5 that the child never exhibits the behavior. We analyzed the correlation between the ratings provided by the teachers and the number of sessions required by the child to request independently (IN) with *AutVisComm*. The correlations and their associated significance values are also shown in Table 1. Requesting an object by gesturing (pointing) requires the child to share attention with the care giver and shift attention between the care giver and the object of interest and hence considered a measure of joint attention [14].

Toy play indicates that children can use toys to represent objects in reality and hence considered a measure of symbolic thinking [15]. The results indicate that the measure of joint attention was significantly correlated with the performance of the children ($r = 0.526$, $p = 0.01$), while measures related to their symbolic processing and imitation ($r = 0.06$, $p = 0.7$) were not correlated.

Table 1. Performance analysis checklist. Statistically significant ($p < 0.05$) correlations shown in bold text.

No.	Checklist Item	Relates To	Correlation(r)
1	**Gets desired objects by gesturing**	**Joint Attention [14]**	**0.526**
2	**Not responsive to other peoples facial expressions**	**Theory of Mind [16]**	**0.477**
3	Has sensory issues	Sensory Issues	0.324
4	Often frightened or very anxious	Sensory Issues	0.144
5	Does not follow simple commands	Receptive Language	0.138
6	Actively avoids eye contact	Eye Contact	0.114
7	Strong reactions to minor changes in routine	Repetitive Behavior	0.102
8	Does not use toys appropriately	Symbolic Processing [15]	0.067
9	Has special abilities in one area	Rules out mental retardation	0.032
10	Has motor control issues	Motor Issues	0.030
11	Rocks self for long periods of time	Repetitive Behavior	0.028
12	Has not developed any friendships	Social overture	0.020
13	Does not imitate other children at play	Imitation	-0.153
14	Prefers to be occupied with inanimate objects	Repetitive Behavior	-0.298

6 Discussion

Two major deficit areas are considered as contributing to the socio-communication difficulties in children with autism - a) deficits in *joint attention,* that is, the capacity to coordinate attention between people and objects; and b) deficits in *symbolic thinking,* that is, the ability to think in terms of representations rather than actual objects, and understanding the concepts of shared meaning. Both these factors are crucial to language development [14]. Using concrete pictorial representations, which are lesser abstract than language, compensates for the deficit in symbolic thinking. This is suggested from our results where the symbol processing ability of the children does not correlate significantly with performance. However, a picture-based communication system cannot compensate for difficulties in joint attention, and hence this correlates with the children's performance.

7 Future Work

We plan to supplement the analysis presented here with the psychophysical studies with the children with autism to see how psychophysical parameters correlate with behavioral parameters. We also plan to measure the progress in the communication capacity in these children with respect to their ability to combine pictures and communicate in pictorial sentences.

References

1. Charlop-Christy, M.H., Carpenter, M., Le, L., LeBlanc, L.A., Kellet, K.: Using the picture exchange communication system (pecs) with children with autism: assessment of pecs acquisition, speech, social-communicative behavior, and problem behavior. Journal of Applied Behavior Analysis 35(3), 213–221 (2002)

2. Dynavox, http://www.dynavoxtech.com/products/maestro/ (last accessed January 24, 2012)
3. VantageLite, http://www.prentrom.com/vantagelite (last accessed January 24, 2012)
4. Gatti, N., Matteucci, M., Sbattella, L.: An Adaptive and Predictive Environment to Support Augmentative and Alternative Communication. In: Miesenberger, K., Klaus, J., Zagler, W.L., Burger, D. (eds.) ICCHP 2004. LNCS, vol. 3118, pp. 983–990. Springer, Heidelberg (2004)
5. Schadle, I.: Sibyl: AAC System Using NLP Techniques. In: Miesenberger, K., Klaus, J., Zagler, W.L., Burger, D. (eds.) ICCHP 2004. LNCS, vol. 3118, pp. 1009–1015. Springer, Heidelberg (2004)
6. Black, R., Reddington, J., Reiter, E., Tintarev, N., Waller, A.: Using nlg and sensors to support personal narrative for children with complex communication needs. In: Proceedings of the NAACL HLT 2010 Workshop on Speech and Language Processing for Assistive Technologies, SLPAT 2010 (2010)
7. Shinohara, K., Wobbrock, J.O.: In the shadow of misperception: assistive technology use and social interactions. In: Proceedings of the 2011 Annual Conference on Human Factors in Computing Systems, CHI 2011 (2011)
8. Sennott, S., Bowker, A.: Autism, aac, and proloquo2go. Perspectives on Augmentative and Alternative Communication 18(4), 137–145 (2009)
9. iAugComm, http://www.apps4android.org/?p=186 (last accessed January 24, 2012)
10. Light, J., Wilkinson, K., Drager, K.: Designing effective aac systems:research evidence and implications for practice. In: ASHA 2008 (2008)
11. Hirano, S.H., Yeganyan, M.T., Marcu, G., Nguyen, D.H., Boyd, L.A., Hayes, G.R.: vsked: evaluation of a system to support classroom activities for children with autism. In: Proceedings of the 28th International Conference on Human Factors in Computing Systems, CHI 2010, pp. 1633–1642 (2010)
12. Alcorn, A., Pain, H., Rajendran, G., Smith, T., Lemon, O., Porayska-Pomsta, K., Foster, M.E., Avramides, K., Frauenberger, C., Bernardini, S.: Social Communication between Virtual Characters and Children with Autism. In: Biswas, G., Bull, S., Kay, J., Mitrovic, A. (eds.) AIED 2011. LNCS, vol. 6738, pp. 7–14. Springer, Heidelberg (2011)
13. Volkmar, F., Cicchetti, D., Dykens, E., Sparrow, S., Leckman, J., Cohen, D.: An evaluation of the autism behavior checklist. Journal of Autism and Developmental Disorders 18(1), 81–97 (1988)
14. Toth, K., Munson, J., Meltzoff, A., Dawson, G.: Early predictors of communication development in young children with autism spectrum disorder: Joint attention, imitation, and toy play. Journal of Autism and Developmental Disorders 36(8) (2006)
15. Piaget, J.: Play, dreams, and imitation in childhood. Norton, New York (1962)
16. Baron-Cohen, S., Leslie, A.M., Frith, U.: Does the autistic child have a theory of mind. Cognition 21(1), 37–46 (1985)