Communication intervention with technology for minimally verbal autistic children

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ABSTRACT

Within the children that have been diagnosed with autism 25% to 50% of them is non/minimally verbal. [1] These children have difficulties learning to communicate at the same pace as their peers. With this research, a variety of technology designs that shows promise to help improve communication skills of minimally verbal autistic children and non-autistic children are evaluated on their type, tasks, and measurements. By the use of this evaluation and examples of technologies, the state of art for technology for communication intervention for minimally verbal autistic children is covered.

Keywords: *autism, minimally-verbal, technology, communication, children.*

1. INTRODUCTION

In the Netherlands, a child in approximately every 200 has been diagnosed with autism [2]. Autism spectrum disorder is a "...developmental disability that can cause significant social, communication and behavioural challenges" ("What is Autism Spectrum Disorder?", 2020) [3]. As this is a spectrum, the difficulties faced differ by individual. Minimally verbal autism is a subgroup in this spectrum that has an especially difficult time with communication. Children with this condition often struggle with significant aspects of communication such as using gestures, speaking, sound imitation and more. [4]

While there are research and products available that would aid autistic children in improving communication skills, this subgroup is often overlooked. [5] This is caused by difficulty in evaluating the situation of children as the current ways of evaluation is not the right fit with their communication abilities and needs.[5]

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We are living in an era in which technology has been gaining a more significant place in our lives by day. With the exponential improvement of technology, we adapt it to new problems and new possibilities faster than ever. Technology also has the potential to be used for the minimally verbal autistic children such that their communication skills improve and/or it aids them in their interactions with the rest of the world.

The importance of communication for human beings is undeniable as we are highly social beings. The quality of communication affects many aspects of our day to day life and our wellbeing. Therefore, using the technological power we have, to improve the wellbeing of minimally verbal autistic children is a goal we should strive for.

This research paper aims to create a good foundation so that a technologic device that focuses on this often-overlooked group can be made accessible with future work. For a product that is most suiting to this goal and the user group, an evaluation of the current solutions is discussed in the paper.

2. RESEARCH QUESTIONS

The main question this research centres around is *"What is the state of the art for aiding minimally verbal autistic children in communication?"* To be able to answer this the following question needs to be answered.

R.Q *What types of technologies are used more frequently for nonverbal children?*

> ***R.Q.1*** *What are the interactions and tasks of these technologies?*

3. BACKGROUND INFORMATION

In this process of evaluating the current technology solutions understanding the user and their needs is essential.

Autism is a neurological developmental disorder that is a spectrum. In this spectrum, every individual has a unique personality and difficulties they face. However, it is possible to see some common traits that should be taken into consideration for the evaluation of technology solutions.

Included below are some of the commonly seen traits of the minimally verbal autistic children that can be improved to increase the quality of communication [6]. These traits include:

- Avoiding eye contact,
- Minimal usage of gestures,
- Echolalia [1]
- Unresponsiveness to own name,
- Unresponsiveness to other speeches,
- Initiation for interaction.

However, these characteristics are laid out to give an image of possible difficulties for the target group and the success of technologies should not be purely based on them. There are many aspects to healthy communication and the success of the intervention might be affected by other circumstances, such as the child feeling comfortable with the environment or the unique preference of the child.

4. METHODOLOGY

This study is a literature view of the state of art for technologies in communication interventions for minimally verbal children. As the minimally verbal autistic children is a very specific target group the technologies and the sources that focus on this group is limited, therefore, the literature research includes a broader user group while maintaining the focus on minimal verbalism.

The literature that was evaluated in the study was found by searching through the platforms Google Scholar and ACM Digital Library. The search was conducted by using terms such as "minimally verbal autistic children technology", "AAC[2] children development disorder technology", "robot nonverbal children" and permutations of that (e.g., "AAC minimal verbal technology", "nonverbal children technology").

Within the papers that resulted from this search, some of them were excluded. The exclusion happened if the paper did not include technology, participants aren't nonverbal children, or it is only a review article and doesn't include a user study.

The papers that were left after the exclusion was analyzed to construct 2 tables. One for the literature with autistic minimally verbal participants and one for the literature with non-autistic minimally verbal participants. These tables were identical on their categories/columns which are the type of technology, what does the technology do, the task of technology, measurements used in the study and the number of participants in this order.

The tables can be found under Appendix A for autistic participants and Appendix B for non- autistic participants. In these tables only short citations are included to increase readability, a table of matching short citations to full citations can be found under Appendix C.

[1] "The involuntary parrot like repetition (echoing) of a word or phrase just spoken by another person."[7]

5. RESULTS

For this research 21 papers that are representative of the state of art for technologies that are used or can be used for aiding minimally verbal autistic/non-autistic children were evaluated. Within these 21 papers, 13 of them are specifically focused on autistic children while the other 8 focuses on the minimally verbal non-autistic children.

5.1 Number of Participants

The number of participants within the studies focusing on autistic children varies from 3 to 125 with a mean of 17 and a standard deviation of 32.22. Figure 1 shows the distribution of participants.

This demonstrates that most studies involve just a small number of participants and are therefore more like case studies than controlled experiments or large-scale studies. An example that is fitting to the general characteristics of the studies is the study by Muharib et al. (2019). In a longitudinal study, Muharib showed 3 children a tablet app and presented detailed results on two of the children's behaviours over 15 sessions. An exception to this is Velez-Coto et al. (2017) in which a tablet is again used for the children to interact with but in this study, 125 participants with an age range of 3 to 16 (mean 13.23) which were chosen with the collaboration of 26 different schools.

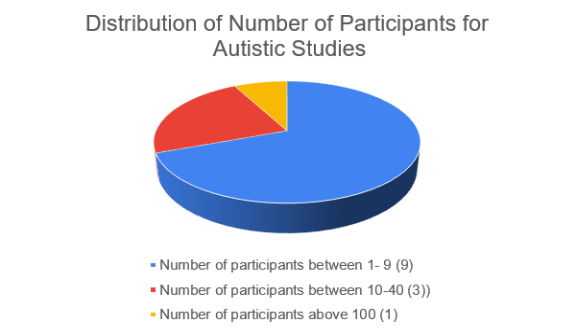

Figure 1. Number of Participants

5.2 Technologies Used

Among the 13 technologies for autistic children, 4 (38%) were tablet/phone apps (that were not focused or exclusively speech-generating), 7 (46%) were speech-generating devices (including speech-generating tablets), 1 (8%) was a tangible ball and 1 (8%) was a robot. Babb et al. (2020), a very recent study is an example for the category of tablet app not focused on speech-generating instead it showed videos to children with instructional tips on what to do in social situations. On the other hand, an example of a speech-generating tablet app which is the most frequently used technology within this group is Muharib et al. 2019's GoTalkNow, which lets a child plays speech audio for different requests.

[2] Augmented Alternative Communication

Among the 8 technologies for non-autistic children, 3 (38%) were tablet/phone apps (that were not focused or exclusively speech-generating), 4 (50%) were speech generating devices and 1 (12%) was a robot. We summarize some studies in more detail for the technologies used, to highlight the overall content of those papers.

Another example of a study where the technology was a tablet/phone apps that were not focused or exclusively speech-generating was by Song et al. (2016). Song, developed TalkLIME, a mobile application that provides real-time feedback for parent-child interaction. This is a significant goal as daily parent-training with the right techniques is a key aspect for the improvement of children's communication skills (Song et al. 2016). After a 6-week study with 8 parent-child participants, the results were measured by the number of utterances and utterances initiated by children. Other than the fact that parents felt more motivated for working with their children the initiation ratio for communication by children has also significantly improved.

Weisblatt et al. (2019) developed a tablet application, Point Outwords. Point Outwords aims at improving manual and oral motor skills which are prerequisites for communication skills. 7 children participated in the study to reach this goal by jigsaw puzzles and object-icon-symbol. The improvement of participants is measured by completion of tasks, the data gathered by the tablet, surveying parents and standardized assessments such as CELF-4[3]. The study also shows the advantages that could be offered by such technology such as the ease of data collection and developing the application in a way that would not allow rewarding for repetitive behaviour which is characteristic for autistic. While the results of the study are hopeful it is not to replace the function of caregivers or therapists and the inclination to repetitive behaviour and short attention span are some of the points for the importance of human inclusion.

TangiBall is a plastic ball which has a speaker attached to it is an example for a more hands-on, physical technology. The speaker can record sounds and to play them back. With TangiBall it is also possible for children to share and pass it around. Being able to share with their peers offers an opportunity to observe turn-taking which is an indicator to assess their ability of interaction with others.

Tito the Robot Mediator is an example of robot technologies. Tito is a humanoid looking robot aimed to be a stepping goal for autistic nonverbal children. Communication with humans is unpredictable and complex which can be overwhelming to autistic children considering their 'deficits' in communication skills. Therefore, Tito allows a more predictable simplified interaction that is more encouraging. It interacts with the user by imitation play patterns showing facial expressions (joy, sadness, anger), body movements (raise arms, dance) and familiar actions (nodding, waving). These interactions aim at encouraging the user to imitate the behaviour increasing their communication skills for day to day situations.

The majority of technology used among all the papers are speech generating devices 11 (52%). Robots and tangible technologies, on the other hand, are used much less in comparison, 3 (14%). There seems to be a similar distribution when it comes to the preference of technology type between non-autistic and autistic minimally verbal children, with speech generating devices being the most common. This could be an indicator that the general approach to improving communicational skills with minimally verbal individuals focuses on supplementing for lacking skills of verbalism without favouring the use of different technologies for autistic children versus non-autistic children.

5.3 Comparison of Technologies

In total for the technologies for autistic children (we exclude tech for non-autistic children from this section due to a focus on autistic children) we found 4 papers comparing speech-generating devices to picture cards, 1 paper comparing it to sign language, 2 comparing it to no device, 3 comparing a non-speech-generating device to no device and 1 paper comparing a robot to a person and 2 making no comparisons (1 tangible and 1 tablet app, both participatory designs).

We compared technologies in three ways. First, some papers explicitly compare technologies in the paper itself. For example, Van der Meer et al. (2012b) compared a speech-generating device (SGD) to picture cards (PC). For these, we summarize some of their results here. This study was conducted with 4 participants and focused to evaluate their preferences and their learning efficiency between the technology options. The success of the sessions was measured by the correct execution of the request depending on if it was SGD or PC. Van der Meer found that 3 out of 4 participants preferred SGD over PC and that the children performed better when they were using their preferred methods to communicate. Van der Meer et al. (2012a) also compared a speech-generating device to manual signing (sign language using hand gestures). Three autistic children aged 5-10 showed a preference for the speech-generating device while one preferred signing. On the other hand, Strasberger S.K. & Ferreri S.J. (2014) made a study where the speech-generating device is compared to no device (training only). In this study, 4 participants were expected to complete 2-step mand sentence sequences either by the SGD or as a response to the question of a peer and all 4 participants were able to utilize SGD for their training.

We also found that the authors who looked at tablet apps similarly compared their technology app to children's typical training without their app. For example, Velez-Coto et al. (2017) compared an app with different learning exercises to the normal training children go through. Within the two main goals in the study, increasing attention and

[3] Clinical Evaluation of Language Fundamentals Edition 4

recognition of visual and verbal representations of objects, they found that the attention improved significantly.

Similarly, one paper on a robot for minimally verbal autistic children also was a comparison. Duquette et al. (2008) compare a robot (Tito) to a human therapist. The participants are divided into two groups one interacting with the robot while the other one is interacting with the therapist. The study concludes that the usage of robot showed a positive impact compared to the human therapist on shared focused attention which includes visual contact, physical proximity, and imitation of facial expressions.

5.4 Tasks of Technology

With the capability of these technologies, a variety of interactions are made possible for the users. Working on motor skills and presenting videos are some examples of these capabilities. Depending on the researchers and the study, how these interactions are implemented differently. For the improvements in motor skills, 3 different studies chose 3 different approaches. Weisblatt et al. 2019 chose to use jigsaw puzzles. The participant was presented with a word from daily life (such as foods, toilet etc.) where the picture of the word was divided to as many jigsaw pieces as the syllables and the children were expected to construct it. The action of dragging specific pieces was aimed to improve the accuracy of movements. Another choice of interaction for improving motor skills this time combined with working with graphics and objects was by Wilson et al. 2018. MyWord, a tablet application was developed where the participant can create their dictionary by the words, pictures and audio chosen. On the other hand, Babb et al. 2020 aimed to improve the motor and communication skills of the participants by packing backpacks. The participants were presented with videos that were instructions for packing. There were 25 steps to the instructions where 15 of them were focused on motor skills such as carrying the backpacks while the other 10 was focused on encouraging communication skills such as asking the secretary for the keys to the storage room.

The capabilities of technologies offer a variety of possibilities on how specific skills can be approached. This in combination with the varied skills and interest of children with the autism spectrum disorder could allow for more fitting interventions to reach goals of improving skills.

5.5 Measurement

The measurements vary in the studies evaluated mainly for two reasons. First is because of the variety of tasks by studies and second is because communication is a complex concept that has different aspects. While verbal communication is very important it is by no means the only way of communicating. Communication is also possible by picture exchange, body language or mutterings. The complexity and variety of these are the cause of variation in measurements by the study. Joint attention, a measure used by Wilson et al. 2019, is "… sharing a common focus with someone by looking at and sending messages about the same object or event."(Wilson et al. 2019). This is a measure that focuses on the non-verbal interaction of participants with individuals around them, communicating over shared attention. Another measure used in the studies is imitation which is " the ability to copy other (people's) sounds, facial movements, body movements…" (Wilson et al. 2019). The study by Duquette et al. 2008 uses the social imitation of the robot Tito as a measurement to see if the intervention is indeed encouraging the participants for facial expressions, body movements and talking.

6. CONCLUSION

Autism spectrum disorder and communication are both complex concepts like the effect of autism is different by individual even though they share characteristics and communication is not merely verbal but has different aspects. Technology offers a variety of options to aid the carers and the educators for communication interventions that fit the fluidity of the concepts dealt with. These options include but are not limited to speech-generating devices, tablet and mobile apps that are not focused on speech generation, robots and tangible products. This study evaluated the technologies for the state of art with the most frequently used option being the tablet or mobile apps that are not focused on speech generation. The technologies are also evaluated on their tasks and the measurements used for the interventions. While other options of technology such as robots and tangible products could be discovered further, as they are the least frequent ones, the usage of technology for minimally verbal autistic children a hopeful image that is deserving of further work.

7. REFERENCES

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Appendix A

Literature with Autistic Minimally Verbal Participants						
No.	**Short citation**	**Technology**	**What Tech Does**	**Task**	**Measure(s)**	**Number of participants**
1	Wilson et al., 2019	tangible ball	records and plays sounds	play time participatory design led by child's interest	by observing the instances of joint attention, turn taking and imitation	10
2	Weisblatt et al., 2019	tablet app not for speech generating	object->icon-> symbol matching, puzzles, encouraging speech	move objects to complete puzzle, match object to letters and verbalize syllables.	by manual and oral motor skills	7
3	Wilson et al., 2018	audiovisual tablet app not for speech generating vs no app	audiovisual dictionary	child creates own dictionary based on his/her interest	by observing engagement and interaction through tablet data and video recordings	12
4	Babb et al. 2020	tablet app not for speech generating vs no app (normal training)	showing videos	child packs food backpacks	by task performance	4
5	Muharib et al. 2019	speech generating app vs without app	speech generation	child creates request ('I want to') sentences	by the number of completed non-vocal and vocal requests	3
6	Lorah et al. 2013	speech-generating device vs picture cards	speech generation vs picture usage	child shows request by touching a picture on the screen vs grabbing and placing a picture card	by the percentage of independent mands	6
7	van der Meer 2012a	speech-generating device vs signing	speech generation vs making signs	child shows request by touching the symbol on the screen vs making the sign for it	by the frequency of correct requesting based on child's preferred stimuli	5
8	van der Meer 2012b	speech-generating device vs picture cards	speech generation vs picture usage	child shows request by touching the symbol on the screen placing the picture card	by the frequency of correct requesting based on child's preferred stimuli	4
9	Boesch et al. 2013	speech-generating device vs picture cards	speech generation vs picture usage	child shows request by pushing the buttons on device vs picking the picture cards	by documenting occurences of social-communicative behavior (eye contact, smiling and physical orientation)	3
10	Strasberger & Ferreri 2014	speech-generating device vs no device (normal training)	speech generation vs normal training	child shows request by touching the symbol on the screen vs answering question directed	by the frequency of independent mands	4
11	Gilroy et al. 2018	speech-generating tablet vs picture cards	speech generation vs picture usage	child shows request by touching the symbol on the screen vs picking the picture cards	by the instances of unprompted and queried requests and general social communication	35
12	Velez-Coto et al., 2017	tablet/phone app not for speech generating vs no device (normal training)	shows interactive activities	child does six different learning exercises	by attention, semantic or visual skills, communication	125
13	Duquette et al. 2008	humanoid robot vs person	robot moves and talks	child explores robot	by social imitation of the robots actions measured by shared focused attention and conventions.	4

Appendix B

Literature with Non-autistic Minimally Verbal Participants						
No.	**Short citation**	**Technology**	**What Tech Does**	**Task**	**Measure(s)**	**Number of participants**
1	Beck et al. 2008	speech-generating device vs picture cards	speech generation vs picture usage	child shows request by touching the symbol on the screen vs picking the picture cards	by the amount of unprompted requests made	4
2	Khan et al., 2016	speech generating device	speech generation	child shows request by touching the symbol on the screen	by the attention and accuracy of usage	2
3	Joen et al. 2014	robot	recognizes sounds and actions, speak sentences and express facial expressions	child interacts with the robot	by interaction with the robot, gestures, speech and vocalization	4
4	Song et al. 2016	mobile phone app	gives real time feedback	aids parent-child training session	by the number of utterences, turn taking and initiation ratio	8
5	Shin et al. 2020	mobile phone / tablet app	allows communication by visual and audio	child chooses between options for actions, sees timeline for future plans express emotions	by the data of used cards and sections of the application	4
6	Boyd et al. 2017	tablet app	offers games in different levels	child chooses the preffered game and level and plays	by multiple cue responding skills	6
7	Caron et al. 2020	tablet app	visual and audio	child chooses a symbol where the word is displayed and later spoken out	by the accuracy of reading 10 words	5
8	Bock et al. 2005	speech-generating device vs picture cards	speech generation vs picture usage	child chooses a symbol on the screen vs picking the picture cards	by the amount of unprompted requests made	6

Appendix C

Citation	Short citation
minimally verbal autistic children	
Cara Wilson, Margot Brereton, Bernd Ploderer, and Laurianne Sitbon. Co-design beyond words: 'moments of interaction' with minimally-verbal children on the autism spectrum. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, pages 1–15, 2019.	Wilson et al., 2019
Emma J Weisblatt, Caroline S Langensiepen, Beverley Cook, Claudia Dias, K Plaisted Grant, Manuj Dhariwal, Maggie S Fairclough, Susan E Friend, Amy E Malone, Bela Varga-Elmiyeh, et al. A tablet computer-assisted motor and language skills training program to promote communication development in children with autism: Development and pilot study. International Journal of Human–Computer Interaction, 35(8):643–665, 2019.	Weisblatt et al., 2019
Cara Wilson, Margot Brereton, Bernd Ploderer, and Laurianne Sitbon. Myword: Enhancing engagement, interaction and self-expression with minimally-verbal children on the autism spectrum through a personal audio-visual dictionary. In Proceedings of the 17th ACM Conference on Interaction Design and Children, pages 106–118, 2018.	Wilson et al., 2018
Babb, S., McNaughton, D., Light, J., Caron, J., Wydner, K., & Jung, S. (2020). Using AAC video visual scene displays to increase participation and communication within a volunteer activity for adolescents with complex communication needs. Augmentative and Alternative Communication, 1-12.	Babb et al. 2020
Muharib, R., Alzraver, N. M., Wood, C. L., & Voggt, A. P. (2019). Backward chaining and speech-output technologies to enhance functional communication skills of children with autism spectrum disorder and developmental disabilities. Augmentative and Alternative Communication, 1-12.	Muharib et al. 2019
Lorah, E. R., Tincani, M., Dodge, J., Gilroy, S., Hickey, A., & Hantula, D. (2013). Evaluating picture exchange and the iPad™ as a speech generating device to teach communication to young children with autism. Journal of Developmental and Physical Disabilities, 25(6), 637-649.	Lorah et al. 2013
van der Meer, L., Kagohara, D., Achmadi, D., O'Reilly, M. F., Lancioni, G. E., Sutherland, D., & Sigafoos, J. (2012). Speech-generating devices versus manual signing for children with developmental disabilities. Research in Developmental Disabilities, 33(5), 1658-1669.	van der Meer 2012a
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Gilroy, S. P., Leader, G., & McCleery, J. P. (2018). A pilot community-based randomized comparison of speech generating devices and the picture exchange communication system for children diagnosed with autism spectrum disorder. Autism Research, 11(12), 1701-1711.	Gilroy et al. 2018
María Vélez-Coto, María José Rodríguez-Fórtiz, María Luisa Rodriguez- Almendros, Marcelino Cabrera-Cuevas, Carlos Rodríguez-Domínguez, Tomás Ruiz-López, Ángeles Burgos-Pulido, Inmaculada Garrido-Jiménez, and Juan Martos-Pérez. Sigueme: Technology-based intervention for low-functioning autism to train skills to work with visual signifiers and concepts. Research in developmental disabilities, 64:25–36, 2017.	Velez-Coto et al., 2017
Duquette, A., Michaud, F., & Mercier, H. (2008). Exploring the use of a mobile robot as an imitation agent with children with low-functioning autism. Autonomous Robots, 24(2), 147-157.	Duquette et al. 2008

minimally verbal but not autistic children	
Beck, A. R., Stoner, J. B., Bock, S. J., & Parton, T. (2008). Comparison of PECS and the use of a VOCA: A replication. Education and Training in Developmental Disabilities, 198-216.	Beck et al. 2008
Khan, M. N. R., Pias, M. N., Habib, K., Hossain, M., Sarker, F., & Mamun, K. A. (2016, December). Bolte Chai: An augmentative and alternative communication device for enhancing communication for nonverbal children. In 2016 International Conference on Medical Engineering, Health Informatics and Technology (MediTec) (pp. 1-4). IEEE	Khan et al., 2016
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Song, S., Kim, S., Kim, J., Park, W., & Yim, D. (2016, September). TalkLIME: mobile system intervention to improve parent-child interaction for children with language delay. In Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing (pp. 304-315).	Song et al. 2016
Shin, D., Song, J., Song, S., Park, J., Lee, J., & Jun, S. (2020, April). TalkingBoogie: Collaborative Mobile AAC System for Non-verbal Children with Developmental Disabilities and Their Caregivers. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (pp. 1-13).	Shin et al. 2020