Wireless Communication Textile Based on Passive UHF RFID

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Abstract—We present a prototype system of a user scenario created in ideation workshops organized for experienced speech therapists working with Augmentative and Alternative Communication (AAC). The goal of the workshops was to create concrete user scenarios for people using AAC, by using the possibilities of Radio Frequency Identification Technology (RFID). Out of the created user scenarios, one was selected to be prototyped and wirelessly evaluated. In this user scenario, a young child with Cerebral Palsy (CP) is sitting in a wheelchair. The child is using Wireless Communication Textile (WCT) patches on the wheelchair table tray to communicate with mother during eating. These WTC patches will create spoken words via a mobile phone application. In this study, we prototyped the user scenario by fabricating the patches with passive Ultra-High Frequency (UHF) RFID technology. Through versatile wireless measurements, we concluded that passive UHF RFID technology with a mobile RFID reader can be used to create a mobile AAC solution for wheelchair users.

1. INTRODUCTION

Cerebral Palsy (CP) is a term covering a group of different disorders of the development of movement and posture causing activity limitation. In addition to the motor disorders a number of comorbidities are accompanied such as disturbances of sensation, perception, cognition, communication, and behavior [1]. According to Rodby-Bousquet & Hägglund's register study, in Sweden, 29 % of children with CP used a wheelchair indoors and 41 % outdoors [2]. It is estimated that 60-85 % of children with CP experience significant difficulties with communication [3]. According to Parkes et al., half the population of children with CP will have one or more impairment of oromotor function or communication or both and the risk of these impairments increases with declining gross motor function and intellectual impairment [4]. Thus, the natural communication methods (speech, sounds, eye gaze, facial expressions, gestures and/or pointing) are often insufficient to meet the functional communication needs of individuals with CP and Complex Communication Needs (CCN) are common. Hence, they use Augmentative and Alternative Communication (AAC) to enhance their communication, participation and access in their daily lives. AAC refers to communication methods used to supplement or replace speech or writing for those who have impairments in producing or understanding spoken or written language. Access to functioning AAC and other assistive technology services and devices at all times is one of the specific communication rights that should be ensured for all people with a communication disability of any extent or severity [5].

The commonly used AAC methods in CP include manual signs, communication boards, books, and/or pictures and VOCAs (Voice Output Communication Aids) or SGDs (Speech-Generating Devices) [6]. Accessing methods involve physical contact with the system using pointing or a touch screen. Sometimes an indirect access or using specialized devices to manipulate an object in order to access the system are needed [7]. Despite the significant advances in the field of high technology AAC systems and assistive technology, several still remain inaccessible to many individuals due to the motor requirements in operating them and the vast complexity of CP. In addition, a range of factors are reported that impact the use of high technology AAC and the barriers related to the use of AAC vary across individuals, AAC modalities, and environments [7]-[9]. Further development of high technology devices is suggested [10][11] stating the urgent need to meet the individual needs of people with CCN, especially for those with severe motor impairments [12].

2. IDEATION WORKSHOPS AND SCENARIO DEVELOPMENT

Due to the urgent need of novel AAC technology and access methods, we organized two ideation workshops for experienced speech therapists in order to create concrete user scenarios for the usage Wireless Communication Textile (WTC) as an AAC solution and access method. In these workshops, the concept of WCT referred to all textile-based solutions with RFID technology either worn directly by the user or existing in close proximity to the user.

In this study, we will create a technical solution for one of the scenarios, a child with CP using WCTs for communication on the wheelchair tray table, whilst dining with his family. The child can't effectively or efficiently use existing AAC technologies, such as pointing to a communication book or application in a tablet computer or use signs due to significant motor challenges imposed by his disability. The child is in the beginning stage of his language acquisition. The child is using a small WCT cloth that has four different patches of preferred vocabulary. For practical reasons we have created this scenario using four separate patches to offer more flexibility and adjustability for the potential user. The vocabulary is extracted from the ideation workshop, as it was described there using a few, basic communicative functions (requesting for action, yes/no, requesting for assistance). In this scenario, the child will touch the WCT patch by placing the hand on top of it in order to activate the preprogrammed spoken word from a mobile application.

3. PROTOTYPE DEVELOPMENT AND WIRELESS MEASUREMENTS

The initial plan was to create the prototype system with the help of Near Field Communication (NFC) tags. However, as the read range of such tags is only a few centimeters, the practical implementation turned out to be too challenging. Thus, passive Ultra-High Frequency (UHF) Radio Frequency Identification Technology (RFID) tags were selected for the laboratory system demonstration to achieve longer read range. Commonly used commercial Dogbone RFID tags [13] were used as wireless inputs, and they were embedded inside yellow cotton bags, as presented in Figure 1. The cotton bags were placed on a table ray, which is a relatively commonly used accessory for wheelchairs. The placement of the tags was selected as the user can easily reach and cover them and the tags are not in too near proximity of the user or the metal parts of the chair. Initially all the tags were readable for the RFID reader. When the user places hand on top of the tag, the hand disturbs the signal, which will make the tag unreadable. This on-off functioning will be then used as the input for the mobile phone application, which will speak aloud the desired predefined words. Mobile application makes the setup adjustable, as the messages behind the tags can be controlled from the app. This type of use of passive UHF RFID technology has been first presented in [14]. As the focus of this paper was to validate the technology and evaluate the wireless performance of the system, three basic setups were created for the evaluation, as presented in Figures 2 and 3. In all three setups, female test subject covered each tag bag separately. As presented, the RFID tags inside the textile bags were lined at the front of the table. In all the setups, the wheelchair table tray was at 70 cm from the floor.

Figure 1. RFID tags are embedded inside yellow textile bags that are placed on the table tray of a wheelchair.

In the first setup (Figure 2), the tags were read from the ceiling (from a distance of 2.70 meters) with a basic UHF RFID reader (Impinj Speedway reader 420) and a circularly polarized reader antenna. The tags and the user were placed in line with the reader antenna. This setup was done to demonstrate integration of the reader equipment as part of a regular home environment. The ceiling was selected for the reader antenna placement, as the equipment would thus be hardly noticeable and provide a good “visibility” to the tags despite the location of the user. We used transmitted power of 30 dB and measured the Received Signal Strength Indicator (RSSI) with the reader software.

Figure 2. Measurement situation in Setup 1, reader antenna on the ceiling, wheelchair directly under the reader antenna.

As shown in Table 1, all the tags were very well readable initially. Further, it was possible to block Tags 1 and 2 with hand (tag not detectable with the reader). However, Tags 3 and 4 were readable even when covered with hand. It would be possible to lower the transmitted power, but that would also affect the read range of the tags. Another opportunity might be to track major droppings in RSSI, but as the signals are anyway noisy and unstable (as presented in Table 1), that was not considered a suitable option either. Additional reader antennas and calibration tags could be added, and other antenna parameters could be combined to the readings to further develop the system, but that would make the system more expensive and complex. Thus, Setup 1 was not considered successful.

Table 1. Wireless evaluation results from Setup 1.

Setup 1	**No covered tags**	**Tag 1 covered**	**Tag 2 covered**	**Tag 3 covered**	**Tag 4 covered**
Tag	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**
1	-47	X	-47	-45	-61
2	-50	-49	X	-57	-49
3	-49	-50	-52	-60	-53
4	-47	-50	-44	-52	-67

In Setup 2, the reader antenna was placed on the wall at a height of 1.23 meters (0.53 meters higher than the wheelchair table tray) at a distance of 2.5 meters from the wheelchair. The distance was selected to mimic a typical use scenario at home. The wireless performance was measured from three directions, as presented in Figure 3. As can be seen from the results presented in Table 2, this setup had the same challenge as Setup 1: It was not possible to completely block all the tags with hand. Thus, also Setup 2 was considered unsuccessful.

Figure 3. Measurement situations in Setup 2, reader antenna directly in front of the wheelchair (left), reader antenna directly from the wheelchair to the side (middle), and reader antenna directly behind the wheelchair.

Table 2. Wireless evaluation results from Setup 2 (from front, right side, and back).

Setup 2 front	**No covered tags**	**Tag 1 covered**	**Tag 2 covered**	**Tag 3 covered**	**Tag 4 covered**
Tag	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**
1	-48	-59	-51	-50	-51
2	-51	-50	-59	-57	-53
3	-51	-50	-55	-64	-55
4	-47	-47	-46	-51	-62

Setup 2, side	**No covered tags**	**Tag 1 covered**	**Tag 2 covered**	**Tag 3 covered**	**Tag 4 covered**
Tag	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**
1	-50	X	-55	-52	-49
2	-58	-61	X	-66	-56
3	-54	-55	-57	-64	-56
4	-49	-50	-51	-55	-63

Setup 2, back	**No covered tags**	**Tag 1 covered**	**Tag 2 covered**	**Tag 3 covered**	**Tag 4 covered**
Tag	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**	**RSSI [dB]**
1	-48	-65	-50	-48	-52
2	-51	-55	X	-58	-51
3	-50	-52	-51	-58	-52
4	-48	-50	-48	-52	-64

In Setup 3, a mobile phone with an integrated UHF RFID reader (C5000 from Handheld-Wireless), attached to the back of the wheelchair, as presented in Figure 4, was used for the measurements. A minimum distance of 0.2 meters (usually recommended by RFID reader manufacturers) between the reader and the user in all situations was taken as the starting point to guarantee safe use. There are also other issues to consider in reader placement: The reader should be kept relatively close to the tags to enable reliable reading but away from the metallic parts. Additionally, the reader should not make the wheelchair dimensions to grow significantly, which was considered in the setup. Blocking each tag by covering it with hand was successful. Thus, Setup 3 was selected for further system development and for additional future measurements with other reader and tag placements.

Continued research and development are called for to enhance communication and participation of people with CCN to meet the individual needs they have, especially for those with severe motor impairments [13]. Further research is required to ensure access to different technologies (e.g., AAC technology, internet, social media) for all individuals with complex communication needs, not just for those able to precisely “swipe” and have other fine motor skills (such as pointing) currently needed to operate these technologies [15]. Based on these preliminary results, it can be concluded that passive UHF RFID technology with a mobile RFID reader has potential to be used to create mobile AAC solutions for wheelchair users.

Figure 4. Measurement situation in Setup 3, RFID reader integrated in the rear left of the wheelchair.

4. CONCLUSION

In this study, we prototyped a user scenario, where a young child with CP is sitting in a wheelchair using WCT patches on the wheelchair table tray to communicate with mother during eating. These WCT patches will create spoken words via a mobile phone application. Through versatile wireless measurements, we concluded that passive UHF RFID technology with a mobile RFID reader is an excellent starting point for creating mobile AAC solutions for wheelchair users. A wheelchair tray table provides a convenient and sturdy surface for placing the smart patches on top of it. One situation emerged during the measurements, which still needs to be resolved, is where a child, while covering one tag, inadvertently also covers another tag. This can happen, for example, when the child reaches out to cover the tag at the top left and at the same time covers the tag at the bottom left with his/her forearm. In such a situation, the system can automatically select the tag furthest from the user to be identified. On the other hand, system optimization can be associated with individual optimization, allowing the system to be adjusted to identify the correct tag coverings based on the user's unique movements and characteristics. Thus, the main advantage of the created solution, in addition to its battery-free nature, is that the use of textile bags can be modified. The individual can use the very movement in their hands that they have. The WCT patches are movable and can be placed to match one’s movement, as far apart as needed or very close together if preferred.

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