DISABILITY AND REHABILITATION: ASSISTIVE TECHNOLOGY
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Possibilities of intelligent textiles in AAC – perspectives of speech and language therapists

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ABSTRACT

Purpose: The growth of new high-technology devices in the field of augmentative and alternative communication (AAC) has been rapid. However, a vast number of individuals with complex communication needs are left without functional means to communicate in their lives. Intelligent textiles are one of the growing industries in health technologies yet to be explored for the possibility of implementation as an AAC solution. This study aimed to investigate the potential of intelligent textiles and their functions in daily life perceived by experienced speech and language therapists and to obtain data, which will offer direction on how to proceed with prototype development.

Materials and methods: Focus group discussions were conducted remotely within two groups of experienced speech and language therapists ($n = 12$). The data obtained from the discussions were analysed thematically.

Results and conclusion: According to the stakeholders in question, intelligent textiles were perceived most useful for individuals with motor disabilities and those with severe intellectual disabilities. The most prominent themes for the purpose of using the intelligent textiles were social interaction and accessing meaningful activities independently. The participants also described how this technology could be used in terms of the textile, the input needed and the output the technology provides. The versatile results are discussed along with directions for future research.

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➤ IMPLICATIONS FOR REHABILITATION

- Wireless textile-based augmentative and alternative communication (AAC) technologies are a new alternative to AAC designs using rigid electronics.
- Intelligent textile-based AAC may help specifically those with motor impairments and intellectual disabilities.
- The technological solution should adapt to the capability rather than the disability.

Introduction

The necessity to design and develop new Augmentative and Alternative Communication (AAC) technologies for individuals with complex communication needs has been acknowledged in many research articles for decades, see, e.g., [1,2]. Despite advances in high-technology research, the existing methods and technologies are still insufficient to meet the functional communication needs for many people who need supports. The attempt to search for new ways to support people with complex communication needs is crucial. Communication is a fundamental human right and all people have the right to communicate effectively and to have access to functional AAC and other assistive technologies [3]. In an attempt to fulfil this basic right for everyone, we are exploring the possibilities of a wireless, intelligent textile technology in an expert-centred approach.

Complex communication needs include severe speech, language and communication impairments in which the natural communication methods, such as speech and gestures, are not enough to meet the communicative needs a person has [4]. The prevalence of complex communication needs varies. Recent estimates suggest that 97 million persons in the world may benefit from AAC [4] and that approximately 0.5% of the population could benefit from AAC in the UK [5]. There is no uniform profile for people with complex communication needs. The only unifying factor is that they are not able to use their speech or writing effectively and, therefore, require supports in order to communicate [4]. Depending on individual circumstances, the need can be permanent or temporary. However, complex communication needs are common in different conditions. In an epidemiological study, Creer et al. [5] identified nine main groups that could benefit from AAC: persons with dementia, Parkinson's disease, autism, learning disability, stroke, cerebral palsy, head injury, multiple sclerosis and motor neuron disease.

Individuals with complex communication needs commonly use AAC to enhance their communication, participation and access in their daily lives. AAC systems are diverse, ranging from unaided

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(such as body language, signs and spoken language) to aided methods in which external products and materials are used [4]. Aided methods are further divided into low-technology and high-technology systems. Low-technology systems include printed word boards and communication books that are not battery powered. High-technology systems include computerized devices, such as dedicated communication devices commonly referred to as speech-generating technologies and a wide range of mobile technologies with different applications supporting communications. Access refers to the means by which the technology is reached or operated [4,6]. Most high-technology AAC systems are accessed by finger tapping or swiping a finger or a thumb, which are common strategies when operating a smartphone or a tablet. Access can also be achieved alternatively [6–9], such as in eye gaze technologies, breath-activated methods and brain–computer interfaces, just to mention a few examples.

Light [1988], as cited in Beukelman and Light [4], has identified four main purposes in the communicative, social interactions – expression of needs/wants, information transfer, social closeness and social etiquette. Through these it is possible to regulate the behaviour of others, share information, develop personal relationships and express politeness. A fifth purpose of communicating with oneself is added to this list by Beukelman and Light [4]. Research widely demonstrates positive effects of AAC supports [2,10–14] across all ages and diagnosis enhancing social communication skills [12,14], which include the four main purposes mentioned above.

Over the last decades, there has been a sizable increase in high-technology AAC research. Mainly this is seen as a growing number of different mobile technologies, such as tablets and smartphones for different groups of individuals [12,15]. In comparison to the traditional AAC technology, mobile technologies are smaller and affordable [8], and they provide access to many applications [15]. The interest in using mobile technologies and applications is further explained by their commonness, ease of use and overall acceptability [8,14,15]. High-technology solutions seem to attract some individuals more than conventional methods. For example, people with autism spectrum disorder prefer speech-output technologies in applications, indicating more interest in technologically based solutions [16] and therefore enabling learning various skills [17].

Despite the rapid growth in the different options for AAC and the acknowledged benefits of using them, evidence suggests that a vast number of individuals with complex communication needs are left without the means to supplement or replace their speech or writing [18]. Stancliffe et al. [19] studied over 13,000 users of intellectual and developmental services in 26 states in the USA and stated that of non-speaking adults, only 3.4% used aided AAC, leaving the rest relying mainly on only gestures or body language. The similar tendency is seen in children as well. Many students across grades from elementary to secondary schools lack access to functional forms of AAC [20]. Furthermore, Johnson et al. [21] found that only 39.35% of AAC systems introduced by the speech and language therapists (SLTs) were used by clients for more than 1 year. This shows that the usage of communication aids is low, and they are not used to their full potential [18]. Those who do attempt to use them face abandonment or rejection of the aid resulting in loneliness [19] and marginalization [2].

The issue of abandonment and rejection is reviewed in articles that report the barriers and the facilitators in using AAC systems [22,23]. The findings suggest that barriers and facilitators to the use of AAC vary across individuals, AAC modalities, services and environments. Barriers associated with the device itself are further explained, such as the ease of use, reliability and voice and language of high-technology devices [22]. Individuals requiring AAC are a very complex group and factors relating to the individual characteristics are considered by Moorcroft et al. [24] including their cognition, movement abilities, attitudes, socioeconomic status and culture. Thus, new technologies are needed especially for those with severe motor impairments [8,25,26] and for those with significant language and cognitive limitations [2,26,27]. Specific attention should be placed on the access methods. Many people are not able to perform the finger tapping or swiping that are currently needed to access different technologies, such as AAC technology, internet or social media [26]. Therefore, other technological innovations may improve AAC solutions, such as sensing technologies, context recognition, augmented reality, machine learning, artificial intelligence [27] and radio frequency identification (RFID) [28].

Seneviratne et al. [29] describes e-textiles in two different ways: they are (a) made of conductive and comfortable-to-wear materials, and (b) ordinary clothing items with conventional sensing, actuating and data transmission modules. In this study we use this definition for intelligent textiles. While wearables and e-textiles have been the focus of interest in such fields as health technology [29,30], very few attempts have been made to explore the potentials of textiles for the use of AAC. Recent advances in the field of health technology include, monitoring cardiac health [31] and depression [32] or diagnosing, preventing, even rehabilitating some health-related problems [32,33]. In the field of AAC, textiles could provide a particularly interesting perspective as clothing is part of everyone's daily living. The main interest has focussed on developing gloves for recognizing signs or sign language [34]. A recent advance in this area is prototyping RFID in gloves [35]. Fleury et al. [36] created a fabric-based and battery-operated speech-output technology worn as a wristband allowing four 30 s messages to be recorded and played. Another example of recent research is a tactile board designed for the deafblind community, in which the messages are translated into vibrotactile signs that are displayed to the individual using a haptic wearable [37].

The challenge when designing new high-technology AAC devices lies in the heterogeneity of the individuals who require them. The designing and developing new systems are still often technology-driven, forcing the end users to adapt to the final product and risking device abandonment or rejection due to the poor fit. According to Lubas et al. [38] user-centred design involves identifying the users, their capabilities, needs and expectations. This design approach highlights considering the needs and skills of the end users early in the process [27] and identifying the real-life challenges [39]. Prototype creation has a central role in user-centred approach allowing the users to provide feedback on different aspects of the design [38]. Therefore, integrating the views and experiences of key stakeholders and end users with research is essential [27,39]. Collaborating closely increases practicality and enables effective translation of technologies to practice [27,40]. Speech and Language Therapists (SLTs) work to prevent, assess, diagnose, and treat speech, language, social communication, cognitive communication and swallowing disorders in children and adults. They have a primary role in the assessment, selection and implementation of AAC strategies, methods and devices [41].

In this study, we are exploring SLTs views and ideas that can be utilized to design and create novel textile-based technologies in AAC. Hence, we organized two focus group discussions for experienced speech therapists to investigate how intelligent textiles could be beneficial for individuals with complex

communication needs. The research questions were: (a) For whom did the SLTs create the ideas? (b) How do the SLTs describe the intelligent textiles? and (c) What do SLTs recognize to be the purpose for using e-textile based AAC?

Methods and materials

Research design

An exploratory and descriptive qualitative study design applying thematic approach was selected for the preliminary nature of the study. The data were analysed inductively [42]. Focus group discussions were chosen because they have previously been used in studies to gather key stakeholders' views in AAC design [43,44] and for their appropriateness in generating new ideas within a social context [45].

Participants, inclusion criteria and recruitment

The participants were selected through purposeful sampling, which is a common technique in exploratory study designs [42, p.7]. Through purposeful sampling it was possible to reach participants who are specifically knowledgeable or experienced with the phenomenon of interest [46] and able to generate insightful information for the purposes of the study [47].

The inclusionary criteria for the participants were as follows: (1) at least 3 years of experience in working as an SLT and, (2) implementing AAC methods at least once a week during the previous year. One AAC meeting a week was considered sufficient as it ensures that the participant implements AAC methods with their clients regularly. Participants were recruited *via* an e-mail distribution list (1338 subscribers) from Finnish Association of Speech and Language Therapists (1823 members). In addition, postings on two social media groups for SLTs (altogether 2357 members) and in-person recruitment provided more availability for participation. In all situations, a general recruitment notice describing the study and the objectives were provided. Interested participants were asked to contact the first author *via* e-mail or phone. A total of 13 people expressed their interest in participating, of which 12 consenting speech therapists were invited to a focus group discussion of their choice. One additional person expressed their interest in the study but did not meet the inclusion criteria. Before attending the focus group discussion, all participants completed a background questionnaire online (University's subscription to Office 365, Microsoft Forms) to collect information regarding their overall experience in speech and language therapy, their range of prior experience with different clients and AAC methods and the frequency of using AAC with their clients.

Table 1. The participants' experience in using AAC methods.

AAC method	How many have used it
Gestures and body language	12
Signing key words and other communication using signs	12
Real Objects	5
Writing	6
Drawing	10
Blissymbols	0
Pictures (e.g., communication books, communication boards, separate pictures)	11
High-technology supports e.g., speech-generating devices, computer-based communication systems, mobile technologies with application for communication	10
Other	1

The mean amount of experience working as a SLT was 20.41 years with a range of 6–36 years. All participants had experience in using more than one AAC method during the previous year (see Table 1). All had used gestures, body language and signs. Most of them had experience in drawing, pictures and high-technology supports. Participants reported using high-technology methods several times ranging from 1 to 5 days a week (mean 3.67 days a week). One participant reported using "other" methods and clarified this as simple equipment related to environmental management, including button-operated toys and fans. Participants used AAC frequently with people with intellectual disability ($n = 10$), developmental language disorder ($n = 10$) and autism spectrum disorder ($n = 8$). A few participants reported using AAC when working with clients with Cerebral Palsy ($n = 2$), hearing loss (2) and progressive neurodegenerative diseases ($n = 1$), and brain injury/brain tumour ($n = 2$). None of the participants had experience in implementing AAC with persons with cleft lip/palate or acquired communication disorders, such as aphasia. Most participants ($n = 8$) worked with paediatrics of which two also worked with adults ($n = 2$). Three did not reveal this information. One participant worked with adults.

Participants reported experience in different high-technology methods. Almost all ($n = 10$) had used mobile technology-based and computer-based solutions, to which the desired communication system or communication boards are uploaded. Many of these supports are robust and allow access to language and large vocabulary. Some reported also using simple speech-generating devices using a limited number of switches. A few participants ($n = 3$) had experience in different access methods that are controlled by gaze. Two participants had no experience in using high-technology AAC methods.

Focus group procedures

Pilot study

Prior to the focus group discussions, the research team held a pilot study remotely using Zoom with two participants from the target population to find out the appropriateness of the questions [42, p. 87] and the extent to which the intelligent textile technology should be explained to elicit discussions and ideas. The technical implementation of this study was also tested, such as the annotate tool and the breakout rooms provided in Zoom. The data obtained from the pilot study were not included in the analysis.

Focus groups

The number of participants in both focus group discussions were 6. In addition, five researchers were present in both groups but did not participate in the discussions, except for the first author who acted as a moderator. The length of a single focus group was about two hours. Due to the COVID-19 pandemic, the focus groups were arranged online using Zoom platform. Participants completed assignments prior to the focus group discussions to engage themselves in thinking of their personal experiences in AAC [44] and to name facilitators and barriers they have encountered while using AAC. Hamilton [48] suggests that having the participants do some thinking in advance and bring ideas with them to the discussion safes time. This was done by using University's subscription to Office 365, Microsoft Forms.

Focus group discussions

Both discussions were conducted by the first author, who is a practicing speech therapist and a doctoral candidate at Tampere

University. The first author also has prior experience introducing and implementing AAC methods to children with complex communication needs and their families. A focus group topic guide was developed by the first author derived from literature and the pilot study (Appendix 1). It was used to ensure that both groups focussed on the same basic information. The guide included the flow and timeline of the groups and questions asked. The participants were advised to ideate freely several times and not to restrict their thinking. However, examples of the textile-based technology were provided based on the pilot study. These included the examples of the possible methods of using it, such as touching, writing or drawing on it and the textile detecting movement. Further, the participants were told that the textile is wireless, washable and feels like normal textile. Special attention was directed into building rapport [49] between the participants and the moderator.

Due to the exploratory nature of the research, one broad question was asked to elicit different ideas for using the intelligent textile technology as follows: What would be the purposes for using textile-based, wireless technology and in what situation could it be useful? Later in the discussion, two additional questions (see Appendix 1) were asked to offer new perspectives for ideation. In addition, the topic guide included steps for voting preferred ideas and creating specific user scenarios. This information was not included in the scope of this research. However, the ideas created during the voting and discussions were included in the thematic analysis.

After the focus group discussions, the participants were asked to complete another Microsoft Forms survey eliciting further ideas and to give feedback in general. A total of 11 participants returned the survey and no new ideas were created.

Data analysis

The process of thematic analysis was conducted according to the common form of six steps, as suggested by Braun and Clarke [50]. Focus group recordings were transcribed verbatim, pseudonymized by two of the researchers and checked for accuracy by the first author. To get a thorough overview of the entire data, the first author watched the video recordings and read through the transcribed text several times while taking initial notes on what was said. The data was then transferred to Atlas.ti 9, a type of Computer-Aided Qualitative Data Analysis Software (CAQDAS). A detailed audit trail was kept through the entire analysis process to increase transparency [42, p.93].

The first and second author then coded the data using the initial notes as codes and added new codes as they went through the text repeatedly. The coding was repeatedly discussed and reviewed by the first and second author during the coding process. In the process of the iterative analysis, the first author developed a structured code book that reveals the brief definition and instructions on when to apply a code and, inversely, when not to apply a code with examples. The structured code book was further discussed and refined in collaboration with the research team. The codes were then sorted into themes and subthemes by the first and second author and later repeatedly reviewed and discussed by the research team to triangulate analysts to avoid researcher bias and selective perceptions of a single researcher [51, p. 660]. The themes were refined and appropriately named until consensus was reached. Any disagreement was resolved through discussion and consensus was reached establishing face validity [42, p. 92]. An intercoder agreement [42, p. 89] was conducted on 20% of the data to increase the validity of data collected and analysed [52], with the agreement of 73.55%. The researchers conducting the intercoder agreement discussed the discrepancies until a consensus was reached. The first author made changes to the codebook accordingly and coded the remaining data using the revised codebook. The prevalence of themes and subthemes was then collated to elaborate the overall focus of discussions in both groups. Lastly, descriptive quotes were retrieved from the data and translated from Finnish to English by the first author. In quotations, the participant is referred to as P and further identified with a number; P1–6 for Group 1 and P7–12 for Group 2.

Ethical considerations

Ethical approval was not required for this study. This study complied with good scientific practice and ethical guidelines. Information sheets and a privacy notice (in Finnish) were provided to the interested parties. The opportunity to contact the first author by e-mail or telephone was provided. Participant consent was collected online using the University's subscription to Office 365, Microsoft Forms which was filled out prior to the focus group discussions. This study and the ethical considerations were again explained to the participants in person at the beginning of the focus groups. The participants were offered an opportunity to ask questions or to have any areas of uncertainty clarified. They were also reminded that they can withdraw their consent at any time. All names were pseudonymized for the data analysis to maintain anonymity.

Results

During the discussions, the participants expressed a range of different ideas related to intelligent textiles. Overall, the atmosphere was polite, respectful and positive. The ideas encompassed descriptions of the individual, the characteristics of the intelligent textile and several purposes for using the technology. Often, all these parameters were discussed within an idea. The flow of using the technology from the individual perspective is shown in

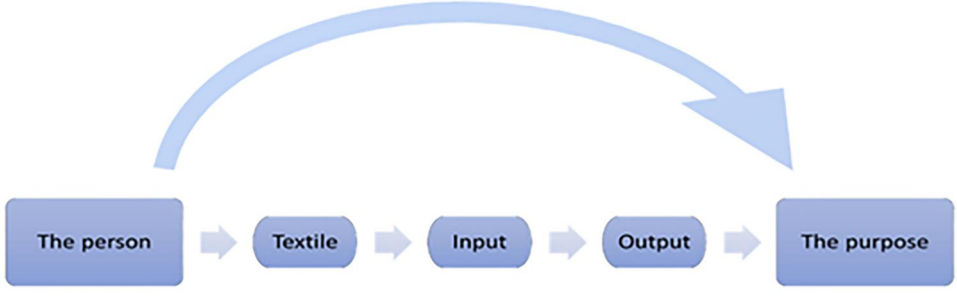

Figure 1. The flow of reaching the desired purpose.

Figure 1. The goal from the individuals' perspective is to reach a purpose meaningful to them. In order to do this, additional steps for using the technology are needed. They are shown in the middle of the figure.

Individuals for whom the ideas were created

Three themes were identified describing the person: (a) functional ability, (b) general reference to disability and (c) the communication partners. The person's functional ability and general reference to disability referred to people with complex communication needs. It was not always clear whether communication partners also needed supports, too.

The discussion mainly centred around people who have different motor challenges that prevent them from using existing technologies. These challenges included reduced range of motion or very restricted ability to move a body part. Furthermore, spasms and other non-deliberate movements that originate from motor dysfunctions were mentioned. Participants also created ideas for people who use or attempt to use signs, sign language or gestures. Harnessing the functional ability that a person has when using gestures or signs was considered important. P2 made this point as follows:

> … when a person with complex communication needs uses signs of their own and sometimes they don't have all their fingers, but they want to sign. The glove could recognise their signs and convert them into speech. In fact, that would support people who use sign language, too. They could sign with gloves … and the application would speak out the signs. (Extract from P2)

When considering using gestures P6 proposed:

> For example, rather than having to press something [to activate the technology], the intelligent clothing would sense the movement if the only thing they could do would be to move their hand just a little. (Extract from P6)

Participants also mentioned that several other functional characteristics can contribute to the need of communication supports, such as a lack of ability to shout, speak, initiate, use current AAC systems, point, produce intelligible speech or understand symbolism in pictures. Different kind of anomalies in hands and face were brought up, as well as different sensory interests, including the need to touch certain textures (such as velcro) or to feel objects in their mouths. Even though the participants described mostly the functional limitations, the focus in the ideas was more on the things the person is capable of doing. Thus, the technological solution should adapt to the capability rather than the disability.

> … if it [the technology] was embedded in clothing and you could do something against your body with … wherever you have the functional ability [tapping the chest] or voluntary movement. With that you could accomplish something amazingly fun. Something you could not do otherwise. Something that is not within reach or where you are always dependent on other people and now you could do it yourself. (Extract from P1)

Although the focus was on the functional ability, the diagnosis was also sometimes mentioned, such as autism, cerebral palsy and intellectual disability. Specific language disorder, deafblindness, mutism and Down's syndrome were mentioned only a few times. The participants also referred generally to disabilities without mentioning the condition, such as severe disability, profound disability, having only early means to interact (as in early communication), (very) low cognitive status and having complex communication needs. Furthermore, the functional ability was further explained after referring to the general reference to disability:

> My perspective is a quite severely disabled person who has all kinds of functional limitations … The little something I am able to do is a big thing. For example, if I can do something like this [taps the index finger and thumb together] … something huge must be accomplished, so that it will motivate to try other things, too. (Extract from P1)

Participants referred to adults considerably less than children even though adults were perceived as one important group for using the textiles. P8, for instance, wondered:

> Would this be most useful for an adult, for a person who has had cerebrovascular incidents, who needs supports in expressing themselves, for example when running errands in a store or somewhere … (Extract from P8)

The participants discussed communication partners who would use the intelligent textile themselves, such as peers, other children, day care assistants, teachers, kindergarten teachers and parents. This includes individuals or groups of individuals using the textile in order to assist the individual who requires AAC, to participate in an activity with them or to enjoy the functions that intelligent textiles could provide themselves. However, it was not always clear whether the communication partners themselves also needed supports. It was suggested that people, perhaps without disabilities, may also want to use the intelligent textile. For example, P1 stated: " … there is also the idea of 'design for all'. Many other air guitarists could be interested in this, because it allows you to make choreographies and play it at the same time [imitates playing a guitar]." At the same time, the clothing could be seen so appealing to others that unwanted touching might occur. This could be prevented by providing intelligent clothing for others, too. P5 described a situation, in which pressing a spot in personal clothing would start music playing: "it is a very nice idea to have the clothes available to all. This way, no one will come slapping you, if other people want to listen to the song, too." In addition, the person with complex communication needs and their peers could use intelligent textiles together. Caregivers were seen as possible users in order to support the person; often to support initiation.

> If the adult's clothing had these possible initiation things, it would be a brilliant device to seek contact. The children will gravitate towards the adult to tell their thing. (Extract from P7)

Description of intelligent textiles

The participants' descriptions of the technology included ideas for the textile itself, the method of operating it as input and the output the technology could provide. The textile, input and output were identified as themes. The textiles were further divided into three subthemes as follows: (1) clothes, (2) accessories and (3) other textiles.

Textiles

Most ideas included clothes – very common everyday pieces of garments or a part of clothing, such as a shirt, a sleeve on the shirt or pants. For example, P8 described an idea using a sleeve: " … would serve people with most severe disabilities if they can ask for help by pressing the other sleeve or say hello or anything. And pressing the other sleeve would produce something else," and P3 ideated: "If I slap my knee [pant leg], music starts playing." P3 also mentioned that: " … I'm also thinking of people who have

trouble initiating … would it increase the amount of initiations if there was a nice sleeve that can be twiddled with?"

Accessories – textiles that are worn in addition to everyday clothing or carried, such as gloves, belts, vests, pieces of jewellery and bags – were also mentioned often. Gloves, together with sleeves, were seen important in interpreting signs.

Finally, other textiles were described. These textiles did not fall into the subthemes of clothing or accessories but were in close proximity to the person, such as a bed cover, rug, wall tapestry and items that are covered or can be covered with textiles, such as table trays, removable textile patches or spots, soft toys and communication books. P6 explained the benefits for removable textiles as follows: " … you can remove them [the textile patches] either from clothing to different clothing or from a chair to chair, because chairs do change during the day."

The input and the output provided by the technology

The participants described the method of input (the method how the technology is accessed or operated) mostly according to the examples given in the focus groups: touching, writing, swiping and motion detection. The method of input was described depending on the individual abilities.

The usual ways to operate the technology ideated by the participants were different kinds of touching or swiping the textile, such as stroking, smacking, squishing, slapping, flicking or pressing. Many participants also suggested ideas using gestures or moving a body part as an input for the technology, such as nodding, turning the head and flailing. This kind of motion detection could be used with people who use signs and sign language as well. Writing was mentioned only once, in which P11 suggested that "Could there be a keyboard, for example, on a wrist for an adult that can write?" One of the input methods differed from the ideas mentioned above. In this method, a monitoring sensor could be embedded in textile, and it would interpret or decode e.g., emotions and feelings. P2 also wondered if the input method, touching or detecting motion, could develop into specific system for the deafblind community: " … just like signs have their own specific meanings, these touches could be developed into specific meanings, too." Adding to this, P1 suggested "Haptics? … Yes, there is some potential there … it [the textile] would interpret the touches somehow."

When considering the technological context of the device, most situations included the idea of using it as an interface to other devices, such as mobile technologies. Most of these ideas were designed for activating the output from an application – either an existing one or one designed for the use of this technology alone. The desired output the technology was speech, but also pictures, sounds, colours and video were mentioned. Participants also described specific features of the textile-based AAC-method depending on the individual. They thought, depending on the situation, that the technology should be simple, easy to implement, individually designed and interpreting. It should be able to differentiate spasms and other involuntary movements from intentional movements and maybe learn to understand the user. Participants described that some additional features could be important in some of their examples, such as the surface of the textile having figures, patterns or colours for easier use.

Purposes for using intelligent textiles

Participants discussed various purposes for usage of intelligent textiles. As a result of iterative coding process, four themes were identified with subthemes as follows: (1) social interaction, (2) accessing meaningful activities independently, (3) interpreting feedback and (4) more complex ideas for learning and rehabilitation. The themes and examples of topics discussed are presented in Table 2 and discussed in detail subsequently.

Social interactions

The first theme of social interaction includes the subthemes of symbolic communication, initiating interaction and playing with

Table 2. Themes, subthemes and examples of the topics discussed by the participants relating to the purposes for using e-textiles.

Theme	Subtheme	Examples of the topics discussed referring to e-textiles
Social interaction	Symbolic communication	• Requesting • Sharing information • Refusing/accepting • Social phrases
	Initiating interaction	• Enabling initiation when in a different room • Detecting the smallest possible initiation • The possibility to increase the amount of initiations • Integrating the natural gestures to the technology • Communication partner wearing intelligent textile to enhance interaction • Nurse call • Starting phone/video calls
	Playing with peers	• Enabling play or playing games • Turn taking • Drawing on wall tapestry
Accessing meaningful activities independently	Turning devices on/off	• Turning music, radio, TV on/off • Enabling the person to get excited about their environment
	Creating entertainment	• Playing an instrument from your clothes • Drawing on textiles • Creating fun independently
Interpreting feedback		• Interpreting feelings and emotions from those who cannot communicate actively • Eliciting data for others to get information on whether the person feels relaxed or like or dislike some activity
More complex ideas for learning and rehabilitation		• Multiple visual representations on textile to enable language learning • Modelling language using symbols that appear on textiles • Interpreting and expanding the (telegrammic) utterance into a complete sentence • Important picture symbols will be highlighted and flashing, while unnecessary ones will disappear. • The textile will detect the speech volume and give feedback.

peers. These ideas were strongly associated with a social, interactive aspect with others.

Participants created the most ideas within symbolic communication – requesting, sharing information, refusing/accepting and greeting. Usually, these functions were identified jointly. The described outcomes were mostly pre-recorded one-word utterances or short sentences, such as "… yes and no, and these basic things, such as help. They could express themselves somehow [using intelligent textiles]. Squeezing, for example, would be yes and, flailing would be no. This would be quite amazing …" (P12). Only one idea had a longer utterance, in which the outcome would act as a communication passport describing the situation: "… a solution with a button to press … The message would come through a speaker: 'I have aphasia and my speech unintelligible and …' [gestures so on …]" (P8). Intelligent textiles could also enable different vocabulary in different contexts:

> … it [intelligent clothing] has multiple levels that can be chosen, such as running errands in a store. That section would have all the utterances needed in a store. Then, the level could be changed to, for example, doing business in a petrol station by pressing this cool, green button on the side [of the shirt] reaching the vocabulary needed there. (Extract from P7).

Participants perceived the intelligent textile being useful for requesting actions or items in the everyday life "… for example, at dinner table they could request for more …" (P3) or "… even if they didn't have a lot of movement, it would be supercool if they would still be able to shout to others 'look at me, hey, listen to me!'" (P2). Sharing information included ideas for commenting, such as fun/stupid, expressing opinions, such as "I like it", making choices about an instrument they wanted to play and sharing information about their lives.

Being able to refuse or accept was identified as an example a few times and it emerged in connection with other examples of social communication. The participants discussed the aspect of being able to refuse or accept as a very basic communicative function. P10 also wondered whether the intelligent textile could help in learning to express refusal and acceptance:

> … I was thinking about a cap or something that would stay up here …. When they nod, it [the technology] would say: yes, yes. And then it would say: no no [turns head]. They [clients] currently spin their head so much that I never know what they mean. Could this help to establish these words? (Extract from P10)

Participants reported a few ideas for social phrases. "Well, firstly, my clothing would say 'Good afternoon' when I stretch my arm to shake hands. It kind of recognises the hand movement and situations" (P7) or "… whoopsie-gesture, something to express that I did not mean that" (P10).

Generally, using the ability the individual has, whether it is touching or moving a body part would result in accessing these desired purposes. All of these purposes encompassed utterances that have speech or pictures as an outcome, a few times even holograms.

In "Initiating interaction" the participants discussed initiation, nurse calls and making phone and video calls. This subtheme includes those ideas that did not have symbolic communication as an outcome rather than sounds to draw attention. Still, the purpose was to interact with others.

Some participants were excited for the opportunity to draw attention in a very small way. They argued that sometimes the small initiations can go undetected even for professionals. The clothing would interpret the initiation and close family and friends would not have to be professionals in detecting them. Initiating through gestures could be helpful, as it would be a natural part of our communication and could integrate into the use of gestures in general. The participants also speculated whether intelligent textiles would enhance initiation or even increase the amount of initiation. A few ideas were also created for the communication partner wearing the intelligent textile themselves. One participant (P12) suggested making the pieces of clothing pairs, so that the initiation would be established *via* the two garments. Another participant (P7) talked about the communication partner wearing clothing that could have patches for the child to initiate. A different idea was also offered, in which the communication partner uses the textile to initiate. In this case, the clothing would have "flashing" images or sounds to attract attention from the person with complex communication needs.

Nurse calls were discussed in only one of the focus groups and three ideas were identified. Despite the low amount of time committed to this discussion it revealed an important aspect of this phenomena and identified the need to design more options and new technology for hospitals and other facilities. The three ideas included discussions of the fact that even though there are a lot of nurse call technologies available, further options are needed. One participant explained that if the person cannot speak and reach for the existing nurse call button, they must wait until someone comes to help. Another participant expanded on that topic ideating that if the only thing a person could do was to move their hand a little, the technology could interpret that. The ability to start phone calls and videocalls would enhance the opportunities for social communication if the person cannot use smartphones and or other calling devices.

Playing with peers was discussed in only one of the groups and was coded four times. The ideas created here were addressed for activities done together to enable play and games using a floor mat or wall tapestry. They included taking turns and using the textile as a communication board to create sentences in a game or playful activity. Drawing on the textile with a poor motor ability with friends and later looking at the outcome from a separate screen was explained by P3 as follows:

> … it would be so nice that somehow, when drawing, different sounds would emerge … or music would be integrated into the drawing. For example, they could somehow draw on a wall tapestry in kindergarten with less motor ability and they could look at the picture of the drawing on a screen it together later on … (Extract from P3)

Accessing meaningful activities independently

Accessing meaningful activities refers to the subthemes of turning devices on/off and creating entertainment. Within them, the focus was more on the things that could be done even when alone. These ideas could offer a means to influence the surroundings independently and utilize the motivational aspect. The subthemes occurred in only Group 1.

Turning devices on/off encompasses the ability to turn music on/off, TV on/off and video on/off *via* the functional ability that the person has.

> You could turn off the entertainment device when a staff member has turned it on –here is your TV and here is your radio, and, then leaves. If you don't want to listen to it all the time, you can turn it off … or some kind of environment control. (Extract from P1).

Two participants found the subtheme of creating entertainment specifically important for the people with cognitive challenges. Within these ideas, the person would use their functional ability with textiles to create something fun, such as music or drawings. The mere experience of being able to impact the environment in an entertaining way can motivate them to persevere

in using the device, as P1 said: "yes, first comes fun, and suddenly, they realise that they can use the same ability for other things too."

Interpreting feedback

The third theme identified from the data is interpreting feedback. Even though only four ideas were created within this theme, it was discussed in length in Group 1. Through the textile, it was speculated whether it would be possible to interpret feelings and get feedback from activities: "would it be possible that this clothing would be like a sensor that somehow interprets feelings from a person who cannot express themselves? Other people would receive the data … whether things are going good or bad or something like that. They would not have to be actively communicating … " (P1). Adding to this, P4 said: "It is a great idea that emotions could be detected … it sounds like science fiction."

More complex ideas for learning and rehabilitation

The fourth theme identified from the data is more complex ideas for learning and rehabilitation. These ideas were created mostly for specific language disorder and mutism. For these conditions, there were no other ideas besides for the more complex ideas for learning and rehabilitation. Most ideas in this theme included multiple visual representations on a textile in the form of full sentences appearing on the textile or full sentences existing on the textile, enabling modelling. Another topic discussed in more complex ideas was the need for technology that could detect the telegrammic utterance of the person and then interpret it and expand it to a full sentence.

> If the system was interpreting, it would serve children with dyspraxia, as fierce it sounds like … A learning system that would learn the child's dysphonology and somehow clarifies the utterance the child is so hard trying to produce. (Extract from P11)

Technology that can detect volume and give feedback was discussed in reference to people with mutism. The textile would create feedback in the form of an image, such as flower petals growing on it or a birthday cake candle lighting as the speaker's speech would reach a desired volume. Some of the ideas were described in a joking manner such as: " … how about a head band and it then reads your mind?" (P9). Another issue discussed here was the possibility to create technology that would highlight important symbols while unnecessary ones would disappear. This was seen particularly beneficial for people with autism spectrum disorder.

Discussion

The aim of this study was to explore the possibilities of a wireless high-technology AAC solution – intelligent textiles for people with complex communication needs and, the purpose for their use in daily life in order to design initial prototypes. The ideas were driven by the experiences and beliefs of SLTs in the field and the results were versatile and interrelated. Most of the created ideas were addressing people with intellectual disabilities and different kinds of motor disabilities who are in urgent need of new technologies [2,8,26,27]. According to these data intelligent textiles can particularly enable them to engage in social interactions and access meaningful activities independently through technology embedded in clothing, accessories, and other textiles. The participants viewed that the technology should be simple, easy to implement and individually designed.

Adapting to capability

Accessing the technology was described by the individual abilities the person has. Thus, the technological solution should adapt to the capability rather than the disability. Most of the ideas utilized two of the access methods provided for the participants during the focus groups: (a) different kind of touching, and (b) detecting motion. The two other suggested methods, drawing and writing on textile, were less discussed in these focus groups. Drawing was mentioned a few times in conjunction with creating entertainment and playing with peers, whereas writing was brought up only once suggesting that creating a keyboard worn as a wristband could support a person who can write.

Touching the textile to activate the technology may support persons who are not able to use other technologies or find them hard to use. Integrating AAC in clothing items may increase opportunities for communication as the technology would be persistently available, as concluded by Fleury et al. [36]. Through intelligent textiles caregiver's assistance for setup and positioning is not needed. Thus, increasing opportunities for spontaneous social interaction. Enhancing multimodal communication [4] includes considering a range of options. For example, a person may be able to use eye gaze technologies for some functions, but require additional technology in other places, such as in bed or on-the-go.

Traditionally, using signs has been considered an unaided AAC method. The problem arises when the signs are not understood in the individual's environment [4]. Further, even if those in the environment understand signs, the motor execution of the signs can be an imprecise or the person can be using their own gestures, resulting in not being understood by even knowledgeable people in signs or sign language. Through intelligent textiles, signs can be either unaided or an aided method depending on e.g., the environment with which the individual. Developing gloves for interpreting sign language should be approached with caution. In his review, Ahmed et al. [34] point out that both hands are needed to produce many signs and that several other features, such as facial expressions, eye and lip movements are needed to convey the meaning. However, having technology that could convert single gestures or signs into spoken words could benefit many.

Activating the switch by chance, for example due to involuntary movements or spasms, may occur, in both using touching or gestures. The participants viewed that the technology should be able to differentiate involuntary and intentional movements and learn the unique features of that one individual, suggested also by Smith [6]. Unintentional activation of a switch may lead to frustration, learned helplessness and device abandonment [53]. This type of learning technology could be achieved by utilizing artificial intelligence and machine learning through the automation of algorithms, predictions and classification capabilities [9,25].

Purposes for using intelligent textiles

The theme of social interaction recurred throughout the dataset and most ideas were created within this theme. It is not surprising that the participants had many ideas in symbolic communication and initiating social interactions, due to their experience in practicing them with their clients. While requesting was mentioned frequently, the participants viewed the technology also being beneficial in other communicative functions expressed symbolically, such as in sharing information, refusing/accepting and social phrases. Research emphasizes the importance to move beyond requesting in order to learn a wider variety of what is

communicated regularly [3,12]. The ideas created for symbolic communication were mostly limited to one-word or two-word utterances and are assumed to be used by a beginning communicator, whatever the condition or the underlying functional ability is. The term "beginning communicator" does not refer to age; rather it refers to the stage an individual is in regarding their language and communication acquisition [4]. The ideas for initiation and the few ideas for making choices and taking turns support this perspective as well [4]. Having the technology embedded in textiles would create opportunities to communicate at all times. However, within these ideas the range of vocabulary is limited. In order to accumulate person's vocabulary and to offer enough opportunities to interact with others, just-in-time (JIT) supports may be one promising solution for some individuals [54–56]. JIT allows the quick and easy programming of vocabulary "on the fly" during daily interactions and is in alignment with early language development theory [56]. For these reasons, designing technology that supports JIT is important. Furthermore, Schlosser et al. [57] predicts that wearable technologies will play a critical role in future JIT supports.

The subtheme of playing with peers highlights an important aspect for using intelligent textiles. The ideas here consisted of technology that is intended to be used together. Children who rely on AAC have problems building and maintaining friendships and have limited opportunities to interact with peers [4,58]. Designing intelligent textiles for peers and close family and friends, such as large textile cloths used as a rug or wall tapestry, or even clothing, would at least be an innovative viewpoint. Unstructured times during the day can offer optimal opportunities for socialization [59] by providing something meaningful and motivating for both.

Some ideas emphasized the need for visual supports for beginning communicators and special consideration should be given to this fact. For example, AAC that utilizes visual scene displays [27] – pictures of meaningful and motivating events – increase the frequency of communication turns, as well as the number of concepts expressed. In terms of including any pictures on or in the textile, the participants brought to the fore that it may be unpractical as it is hard for the person to see the pictures themselves. Instead, the intelligent clothing could act as an interface for using other communication supports, such as mobile technologies or computers with visual supports.

Besides using AAC for social interactions, some persons with disabilities may require other assistive technology [60]. In this study, this issue was addressed in "accessing meaningful activities independently" perceived by SLTs. Having the ability to control one's environment, such as turning devices on and off, can result in increased independent control, choice, peace of mind and connection [61] and improving the quality of life [60]. Furthermore, having the opportunity to control environment or to create entertaining activities for oneself without assistance, such as playing music, drawing and such *via* intelligent textiles may increase motivation and offer a means to learning other things.

The ideas in interpreting feedback emphasized the need to create a way to communicate for those persons who cannot use any external devices or communicate actively due to the severity of their condition and their serious functional limitations. While the ideas created here were abstract and lacked concreteness in this context, the concept of collecting feedback or even to communicating non-actively has been acknowledged in brain–computer interface methods that do not require body movements [9]. Currently, this technology is prone to classification errors and problems, and is not yet practical for supporting communication in everyday use as extensive support is needed [9]. Research has been focussing on e.g., monitoring depression [32], detecting emotions [62] and movement of bedridden patients using e-textiles [63]. As research is on its way to having a passive communication method for this group of people, maybe P1's wish may come true in the future

> that they wouldn't have to be the active communicator, who says that this is how I am feeling, but the device or the textile could interpret it somehow, is it possible? It is an impossible thought for me, but a dream. (Extract from P1)

Nonetheless, ethical issues need to be considered in this scenario. The clothing or textile collects data about the person, and if a person is unable to actively communicate, it is safe to assume that they are not able to give their informed consent to collect personal information [64]. Sipilä et al. [64] also raise awareness to proper sensitivity and accuracy of the sensors used.

The discussions in more complex ideas for learning and rehabilitation were speculative in nature and reflected perhaps the participants' attempts to create more ideas in their fields of interest and expertise. The participants wondered whether the display could be on the textile rather than on a separate screen making it impractical for the user. Instead, accessing other technologies *via* intelligent clothing would be helpful for some persons. The need to enable more complex utterances including grammar refers to existing methods as well, not necessarily through intelligent clothing. Moreover, these views may have value when improving existing AAC methods and developing other, novel technology.

There were some differences in the focus groups reflecting the focus of interests among participants (see Table 3). In both groups, the discussion mainly focussed on the theme of social interaction and both groups ideated about the same proportion of ideas for the purpose of using intelligent textiles. However, the discussion in Group 1 laid in the problems of the more severely limited functions also addressing the themes of accessing meaningful activities independently and interpreting feedback. Group 2 stayed more firmly on the social communication area, generating also more complex ideas for learning and rehabilitation. Due to the response interdependent nature of focus groups [42], the numbers of ideas are presented for the reader to elaborate the overall understanding on the topics discussed in each group. What stands out in the table is that some themes are not discussed in both groups. The advantage of focus groups lay in the

Table 3. The overall presentation of ideas discussed in reference to the purpose of using intelligent textiles.

Theme	Subtheme	Group 1	Group 2	Total
Social interaction	Symbolic communication	13	27	40
	Initiating interaction	11	7	18
	Playing with peers	4	0	4
Accessing meaningful activities independently	Environment control	6	0	6
	Creating entertainment	10	0	10
Interpreting feedback		4	0	4
More complex ideas for learning and rehabilitation		0	12	12
		48	46	94

more complex level of discussions allowing different opinions being discussed immediately. However, in group discussions the participants can be influenced by their peers [65] resulting sometimes in averaging of opinions. It is typical that one person will start a conversation and others will follow. The individual responses are dependent of each other in a social context [42, p. 119].

The participants also described barriers in current AAC systems and different situations in which the intelligent communication textile could overcome them. In addition, the participants ideated six finalized user scenarios. These results were not included in the aims of this article and will be published in separate articles.

Limitations

The limitations of this study relate to the size of it and the characteristics of the data collected. This study reflected the views of 12 SLTs in Finland explored in two focus group discussions. We acknowledge that the recommendation for having multiple focus groups to reach data saturation was not accomplished to gain all information that SLTs may produce. Hennink et al. [66] recommend four focus groups to achieve code saturation. That said, an effort was made to include multiple groups for the study by employing a variety of channels to reach eligible participants. The topic of creating wireless AAC technologies for textiles is novel, perhaps resulting in a low participation rate for the study and the formation of only two groups. However, relatively few focus groups are needed to generate most new issues in a study [66]. For example, the first group produces 60% of new codes and the percentage declines fast with following groups [66]. In this study, we strengthened the impact of these two focus groups by providing the participants an opportunity to formulate their own individual ideas outside the social context through pre-discussion assignment and the possibility to add more ideas after the discussions. As a result, we gained many applicable ideas for initial prototype development.

The data obtained *via* focus groups are very context specific [45] and they provide a limited time to explore many topics. These discussions focussed on activating the technology by touching or motion detection, whereas drawing and writing on the textile were left almost unexplored. Among the limitations is the lack of representation of participants experienced in working with individuals with aphasia, for example. No ideas were created for this diverse group; however, this group was mentioned in discussions and may be one of the groups that should be further researched in this context.

A pilot study is critical to expose any possible shortcomings when collecting the data. As a result of piloting our study, we decided to have one researcher in charge of any technical issues during the focus groups. Even with careful preparations, we encountered technical problems with audio, video and the usage of annotation tool provided by Zoom with some participants. While two participants commented on the technical challenges, most participants felt that technical problems are somewhat inevitable and did not interrupt the flow of the discussions greatly. This complies with an earlier study by Archibald et al. [67] in which most participants described their experience as highly satisfactory despite some experiences with technical issues. Ethical considerations for focus groups must be acknowledged [68]. While the data collected in this study were not sensitive, other groups might be exposed to this kind of information. Especially in those cases, participants should be reminded that everything said in groups is confidential.

Future directions

The topic of designing functional AAC systems is complex and the people requiring different solutions are heterogeneous. Wireless textile-based AAC technologies are a new alternative to prior wearable AAC designs using rigid electronics. The key question, according to the participants in this study, is the extent to which an individual will be able, given their limited functional ability, to provide the necessary input to the textile. While these results suggest that textile-based AAC may help specifically those with motor impairments and intellectual disabilities, continuous research is needed to explore and create new technologies for them. Furthermore, more research is needed to address those with acquired communication disorders [69].

It would be very exciting to have AAC embedded in the person's own clothing – clothing that are affordable, fashionable and enjoyable [70]. Research suggests that it has been difficult to meet the demands of ordinary clothing when designing wearables, such as the flexibility, stretch of clothing, comfortability and ease of washing [71,72]. With these preliminary results that indicate the benefits of wireless textiles for people with complex communication needs, further research is needed to solve these issues.

To gain a more holistic perspective on the matter and to expand on the ideas of this study, the views of other key stakeholders should be explored, such as nursing staff, occupational therapists, physiotherapists, the school and kindergarten teachers and caregivers. Forming specific questions for specific populations would offer the possibility to explore these ideas from different perspectives. And, most importantly, the actual perceptions of people with complex communication needs to research and design process are crucial [39]. Beneteau [73] offers an overview of qualitative methods that can be used to include participants who need supports in their communication. It would be beneficial to design initial prototypes [74] and have those evaluated and further ideated by them [38]. Smith [6] encourages continuing to imagine what could be possible and committing to achieving that vision with people with complex communication needs.

> … if I can imagine something, I believe that at some point, someone can carry it out … First, it begins at some point and then kind of expands when we realise what technology allows … the dialogue between these needs and technology is interesting. (Extract from P7)

Our conclusion is that an intelligent textile-based AAC provides opportunities to serve several different purposes, especially for social interaction and accessing meaningful activities independently, according to experienced speech therapists in Finland. They believed that it would be most suitable for persons with intellectual disabilities and different kinds of motor disabilities. These data provide a starting point for initial prototype development.

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Appendix 1. Focus group topic guide

1. **Meet and greet the focus group participants at the start of the focus group: 15 min**
   - Meet attendees individually and greet them.
   - Introduce yourself and offer background information about the research and your own motivation to study this.
   - Explain the aims of the study.
   - Remind the participants that the discussion will be recorded, transcribed, and analysed.
   - Brief introductions of research group and participants with video. From this point the rest of the research team will not have their video on.
   - Ask participants to keep their video on.
   - Explain that they can ideate freely and not to restrict their thinking.
2. **Quick icebreaker to get started: 5 min**
   - Introduce a fun picture and elicit conversation on what could be said in the situation the picture represents.
3. **Pre-discussion assignment: 10 min**
   - Explain the goals for pre-discussion assignments.
   - Introduce the pictures of the AAC-methods the participants have enjoyed using.
   - Elicit short discussion and build rapport.
   - Introduce the facilitators of AAC perceived by the participants prior the group.
   - Quiet work for 5 minutes and opportunity to add to the list.
4. **Introducing the topic of the group discussion: 15 min**
   - Introduce the list of the barriers that participants have sent prior the group.
   - Quiet work for 5 minutes.
   - Opportunity to add and discuss.
   - The engineer in the research team introduces the textile-based wireless AAC-technology with pictures of examples of usage: you can touch it, write on it, draw on it and the textile can detect movement. Further, the textile is wireless, washable and feels like normal textiles.
5. **Group discussion/Ideation: 35 min**
   - Re-introduce the list of barriers and ask the participants to ideate ways in which the textile-based wireless technology could be useful asking the following broad question:
   - What would be the purposes for using textile-based, wireless technology and in what situation could it be useful?
   - Remind the participants to ideate freely and not to think of the technical possibilities they currently think that exists.
   - Quiet work for 5 minutes and then free discussion around the theme.
   - Prompts: Who, how and what?
   - Offer the following questions to ideate from a different perspective:
     1. What if the caregiver is not in the same space?
     2. What if a year has passed and the textile-based had worked wonders?
6. **Evaluating the ideas, 10 min**
   - One of the team members teaches how to use the annotation tool in Zoom.
   - Ask the participants to select two barriers that the wireless textile-based AAC could solve.
   - Ask the participants to apply a sticker on top of the selected barriers using the annotation tool.
   - Select three of the most voted barriers to be further ideated upon.
   - Present them to the participants: "Here are the barriers we just discussed and selected for further development. You can use ideas that were created during the previous discussion or come up with an entirely new idea or perspective".
7. **Developing the best ideas further into thought-through ideas in teams of two: 25 min**
   - Explain the goal for this section and introduce the specific questions
   - Who would use the textile? How old are they? Why are they not able to use natural speech? What is the situation? What would they want to say/do? To whom would they communicate? Where is the wireless textile-based AAC? How would it be used? What would happen?
   - Explain that the questions are visible in the chat.
   - Explain that they can, at any time, return to the discussion room for further guidance.
   - Split the participants randomly in teams of two to develop the idea further.
   - Have the participants work in pairs for 10 minutes in breakout rooms available in Zoom.
   - Present the finalised ideas to the whole group and elicit discussion.
8. **Goodbyes: 5 min**
   - Thank everyone for participating and acknowledge each participant and ask for further comments, thoughts, or ideas.
   - Remind the participants that an additional feedback form is available online in which they can also give new ideas or comments that may have emerged after this discussion.
   - Ask for permission to send a small present to each participant.