Case Study

Smart clothing and furniture for supporting participation-co-creation concepts for daily living

Tiina Vuohijoki[1] · Tiina Ihalainen[2] · Johanna Virkki[1]

Received: 13 December 2022 / Accepted: 20 February 2023
Published online: 22 March 2023

Abstract
Participation and social inclusion influence individuals' health and well-being. These factors can be easily disturbed, especially for those with disabilities. Designers and engineers have tried harnessing technology to assist people via producing prototypes of assistive devices, such as smart clothing and furniture. This study approaches that user surface and inspects the user's needs for participation through clothing and furniture. We thus arranged two similar workshops with student participants ($n = 37$) from four different educational units, creating 10 innovative concepts to support participation and social inclusion. All aimed to support participation via improved self-regulation, increased safety, or environmental control. Most of the concepts were connectible to another device, such as a mobile phone. All devices were made adjustable to meet personal preferences. This study aligns with previous ones by concluding that assistive technology should be unobtrusive, give timely responses, and interact with other devices. These initial concepts are ready to be turned into tangible prototypes.

Article highlights

- Participation and social inclusion have remarkable meaning for an individual's well-being and health. Commonly, assistive technology aims to solve challenges in daily living by promoting *health* and *well-being*. For this reason, we arranged two similar co-creation workshops and asked the participants to innovate smart clothing and furniture concepts that will promote greater participation and more social inclusion.
- This study also identified users' needs, such as increased safety and independence, supported communication, self-regulation and awareness, and an effective learning tool.
- The majority of the concepts were designed to be adjustable to meet personal preferences, let individuals interact with other devices (such as a mobile phone), and give timely responses.

Keywords Participation · Assistive technology · Smart clothing · Smart furniture · Concept · Co-creation

✉ Tiina Vuohijoki, tiina.vuohijoki@tuni.fi; Tiina Ihalainen, tiina.ihalainen@tuni.fi; Johanna Virkki, johanna.virkki@tuni.fi | [1]Faculty of Information Technology and Communication Sciences, Tampere University, Tampere, Finland. [2]Faculty of Social Sciences, Tampere University, Tampere, Finland.

1 Introduction

The phenomenon of participation has been widely researched [1, 2]. It is defined by The World Health Organization (WHO) as "involvement in a life situation", while the definition offered by the International Classification of Functioning, Disability, and Health (ICF) includes being autonomous or in control of one's life through assistance, if one is unable to be completely independent [3, 4]. In contrast, social exclusion is often referred to as the opposite of participation and categorized as a loss of social relations [5]. These social losses and barriers that prevent participation can be caused by a weakened ability to perform, challenges in undertaking or receiving communication; executive functioning; or self-regulation difficulties [6–10]. Often these barriers stigmatize people, aggravating their ability to participate [6]. The issues mentioned here, however, are just the tip of the iceberg when describing the causes of social exclusion. Thus, it is important to establish how participation can be better supported for all.

As smart wearables do aim to improve human life, they often seem to correlate with participation: We thus briefly introduce a few smart wearables, such as a head-worn navigation device to assist indoor navigation—easing the daily walks of the visually impaired [11]. Due to the navigating difficulties in various situations, researchers have discovered how to help the visually impaired find and use crosswalks [12]. This solution utilizes consistency analysis and transfers information to the user's wearable device. Navigation challenges have motivated other researchers to develop a haptic stimuli device [13]. This device, designed like a belt, gives navigation instructions by vibrating the side that must turn to reach a destination. Another example of participation with a cloth is a garment used for attention deficit hyperactivity disorder (ADHD) children to assist them in maintaining attention [14]. A gyro glove developed for people with Parkinson's disease reduces involuntary hand movements to ease the user's daily tasks [15, 16].

Correspondingly to these smart wearables, some research has addressed smart homes with smart furniture and their potential for better assisted living has been established [17–22]. Many of these examples utilize camera detection and have complex, customizable system architecture to track and support the user's behavior and vital functions [17, 19, 21]. For example, a smart home solution with intelligent interior units aims for personalized health care and activity support for elderly people [21]. Here, the prototype units are arches that collect data from the covered area and both movable and immovable arches are presented. Assistive robotic micro-rooms, on the other hand, aim for multi-dimensional assistance in the activities of daily living (ADL), such as eating, dressing, toileting, bathing, and transferring [19]. A mirror with facial, voice, and speech recognition has also been developed as an assistive tool for self-regulation [23]. This mirror can offer feedback to the user and also share the patient's information with possible caretakers. Researchers have also prototyped a headband for detecting expressions and cognitive activities that can help monitor the user's emotional stress or cognitive workload [24].

Pushing TV remote control buttons or operating a light switch is impossible for some people, so this research explored alternative ways to produce mechanical input. These alternative methods include speak-recognition. Those who cannot speak could benefit from a glove that turns gestures into speech from pre-recordings [25]. Further, a home automation system can turn electroencephalography (EEG) signals into commands, enabling wheelchair movements and fan activation [26]. "Smart Sensory Furniture" is part of ambient assisted living and is a solution that also senses the user's possible risk behavior [27]. Previous research introduced an electronic bed with a depth camera to monitor the user's movements [21, 24]. These examples are just a minor group of references for how different stakeholders have tried to support participation using technology, many of which also utilize clothing or furniture to achieve their purpose.

As noticed, assistive technology that supports participation exists. Even so, for some reason, these devices are not commonly adopted into the daily living of those who need assistance: Some of these inventions might be too expensive to implement, too complex to include for in-home use, or some of the prototypes might "work on paper but not in practice". To our knowledge, smart clothing and furniture are rarely studied, particularly from the perspective of participation, and for this reason, this study seeks new insights that will help address these research gaps. The previous research has focused on technical descriptions of prototype development, while we aim to bring forth and examine the actual user needs for smart clothing and furniture supporting participation. In contrast to technical descriptions, there is much less information about what qualities these should have to serve their users well. Thus, our interest is to promote both greater participation and more social inclusion.

To attain feasible, operative, and practical devices that do support participation, some conceptualizing was necessary. As a result, we offer two research questions: (RQ 1) what sort of smart clothing and furniture actually support participation and social inclusion? (RQ 2) in what way do such devices support participation? These research questions were answered through workshop activities. This

introduction thus gives a brief overview of the phenomena of participation and participation related to smart clothing and furniture. The second section, Methods, is concerned with the methodology used for this study and the third chapter presents the workshop results. Chapter four, Discussion, analyzes the results, and the final chapter, Conclusions offers a summation of the conducted study, its limitations, and suggestions for further research.

2 Methods

We organized two multidisciplinary workshops to gather detailed information through a co-creation process where all involved stakeholders contributed to the problem-solving process and created a collective solution [29–31]. Deliberation on whom we included in these co-creation workshops was carried out with several goals/issues in mind. At first, we were interested to gather as many concepts that cover participation and social inclusion as comprehensively as possible. Thus, we did not organize a workshop for specific end users, such as people with physical or cognitive disabilities. Still, we also wanted the insights of those who (1) understand the end user's everyday life, and if possible, (2) those who have the vocational competence and understanding of this user's possible challenges. Occupational therapy, special education, and logopedics students were identified to meet the criteria. The role of the student might also allow ideating without a single strong specialized professional perspective, such as senior care or children with disabilities. Thus, we sent invitations to four anonymized educational institutes and the representatives of four academic programs for secondary educational units. These invitations provided information regarding the study and privacy statements were signed before any participants could participate in the workshops. Altogether, 37 voluntary and adult participants (18 in the first workshop and 19 in the second) attended. The group included 34 occupational therapy students, 1 engineering student, 1 special educational student, and 1 logopedics student.

Both workshops were conducted in Finnish, lasted 2 h, and were placed on the digital platform, Zoom. Both workshops were also recorded. Three researchers conducted the events, and two research assistants took care of the technical implementation, such as the division of the participants into break-out rooms.

Both digital workshops had the same structure: Welcoming, followed by a visual icebreaker to increase social communication [32, 33]. Following the icebreaker, the researchers introduced the concept of participation and the possibilities of smart fabrics. Participants were asked to innovate solutions to support participation through smart clothing and furniture in smaller groups with four to five participants, and 20 min was allocated for this group activity. We offered questions to support the ideation: (1) Who is the user? (2) How does the idea work? (3) How does the user benefit from it? After the group activity, the ideas were presented to others and further developed with the other participants. As workshop facilitators, we avoided guiding the discussions in any direction. Finally, the workshop ended with conclusions on the concepts and closure.

The data gathered were analyzed by watching the video recordings thoroughly and transcribing the detailed parts regarding concept presentation and further innovation. For each concept, five items were offered in detail: (1) the purpose of the concept, (2) what kind of qualities/features the possible end users would have, (3) what kind of input is gathered (4) the venue where the concept can be connected, and (5) what is the benefit of the concept for the user. Our data analysis route is illustrated in Table 1. Data analyzing route is explained with an example. We gathered the concepts into a single table, Table 2. 10 innovative concepts supporting participation and social inclusion. Unfortunately, 4 items were left without any information, and they are marked in Table 1 as "no data". The results are presented as was done in the previous studies by Sipilä et al. 2021 and Nissinen et al. 2021 [34, 35].

3 Results

The workshops yielded ten concepts that supported participation and social inclusion. There were six garments, three furniture pieces, and one assistive tool (see Table 2. 10 innovative concepts supporting participation and social inclusion). Nine concepts were common clothing and furniture, for example, shirts, pants, a table, and a bed. Concept 5 was considered a tool and was neither furniture nor cloth.

Table 2 demonstrates that the purposes of the concepts varied. There were garments, which aimed to help emotional regulation and communication; one navigation cloth, a mattress, which senses the user; a commander bar compatible with all home equipment; a gaming table; and a stability cloth. These concepts aimed to assist people with challenges by regulating emotions; communication; memory; moving, or sicknesses. Versatile people; children, the young, elderly, and immigrants were found to benefit from these ten concepts. The users would have certain qualities, which make participation and social inclusion challenging and these seem to be related to multiple areas of mental (anxiety), physical (stroke), and cognitive challenges (memory) in different forms (Table 2, column: Users are people with these qualities).

Table 1 The data-analyzing route is explained with an example

Phase	Phase 1	Phase 2	Phase 3	Phase 4
Action	Highlighting the meaningful content	Sharing the content to become items	Finding similarities/ connections between the items	Assing names for each item group
Quote: "We have created this smart cloth, which helps the user to move independently. For those who might have memory issues. This [vest] could come with a route application to assist the person to move the pre-programmed routes, so it could be programmed onto cloth. It could offer feedback if the person is going in the wrong direction. It could be a vest, so you could use it all year. It reduces the perceived unsafety and supports participation because it enables independent moving."	We have created this smart cloth, which helps the user to move independently. For those who might have memory issues. This could come with route application in order to assist the person to move the pre-programmed routes, so it could be programmed onto cloth. It could offer feedback if the person is going to wrong direction. It could be a vest, so you could use it all year. It reduces the perceived unsafety and supports participation because it enables the independent moving	Helps the user to move independently for those who might have memory issues with route application to assist the person to move the pre-programmed routes could offer feedback if the person is going in the wrong direction A vest reduces the perceived unsafety supports participation because it enables independent moving	A vest, helps the user to move independently For those who might have memory issues with route-application to assist the person to move the pre-programmed routes could offer feedback if the person is going in the wrong direction reduces the perceived unsafety supports participation because it enables independent moving	The purpose of the concept: helps the user move independently What kind of qualities/features possible end users can have, For those who might have memory issues What kind of input is gathered It could offer feedback, if the person is going in the wrong direction and tracks person's moving/transferring Where the concept can be connected with route application to assist the person to move the pre-programmed routes What is the benefit of the concept to the user reduces the perceived unsafety, supports participation because it enables independent moving

Table 2 10 innovative concepts supporting participation and social inclusion

Concept	Purpose	Users are people with these qualities:	Input	Connectible with:	Possible benefits
Concept 1: A pressure shirt or pressure headwear device for stressful situations; could also change the temperature	Adds gentle pressure and/or adjusts the temperature of the fabric when certain parameters are achieved; aims to ease users' well-being	– Anxiety or panic attacks – Cannot identify and/or verbalize feelings or other needs –Weakened thermoregulation –Hyperactivity disorder	– heart rate – Temperature – Sweatiness – Electronic conductivity of the skin – Adrenalin spikes – Movements and maneuvers	Mobile; send data to mobile application	– Leads to better coping when in situations that are typically distressing (e.g.) shopping – Prevents escalation of feelings – Supports self-awareness; could be used as a learning tool for self-regulating – Increases perceived safety – Helps with relaxing and sleeping – Assists the user in being heard and being recognized better/easier – Is portable and operable in versatile situations (versus a weighted blanket)
Concept 2: Shirt with communication assistance	Translates user's vocables and/or movements into writing, pictures, speech, voices, or videos	– Stroke – Writing disability – Speaking disability	– Vocables – Movements – Collecting information on sensory activities	(e.g.) Mobile; data output comes from mobile applications' screens	– Enables communication in different forms (speech, writing) – Enables verbal expression, even when the user cannot speak – Increases perceived safety
Concept 3: Navigation vest	Assists navigation; gives advice; notifies of risks, seeks to stop the user if the user is in danger	– Memory challenges – Mobility issues – Disability – Young	– Tracks moving and traveling	Mobile data transfer between the mobile and shirt	– Enables independent movement – Increases safety if danger or risks to the user are noticed – Reduces perceived feelings of insecurity – Supports learning a new route (e.g.) for schoolchildren
Concept 4: Smart mattress	Senses movement and moisture	– Severe motor disability – Mobility challenges	– Moving – Moisture	Mobile	– Offers timely assistance – enables rearranging of work tasks – allows the user more privacy
Concept 5: Commander bar	Enables eye tracking in technical solutions at home	– Severe disability – Autism spectrum disorder	– Eye movements	All the technical solutions at home	– increases feelings of being in control of situations – increases perceived participation

Table 2 (continued)

Concept	Purpose	Users are people with these qualities:	Input	Connectible with:	Possible benefits
Concept 6: AI game table	Activates and reduces loneliness using gamification	– Advanced age – Immigrant background – Mental disorders – For all people	–voice/language – eye movements – mouth blow	"no data"	– Activates user – Decreases perceived loneliness – Supports participation because the user can speak in his/her own native language
Concept 7: Pressure outfit	Enacts physical pressure on the user to ease their being	– Hyperactivity (especially in children) – Emotional and sensory regulation challenges – Difficulty coping with stressful situations – Diabetes – Old age	– Stress levels – Motoric restlessness – Heart rate – Temperature – Blood sugar – Vitality levels – "*Fluids that flow within the body in stressful situations*"	Mobile	– Improves focus (e.g.) in daycare or at school – Helps the user stay calm – Helps identify stress – Increases perceived safety – Offers data to guardians/caregivers– helps notify the user and caregiver of the stress before escalation; ensures timely help
Concept 8: Rehabilitation pants or a shirt	Promptly provides the needed support; activates the right muscles in a specific action; prevents falls	– Challenges when using the middle of the body's compensatory movements – Stroke – Elderly	"No data"	"No data"	– Increases perceived safety when moving independently – Does not passivate the user – Prevents falls – Leads to a comfortable user experience
Concept 9: Bed with speak-command	Enables independent movement and position changing	– Tetraplegia – Severe disabilities – Spends most of the day bedridden	– Movements – Voice – Temperature – Heart rate	"No data"	– Supports independence (i.e.) independent position changing – Helps reduce pain – Reorganizes resources of the care unit positively
Concept 10: Sensory regulation shirt	Helps with emotional regulation by giving stimuli (voice, vibration, pressure, temperature)	– Emotional regulation challenges (in identifying and coping with them)	– Emotions and feelings	"No data"	– Assists in controlling stress – Assists in regulating emotions – The user learns emotion-regulation

All concepts would be individually programmed or adjusted to meet the user's individual needs and preferences. Additionally, most of the concepts were considered as being connectible with a mobile phone or another technical device; the concepts gathered data in diverse forms from the user. The desired data included voice or vocables, maneuvers, movements, eye movements, sweatiness, heart rate, the electrical conductivity of the skin, adrenaline spikes, body warmth, and blood sugar. Furthermore, the concepts, which gathered data, also offered feedback to the user or caregiver in a variety of forms, such as voice, vibration, pressure or temperature change, and text messages.

We identified two main ways of enabling the actions: Impacting the physical environment and self-regulation. Three (1, 7, 10) of the garments aimed for better self-regulation and awareness by offering feedback when the user's physical parameters were crossed. Half the concepts considered controlling the physical environment (4, 5, 6, 8, 9) with either voice or movements. The nature of needed assistance also varied, (e.g.) some users needed assistance at a store and some during a school day, while other users needed help when lying on a bed or when walking.

4 Discussion

In this study, two multidisciplinary workshops were organized to develop smart clothing and furniture concepts that support participation. A total of 37 voluntary participants participated in a co-creation process, which produced 10 concepts. Based on these results, it can be stated that when designing smart clothing and furniture that aims to support participation, the process and outcome should further enable the user's capabilities through a personalizable smart cloth or furniture, which gathers information in several ways, provides feedback to the user and, if needed, is also connectable to other devices. This kind of cloth or furniture will assist the user by increasing independence, offering timely help in specific situations, increase safety, assist communication, and enable more and better self-regulation learning.

4.1 Increases user independence

All these concepts aimed to increase the user's independence and support participation and social inclusion [4]:

> It [commander bar] would bring more sensation of I'm in control, *me,* and I'm doing things in *my* life. Not that everyone else is doing my things. (Concept 5)

Being able to cause mechanical input was seen as one aspect of independence. The furniture and technical tool concepts of 4, 5, 6, and 9 offered alternative ways to produce mechanical input (e.g.) moving, voice, speech recognition, or with blow mouth as well as the gesture glove, EEG-signal command wheelchair and bed with an in-depth camera which determine the distance between the camera and the subject [25, 26, 28]. The following quote from the participant empathized with the user:

> This [Ai game table] could come with a part, which allows you to play with an eye command if you are not able to move [chips] with hands." "…then, we tested at school this blow mouth controller. You could write with it. So, it could utilize that too, and you do not need hands. (Concept 6)

4.2 Offers timely help in specific situations

In addition, all the concepts helped in a timely way and only when the user truly needed it:

> "The smart vest would only give feedback if the user were going to walk in the wrong direction. (Concept 3).
> We thought this mattress could be personalized to meet user needs; it would not send a message necessarily to a nurse if the user turns over. Only when it is a matter of emergency." (Concept 4)

All concepts aimed at situational assistance. In other words, the concepts would not operate continuously, but would automatically identify the interference or activation in real time. Somewhat surprising was that all the concepts intended to support participation in one preselected manner: one concept aiming to assist navigation (Concept 3) and one assisting communication (Concept 2), while others assisted in regulating emotions (Concepts 1, 7, and 10) as did the previous contributions of [12–16, 25–28]. Even though all the concepts were ideated as their own unique entities, some of the participants did combine two of the concepts, the vest (Concept 3) and the AI game table (Concept 6) in the following manner:

> "Participation could be increased if one could plan the route on the table [AI game table] like a game and plan all the solutions, in a way that if you are going to store, I can plan in which route I take and if I choose this route, this will happen and after planning the route, it could be connected to the vest and then you would have planned your actions and what you would do."

Furthermore, a few relatively surprising insights were specified regarding the workload of people around the user. Tasks and daily routines could be planned differently because of the device. For example, visiting the patient's room could become less frequent, as the user could perform functions, such as operating a light switch or a television remote. As one participant described the bed that had a speech command:

> "The bed could send an alarm when the user must change position, to avoid ulcers. The bed could automatically change the user's position, and then the caregiver will not have to come in only for changing position. This bed would also support independence." (Concept 9)

4.3 Increasing safety

The results indicate that intercepting safety issues supported participation, as the user's perceived safety is increased through an easily operated safety solution concerning their bodily limitations. In turn, it minimizes physical risks, such as traffic accidents, falling, or pressure damage (Concepts 3, 4, 9). As timely assistance can be seen as a safety issue, all the concepts aimed to provide prompt, accurate assistance for various needs.

> "This [vest] reduces the feeling of unsafety and supports participation by being able to move to meaningful places [for the user] and the most important part is the safety. After programming the right routes, it could remind the user 'do not go there', 'stop'."
> "We were thinking to add something that gives impulses to the user if there is upcoming danger and in a way that the user must stop right away and think why this vest is warning me." (Concept 3)

4.4 Assisting with communication

Supporting communication was seen as a factor in assisted participation and social inclusion [8, 25]. Shared language in its various forms seems critical for users to perceive themselves as being included or social participants. Language, in this context, means speech and joined spoken language, along with symbols, signs, or vocals.

> "This could interpret the user, his/her speech or movements, in a way that it would enable communication with the person who cannot write because of cognitive decline." – "This supports communication and participation but also increases the perceived safety. Imagine if this kind of person is lost and needs help, then the person could ask for it without writing or saying it" (Concept 2)

> "Looking at that cultural background aspect…you could choose [Ai game table] from different languages and by that choice the participation and the feeling of safety is created in that always someone understands the player or the user." (Concept 6)

4.5 Learning self-regulation

Interestingly, most of the concepts that were offered raised the learning self-regulation aspect. Consistent with the earlier findings, Concepts 1, 7, and 10 aimed to give feedback and detect emotional workload [14, 23, 24]. As claimed in the previous study, self-regulation challenges might be related to social exclusion [9]. These devices were seen as tools for the user; and the close ones, for identifying bodily reactions (e.g.) heart rate, temperature, and accelerating movements. Based on any changed parameters, the garment would give feedback. Users could then (1) change their environment; (2) adjust their bodily functions by creating space for self–awareness; or (3) request help. In general, the concepts focused on enhancing the user's abilities and awareness. One participant described the meaning of self-tracking:

> "For example, the person who could use a mobile phone and could follow the state of being from the mobile screen could also have the opportunity to foresee and learn to identify the early markers of a panic anxiety attack." (Concept 1)

4.6 Technical aspects

With the use of clothing in Concepts 1, 2, 3, 7, 8, and 10, intelligence should be integrated with the majority of the user's garments; if a garment is in the laundry, the user still has other intelligent garments to wear. This challenge is not present when adopting smart furniture concepts since only one piece of a specific device is needed in one home. However, that furniture is bound to a specific location, and the user cannot benefit from it anywhere else. Further, the assistive tool, the commander bar, can be integrated into all technical equipment in a home, but it does require the collaboration of different smart home systems.

The core of our findings is that smart clothing and furniture that is assisting participation and social inclusion should be individually adjustable. Nevertheless, finding proper features and stimulus volume could be tricky, as one workshop participant explained:

> "We discussed adjustable temperature control. If it could produce warmth because for some people warmth increases the feeling of safety. But then

again, we thought that it might be a bad thing to only warm up (the device) because some other people might find warmth discomforting." (Concept 1)

To tackle the challenge of finding the right settings for each user, one participant offered a solution for relatives:

"If this [device] was adopted to the user with severe disability, then relatives and people who know the user should be involved in deployment. Commonly they are the ones who read and understand the user in the best possible manner, maneuvers, and behavior. When the deployment phase has ended, the garment would learn from the programmed information." (Concept 2)

Most of these concepts require microphones, speakers, and a variety of sensors to be implemented. One remarkable issue to address was that they need power sources and wireless data transferring. Interestingly, mobile devices (or portable touch pads) played a significant role in the created concepts, as they would be used to track data and customize the actual device. This finding is contrary to several previous studies which did not utilize mobile devices in their inventions [12–14, 16–18, 23–27]. Connecting a mobile device could turn the cloth or furniture into a user interface, and thus we could use the microphone and speaker from the device for a positive advantage in our future prototypes.

4.7 Data protection

The connection to other devices of course raises the question about data security, data handling environment, and granting access to personal data (Concepts 1–7, 9, and 10), which is highly regulated in the European Union [36]. These concepts aim to help people who are in a vulnerable position compared to others and thus gather health-related data. Therefore, data handling should be planned with caution [37, 38]. In situations with people who have disabilities, it is not always clear who should have access to personal data [39]. Depending on the situation, access should be permitted to a relative, teacher, or healthcare professional, who is involved in that user's care. Nevertheless, excluding someone from access might create another issue. Could the safety of the user be in danger? Another source of uncertainty is how different companies would utilize the data gathered from the users [38]. Currently, companies commonly use personal user accounts. These solutions rarely can be adjusted into (e.g.) care facility needs, where multiple care workers would need access to a user's account.

4.8 Limitations

One limitation of this study is that it does not provide an end user's viewpoint. Another limitation is the difficulty in offering description that will interest professionals in different fields. When emphasizing the technical results, we are in danger of regarding out the reason for why these innovations are needed. Thus, by providing insights from workshops as immutably as possible, we tried to protect the findings' versatility. The third limitation, the small number of participants, meant that we cannot generalize this data. Still, we can offer concepts that have been created based on the vocational perspective of the potential user. In addition, while our workshop participants were mainly occupational therapist students, the concepts were diverse, so we gained valuable information regarding the potential of smart clothing and furniture for supporting greater participation. When evaluating the data analysis in this study, our method was relatively light and did not offer deep knowledge about the phenomena of supporting participation with smart clothing and furniture. Nevertheless, this particular data analyzing pact was necessary for identifying purposes. When assessing this analyzing method using our set of offered research questions, this data analyzing method supported the goal of answering our research questions.

5 Conclusions

Through co-creation workshops, we gained new concepts and understanding to help support participation and social inclusion through clothing and furniture. In them, 37 voluntary participants created 10 concepts for tools to support self-regulation and environmental control. Most of the concepts were connectible with another device, and almost all were individually adaptable. The specific concepts were a pressure shirt or headwear for stressful situations, a shirt with communication assistance, a navigation vest, a commander bar for technical solutions at home, an AI game table, a pressure outfit, rehabilitation pants or shirt, a bed with speak-command, and a sensory regulation shirt.

In the beginning, we set forth two research questions, the first was *what sort of smart clothing and furniture actually support participation and social inclusion?* Based on our findings we established that smart clothing and furniture that supports participation is most likely to be conventional looking, individually adjustable, and gather a variety of data from the user to produce its impacts. The second research question was *in what way do such devices support participation?* Again, when examining the results of this study, we can state that smart clothing and

furniture does aim to support participation, support the user by increasing independence and safety, offer timely help in specific situations, assist with communication, and help the user learn self-regulation.

During this study, participation was recognized as a vast phenomenon that can be supported in innumerable, adjustable ways to help various users in countless situations. The challenge is not to find a proper selection of assistive tools to support participation, but rather to create an ecosystem of intelligent support matters that automatically balances the user's abilities and disabilities and assists only when needed. All the concepts offered do aim to increase involvement in a life situation and create technological assistance when independent participation is challenged [3, 4]. Thus, we should continue to strive toward adjustable and transformative solutions that are not only simple to use, but also as unobtrusively as possible.

Our future research on smart clothing and furniture and the potential for utilizing such devices to support participation and social inclusion will continue through prototyping and feasibility studies. Currently, our research interest continues to work toward assisting communication with smart clothing and furniture. Our goal is also to involve end users in further concept creation as much as possible and feasible.

Acknowledgements We thank all the participants who kindly contributed. Through this study, we gained valuable insights that will greatly help us to further develop the created concepts offered in this effort

Authors contributions VT: Conceptualization, writing–original draft, Methodology. IT: review and editing, Supervision. VJ: review and editing, Supervision, Funding acquisition.

Funding Open access funding provided by Tampere University including Tampere University Hospital, Tampere University of Applied Sciences (TUNI). This work was supported by Jenny Ja Antti Wihuri Foundation and Ministry of Education and Culture, Finland; TEKOS—Teknologialla osaamista, verkostolla vaikuttamista -project.

Data availability The participants in this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research, no supporting data is available.

Declarations

Competing interests The authors declare no competing interests.

Competing interest The authors declare that they have no conflicts of interest and no relevant financial or non-financial interests to disclose.

Ethical approval This study involved human participants, and this study followed the ethical guidelines of the Finnish National Board on Research Integrity TENK [40].

Consent to participate We obtained informed consent from all the participants.

References

1. Nussbaum M (1990) Non-relative virtues: an Aristotelian approach. In: Nussbaum M, Sen A (eds) The quality of life. Oxford University Press, New York, pp 242–269
2. Rochette A, Korner-Bitensky N, Levasseur M (2006) 'Optimal' participation: a reflective look. Disabil Rehabil 28(19):1231–1235. https://doi.org/10.1080/09638280600554827
3. World Health Organization. Regional Office for Europe. (2019). Participation as a driver of health equity. World Health Organization. Regional Office for Europe https://apps.who.int/iris/handle/10665/324909. License: CC BY-NC-SA 3.0 IGO
4. Perenboom RJ, Chorus AM (2003) Measuring participation according to the international classification of functioning, disability, and health (ICF). Disabil Rehabil 25(11–12):577–587. https://doi.org/10.1080/0963828031000137081
5. Hawton A, Green C, Dickens AP et al (2011) The impact of social isolation on the health status and health-related quality of life of older people. Qual Life Res 20(1):57–67. https://doi.org/10.1007/s11136-010-9717-2
6. Stangl AL, Earnshaw VA, Logie CH et al (2019) The health stigma and discrimination framework: a global, crosscutting framework to inform research, intervention development, and policy on health-related stigmas. BMC Med 17:31. https://doi.org/10.1186/s12916-019-1271-3
7. Light J, McNaughton D, Beukelman D et al (2019) Challenges and opportunities in augmentative and alternative communication: research and technology development to enhance communication and participation for individuals with complex communication needs. Augment Altern Commun 35(1):1–12. https://doi.org/10.1080/07434618.2018.1556732
8. Erez AB, Rothschild E, Katz N et al (2009) Executive functioning, awareness, and participation in daily life after mild traumatic brain injury: a preliminary study. Am J Occup Ther 63(5):634–640. https://doi.org/10.5014/ajot.63.5.634
9. Cole J, Logan TK, Walker R (2011) Social exclusion, personal control, self-regulation, and stress among substance abuse treatment clients. Drug Alcohol Depend 113(1):13–20. https://doi.org/10.1016/j.drugalcdep.2010.06.018
10. Goll JC, Charlesworth G, Scior K et al (2015) Barriers to social participation among lonely older adults: the influence of social fears and identity. PLoS ONE 13(7):e0201510. https://doi.org/10.1371/journal.pone.0201510
11. Bai J, Lian S, Liu Z et al (2018) Virtual-blind-road following based wearable navigation device for blind people. IEEE Trans Consum

Electron 64(1):136–143. https://doi.org/10.1109/TCE.2018.2812498
12. Cheng R, Wang K, Yang K et al (2017) Crosswalk navigation for people with visual impairments on a wearable device. J Electron Imaging. https://doi.org/10.1117/1.JEI.26.5.053025
13. Rosalam CM, Faisul AA, Ruhaizin S et al (2020) Non-intrusive, visual-less, wearable haptic stimuli navigational assistance for elderly with dementia. Malaysian J Public Health Med 20(1):128–137. https://doi.org/10.37268/mjphm/vol.20/no.Special1/art.699
14. Sonne T, Obel C, Grønbæk K (2015) Designing real time assistive technologies: a study of children with ADHD. In Proceedings of the annual meeting of the Australian special interest group for computer human interaction (OzCHI '15) 34–38. https://doi.org/10.1145/2838739.2838815
15. Ong JF, Gan B, Koh B et al. (2021) Tremor stabilization apparatus and methods. GyroGear Limited. United States Patent. no US011079225B2.
16. Desai VS, Anandh S (2021) Effectiveness of Gyro based handglove for improving activities of daily living among the individuals suffering with hand tremors. Indian J Forensic Med Toxicol 15(2):234–238. https://doi.org/10.37506/ijfmt.v15i2.14313
17. Sato T, Harada T, Mori T (2004) Environment-type robot system "RoboticRoom" featured by behavior media, behavior contents, and behavior adaptation. IEEE/ASME Trans Mechatron 9(3):529–534. https://doi.org/10.1109/TMECH.2004.834650
18. Pyo Y, Hasegawa T, Tsuji T, Kurazume R, Morooka K (2014) Floor sensing system using laser reflectivity for localizing everyday objects and robot. Sensors 14(4):7524–7540. https://doi.org/10.3390/s140407524
19. Linner T, Güttler J, Bock T, Georgoulas C (2015) Assistive robotic micro-rooms for independent living. Autom Constr 51:8–22. https://doi.org/10.1016/j.autcon.2014.12.013
20. Mtshali P, Khubisa F (2019) A smart home appliance control system for physically disabled people. IEEE, conference on information communications technology and society (ICTAS), pp. 1–5. https://doi.org/10.1109/ICTAS.2019.8703637
21. Hu R, Linner T, Trummer J et al (2020) Developing a smart home solution based on personalized intelligent interior units to promote activity and customized healthcare for aging society. J Population Ageing 13(2):257–280. https://doi.org/10.1007/s12062-020-09267-6
22. Merilampi S, Poberznik A, Saari S et al (2020) Modular smart furniture system for independent living of older adults- user experience study. Gerontechnology 19(4):1–13. https://doi.org/10.4017/gt.2020.19.04.392
23. Silapasuphakornwong P, Uehira K (2021) smart mirror for elderly emotion monitoring. IEEE 3rd global conference on life sciences and technologies (LifeTech), pp. 356–359. https://doi.org/10.1109/LifeTech52111.2021.9391829
24. Zhou B, Ghose T, Lukowicz P (2020) Expressure: detect expressions related to emotional and cognitive activities using forehead textile pressure mechanomyography. Sensors (Basel) 20(3):730. https://doi.org/10.3390/s20030730
25. Ahmed SF, Ali SMB, Qureshi SSM (2010) Electronic Speaking Glove for speechless patients, a tongue to a dumb. IEEE conference on sustainable utilization and development in engineering and technology, pp. 50–60. https://doi.org/10.1109/STUDENT.2010.5687009
26. Ghaffar M, Sheikh SR, Naseer N et al. (2021) Assistive smart home environment using head gestures and EEG eye blink control schemes. In International conference on artificial intelligence and mechatronics systems (AIMS) pp.1–6. https://doi.org/10.1109/AIMS52415.2021.9466031.
27. Bleda AL, Fernández-Luque FJ, Rosa A et al (2017) Smart sensory furniture based on WSN for ambient assisted living. IEEE Sens J 17(17):5626–5636. https://doi.org/10.1109/JSEN.2017.2721434
28. Martinez M, Rybok L, Stiefelhagen R (2015) Action recognition in bed using BAMs for assisted living and elderly care. In 2015 14th IAPR international conference on machine vision applications (MVA), pp. 329–332. https://doi.org/10.1109/MVA.2015.7153197.
29. Ramaswamy V, Ozcan K (2018) What is co-creation? An interactional creation framework and its implications for value creation. J Bus Res 84:196–205. https://doi.org/10.1016/j.jbusres.2017.11.027
30. Lee JJ, Jaatinen M, Salmi A et al (2018) Design choices framework for co-creation projects. Int J Des 12(2):15–31
31. Triberti S (2015) Giuseppe R (2015) Engaging users to design positive technologies for patient engagement. In: Graffigna G, Barello S, Triberti S (eds) Patient engagement: a consumer centered model to innovate healthcare. De Gruyter Open, pp 56–65
32. Clear T, Daniels M (2001) A cyber-icebreaker for an effective virtual group. Assoc Comput Mach, ACM SIGCSE Bull 33(3):121–124. https://doi.org/10.1145/377435.377662
33. Hamilton P (2016) The workshop book: how to design and lead successful workshops. Pearson Education, Harlow
34. Sipilä E, Rauhala EL, Elo C, Nissinen, et al (2021) Technology-related challenges in smart clothing-viewpoints from ideation workshops. In IEEE. https://doi.org/10.1109/SEGAH52098.2021.9551863
35. Nissinen J, Konttinen S, Rauhala EL, Elo C, Virkki J, Ihalainen T (2021) The possibilities of smart clothing in adult speech therapy: speech therapists' visions for the future. In IEEE, p. 202. https://doi.org/10.1109/SEGAH52098.2021.9551851
36. European Union. General Data Protection Regulation (GDPR). Regulation (EU) 2016/679 of the European Parliament and of the Council. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0679
37. Sannon S, Forte A (2022) Privacy research with marginalized groups: what we know, what's needed, and what's next. Proc. ACM Hum.-Comput. Interact. 6:455. https://doi.org/10.1145/3555556
38. Shahid J, Ahmad R, Kiani AK, Ahmad T, Saeed S, Almuhaideb AM (2022) Data protection and privacy of the internet of healthcare things (IoHTs). Appl Sci 12(4):1927. https://doi.org/10.3390/app1204192
39. Kamleitner B, Mitchell V (2019) Your data is my data: a framework for addressing interdependent privacy infringements. J Public Policy Mark 38(4):433–450. https://doi.org/10.1177/0743915619858924
40. The ethical principles of research with human participants and ethical review in the human sciences in Finland (2019) Finnish National Board on Research Integrity Guidelines. https://tenk.fi/en/ethical-review/ethical-review-finland