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Sensors in the care of persons with visual- or visual-and-intellectual disabilities: Use, needs, practical issues, and ethical concerns

Gerdien Woensdregt[a,b,c], Graziana D'Addabbo[b,c], Hans Scholten[a], Claudia van Alfen[a] and Paula Sterkenburg[a,b,c,*]
[a]*Bartiméus, Doorn, The Netherlands*
[b]*Department of Clinical Child and Family Studies, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands*
[c]*Amsterdam Public Health Research Institute, Amsterdam, The Netherlands*

Abstract.
BACKGROUND: Sensor technology may improve the quality of life of persons with visual and/or intellectual disabilities. However, there is no general consensus on its utility and implementation.
OBJECTIVE: In this exploratory study the aim was to provide an overview of sensors for persons with disabilities to address priorities and ethical concerns for future research.
METHODS: Using a qualitative (Delphi) method, 17 interviews were carried out with 20 representatives in the field of visual- or visual-and-intellectual disabilities (in general: six experts in sensor technology, domotics, and eHealth, specific for persons with a visual or visual-and-intellectual disability: three client representatives; three caregivers; four care team managers; two developmental psychologists; one physician; and one paramedic; age ranges 25–61 years). Atlas.ti software was used to code data and major themes were identified using qualitative analyses.
RESULTS: The most used sensors were for surveillance and health and the most desired were for behavior. Different sensors were considered most important for future implementation by the groups of participants, such as sensors for lighting, posture, and entertainment by client experts. Furthermore, the majority of participants agreed that sensors should be easy to use and understand and ethical issues (e.g. privacy, informed consent) should be considered.
CONCLUSION: The current applications of sensor technology in clinical practice and future research needs were determined by interviewing experts, caregivers, and client experts.

Keywords: Sensors, sensor technology, visual and or intellectual disability, quality of life

1. Introduction

Visual and/or intellectual disabilities may have a profound impact on the life of those affected and their caregivers. Persons with disabilities experience difficulties in their mobility, independence, and social environment due to their impairment [1]. At the same time, caregivers face daily challenges when trying to understand signals from people who have difficulties in verbal and non-verbal communication [2]. Sensor technology may be an innovative solution to problems encountered by persons with visual- or visual-and-intellectual disabilities and their families. The advent of sensor technology may have a substantial impact on the quality of life [3] of persons with disabilities, improving their independence, productivity, and individual and social functioning [4]. Sensors can be used as assistive technology, providing equipment, sys-

*Corresponding author: Paula Sterkenburg, Department of Clinical Child and Family Studies, Vrije Universiteit Amsterdam/FGB, Van der Boechorststraat 1, 1081 BT Amsterdam, The Netherlands. Tel.: + 31 20 5988890; Fax: +31 20 5988745; E-mail: p.s.sterkenburg@vu.nl.

tems, and devices that can help others to understand the wishes of a person with a visual- or visual-and-intellectual disabilities [5]. In summary, sensor technology has the potential to substantially reduce the burden and limitations associated with visual- or visual-and-intellectual disabilities.

The use and possibilities of sensor technology have greatly increased for the following reasons: 1) the Quantified Self movement [6] raised awareness about the use of sensor applications for self-tracking; 2) the costs associated with sensor technology have greatly decreased due to standardized interfaces for transferring data; and 3) there is an increase in the availability of advanced sensor devices that can be used to monitor human activities (for medical and non-medical uses) or to measure and interpret our surroundings [7]. There is not a general consensus on using technology for the care of persons with visual- or visual-and-intellectual disabilities. In a preview study, Wolbring and Cleopatra [8] interviewed the staff of a disability service organization. Overall, these subjects did not consider sensors as negative, but raised issues about their difficult use and interpretation as well as the related ethical concerns. More recently, Broerse et al. [1] reported on the opinions of clients with visual impairments about the use of sensors. They underlined the added value of specific sensor applications in their daily life. Furthermore, there is no agreement on which sensors are most helpful, desired, and accepted. In contrast, the ethical aspects connected to the use of sensors are generally well recognized by all caregivers, clients, and others involved in this field. Progress in sensor technology may significantly impact privacy [9] and there is a high risk for this [10], in particular if clients and caregivers do not control their own sensitive data. For this reason, ethical issues on privacy and safety are a current theme in the general discussion related to sensor data collection [11,12].

This exploratory study summarizes the perspectives of different experts in the field of visual- or visual-and-intellectual disabilities, eHealth, domotics, and sensor technology; caregivers; and client experts to gain a better understanding of the priorities concerning the use of sensor technology in the care for individuals with a visual- or visual-and-intellectual disabilities. The main research questions investigated were: Which sensor applications are more commonly used in the field? Which sensor applications are considered most important now and for future implementation? How should the output generated by sensors be displayed and stored? What should the sensors look like? What are the main ethical concerns related to the use of sensor technology? The main objective was to identify the most relevant themes in the field of sensors for persons with visual- or visual-and-intellectual disabilities. We also aimed to provide an overview of using sensors for persons with visual- or visual-and-intellectual disabilities, to identify a selection of sensors that should be tested in follow-up pilot studies for their future implementation, and to address ethical concerns.

2. Methods

2.1. Design and procedure

The present study was based on a qualitative research design. We used the Delphi method, which is a social research technique that aims to systemize opinions or judgments of a panel of experts to define a reliable group consensus on a specific topic [13,14]. Data were obtained between July and December 2016 from semi-structured interviews discussing a broad spectrum of information about sensor technology in the field of visual- or visual-and-intellectual disabilities. The interview questions were open at the beginning and then more specific. They focused on: sensor applications known or used by participants, areas in which sensor applications can be used for a person with a visual- or visual-and-intellectual disabilities, and specific kinds of sensor applications that can be useful and appropriate. Furthermore, questions were asked related to the use and collection of data, user-friendliness, and ethical concerns surrounding the use of sensory technology. Examples of questions on sensors were: “Are you currently using sensor applications?”, “Which sensor applications would you like to use in your job and/or life?”, or “Which sensor applications could be useful for adults and children with a visual- or visual-and-intellectual disabilities?”. Examples of questions on the use and storage of data and user-friendliness were: “Who should use the sensor data?”, “Where should sensor data be stored?”, and “How to make sensor applications user friendly?”.

The research procedure was as follows. 1) Participants were encouraged to share their thoughts on the use of sensor technology for individuals with visual- or visual-and-intellectual disabilities. 2) A concept report, with the main themes generated from the interview data, was sent to the participants to obtain their feedback. 3) The participant’s feedback was included in the research report. 4) Based on initial re-

Table 1
Demographic characteristics of participants (age, gender, role, role specification, organization)

Participants*	Interview	Age	Gender	Role	Role specification	Organisation
1	1	40	F	Care professional	Physician	Bartiméus
2	2	43	F	Client representative	Family member	Bartiméus
3	3	52	F	Expert	Sensor technology in disabled care	Other
4	4	25	F	Client representative	Client	Bartiméus
5	5	58	F	Care professional	Developmental psychologist	Bartiméus
6	5	38	M	Care professional	Caregiver	Bartiméus
7	5	61	M	Management	Manager	Bartiméus
8	6	45	M	Client representative	Client	Bartiméus
9	7	53	F	Care professional	Paramedic	Bartiméus
10	7	58	F	Care professional	Caregiver	Bartiméus
11	8	51	F	Expert	Domotica in geriatric care	Other
12	9	41	F	Expert	Sensor technology in disabled care	Other
13	10	46	F	Expert	Domotica in geriatric care	Other
14	11	33	F	Expert	e-Health in geriatric care	Other
15	12	34	F	Care professional	Outpatient caregiver	Bartiméus
16	13	38	F	Management	Manager	Bartiméus
17	14	30	F	Care professional	Developmental psychologist	Bartiméus
18	15	46	M	Management	Manager	Bartiméus
19	16	55	M	Management	Manager	Bartiméus
20	17	26	F	Expert	Sensor technology	Bartiméus

*Identification number of the participants.

sults, sensor applications were chosen. 5) To verify these choices, the report was again shared with the participants. 6) This feedback was incorporated in the final research report. 7) Based on this report, sensors were selected to evaluate their added value for persons with visual- or visual-and-intellectual disabilities in several future follow-up pilot studies.

2.2. Participants

An important aspect of the Delphi method is that the participants cover a wide array of interests and problems [15]. Participants were selected by purposive sampling from an initial list of eligible subjects; those enrolled had to satisfy two main criteria: expertise in the present field of research and involvement in the care of persons with visual- or visual-and-intellectual disabilities. This group was expanded by using a snowball sample: participants selected through purposive sampling were asked to provide the contact details of professionals who, according to them, were experts in this field of research and could contribute to the data collection. The result was a list of 31 eligible participants who were differently involved with adults and children with visual- or visual-and-intellectual disabilities, domotics, eHealth, and sensor technology. Due to overlap in expertise, two representatives were not approached. Information about the project and an invitation to participate was sent to 29 possible participants. Among these eligible participants, 20 accepted to participate in this study. Reasons for not participating were: lack of time due to other responsibilities ($n = 6$), incorrect contact details ($n = 1$), no sufficient knowledge on the topic (according to the participant) ($n = 1$), and no reply ($n = 1$).

The final sample of participants in this sensor project included: care professionals ($n = 7$) with different positions (two developmental psychologists, two caregivers, one paramedic, one physician in the care of individuals with intellectual disabilities, and one outpatient caregiver); managers ($n = 4$); client representatives ($n = 3$); and experts ($n = 6$) (three in eHealth, domotics, and sensor technology in geriatric care, two who care for a person with a disability, and one in general sensor technology). Among the 20 participants, 75% ($n = 15$) were directly involved in the Department of Information Communication Technology for Visually Impaired People (ICT4VIP) of Bartiméus, a Dutch organization that aims to improve the quality of life of people with a visual impairment. The remaining 25% of participants ($n = 5$ experts) were from other organizations (e.g. Philips, Vilans, and Sensara). The group included 15 women and five men and the average age of the participants was 43.7 years (SD: 10.5). Participation in this sensor project included taking part in an interview, providing online feedback on a concept report, and listing sensor applications to be tested in follow-up pilot studies. Overall, 17 interviews were conducted, 15 with an individual format and two with a group format with two and three participants. Table 1 provides information on the demographic characteristics of the 20 participants.

2.3. *Data analysis*

The recorded interviews were transcribed verbatim and subsequently coded using the software program for Qualitative Data Analysis, Atlas.ti 7 [16]. The following procedure was then used for the thematic analysis [17]. The researcher started by reading through the transcribed interviews repeatedly to get an overview of the content, initial codes were then generated, quotations were grouped according to these codes, and the main themes of the assigned codes were identified based on the interviews and subcategorized. The analysis report was written and all participants were asked to provide feedback. The first analysis was executed by the same researcher (G.W.) who conducted the interviews. To determine reliability, the last author (P.S.) analyzed three transcripts independently from the researcher. Finally, the analysis was discussed with the authors (H.S., C.v.A.).

3. Results

Qualitative analyses of the interviews of the 20 participants in this study identified six main themes: 1) known and used sensor applications (surveillance, health, behavior, orientation/localization, and sleep); 2) desired sensor applications (behavior, orientation/localization, health, activation/entertainment, surveillance, falling, lighting, posture, and sleep); 3) sensor output (use of output, display of output, and storage of data); 4) user-friendliness; 5) reliability; and 6) ethical concerns (clients, staff versus technology, no ethical concerns).

3.1. *Known and used sensor applications*

Five categories were identified for the theme "*Known and used sensor applications*": surveillance, health, behavior, orientation/localization, and sleep. Table 2 shows the frequency of known and used sensors. The majority of sensor applications were in the category of surveillance and health. The applications that could not be classified in the main categories were included in the residual category of "remaining".

3.2. *Desired sensor applications*

Within this theme, the main categories were ranked based on an index (I) quantifying their importance. The index was calculated as the number of times participants mentioned a category divided by the number of interviews ($n = 17$). Ten categories of "*desired sensor applications*" were identified: behavior (I = 1.06), orientation/localization (I = 1.0), health (I = 1.0), activation/entertainment (I = 0.94), surveillance (I = 0.88), falling (I = 0.59), lighting (I = 0.47), posture (I = 0.35), and sleep (I = 0.35). Desired sensor applications that did not fit in these categories were placed in the category "other desired sensor applications".

3.2.1. *Behavior*

Behavior had the highest index of importance of all categories (1.06). In two interviews, participants said they would like to use a sensor application to understand a client's behavior. One representative said: "I cannot think of applications to increase independence for the clients that I work with, but I can think of applications to 'translate' behavior so that we can understand it. To be ahead of stress, if you see that the stress levels are rising than you can intervene and bring it down to an acceptable level." (i7) A sensor application providing biofeedback was also mentioned in two interviews. "I think that it would be nice if we could use it [a biofeedback sensor] because you can get good insight [into] stress levels." (i5) Other sensor applications that participants mentioned in this category included measurement of wellbeing, muscle strain, tension, stress, and cognition. Furthermore, using sensor applications for communication, wandering behavior, and striking behavior was discussed. Other ideas were a camera that starts automatically when it detects certain behavior and a mattress that can measure emotion.

3.2.2. *Orientation and localization*

Within the category "*orientation and localization*", a sensor application that can help to localize obstacles was often mentioned (in four interviews). One representative said: "In our city center we suffer from illegally parked bicycles and scooters. You don't see them [if you have a visual impairment]. It would be nice if you could anticipate and prevent bumping against them and falling." (i4) Sensor applications for orientation in the home were mentioned in two interviews. An example was: "A sensor that you can attach to the bathroom door which makes a flushing sound when you walk past it. Then you will know where you are. (...) it could help with orientation issues of clients." (i15) Sensor applications used to better localize within the home were mentioned in two interviews. One participant said: "Imagine that you lost something. What if

Table 2
Known and used sensor applications, frequency

Surveillance	*N*	Health	*N*	Behaviour	*N*	Orientation/localisation	*N*	Sleep	*N*	Remaining	*N*
Intercom system	4	Epilepsy	4	Smart lock	7	I-care	3	Actiwatch	2	Falling	3
Laser beam	3	Saturation	2			Localisation of obstacles	2	Sleep pattern	4	Doors open/close	2
Out of bed alert	3	Blood pressure	1							Thermostat	2
Door open alert	2	Glucose	1							Lights on/off	2
Movement sensor	2	Brain activity	1							Penfriend	2
General night care	2	Ear thermometer	1							Heartbeat	2
Life style monitoring	3	ECG	1							Liquid alert	2
Leave the room alert	1	Muscle train	1							Smoke detector	1
Optical sensor	1									Bath water alert	1
Wander detection	1									Game	1
										Doorbell alert	1
										Pressure	1
										Colour recognition	1
										Parking sensor	1
										Gas detector	1

you could put a simple sticker on it and if you press a button the sticker will make a beeping sound?" (i11) Sensor applications used for travel information and applications that give warnings when people approach were also mentioned in two interviews. Other ideas were: sensor applications for the localization of children (for deaf-blind parents), sensors warning when a dog approaches, indicating where grocery stores are located, and signaling that someone is looking at you.

3.2.3. *Health*

Three participants expressed the desire for a sensor that can check the weight of a person with severe or profound intellectual disabilities. Sensors that can measure blood pressure, blood sugar, pain, or general physical measurements were each mentioned in two interviews. One participant said: "I previously treated a client who was in very bad shape because [he was] overweight. I think about blood pressure, respiratory rate, heart rate, lung function. I would be pleased if it was possible to take these measurements in an easily accessible way while performing the treatment. It would give better scientific support. I would look for something noninvasive, like [a sensor] around the wrist" (i13). Other desired sensor applications within the category "*health*" were: measuring saturation, temperature, loss of fluids, and epilepsy.

3.2.4. *Activation and entertainment*

Entertainment was mentioned in four interviews and activation in three interviews. "I think that activation is important for clients with severe mental disabilities. Gaining new experiences is also important, improving their quality of life. Activation is important, but also the opportunity to be able enjoy something in peace." (i5). The use of robots as companions was suggested in two interviews. One representative reported: "Robots in health care are a contemporary issue. A robot doesn't replace care givers, but it could be a beautiful tool for people who are alone. For our clients it would be nice to have a robot seal (Paro) or something similar. Our clients are alone a lot." (i14) Other aspects mentioned concerning activation and entertainment were: the possibility to adjust the sensor technology in a controlled multisensory environment (snoezelen room), an all-in-one device for technical equipment, a device to operate television and sound systems in an accessible way, a pedometer for general activity registering the number of steps taken, or a device that can make running more accessible.

3.2.5. *Surveillance*

Within the category "*surveillance*", sensors were grouped that keep track of or help clients, as to prevent dangerous situations. A sensor application that can be used to open doors was mentioned in four interviews. A participant said: "According to me, technology concerning the possibility to open doors is important. Maybe it is possible to use sensors that can detect if the client wants to walk through the door. The sensor then 'knows' whether or not a client has access to this building and can automatically open the door so that the client can enter" (i15). Sensors used to lock doors were discussed in two interviews. Other sensor applications within this category were: face recognition, securing the refrigerator, leave-the-room alerts, surveillance in general, surveillance using Internet of Things applications, and surveillance using heat detection.

3.2.6. *Falling*

A sensor application that can be used to detect and prevent falls was mentioned in four interviews and could therefore be stated as a major concern. "Preferably you would want to know when someone starts to waver and receive a signal when that happens. In this way you could prevent the fall" (i5).

3.2.7. *Lighting*

Sensor applications that can adjust illumination in the rooms for certain clients were discussed in two interviews. "Imagine that a client is intolerant of bright lights. The client may benefit from a sensor that can adjust the lights in his environment automatically." (i15) Sensor applications that can turn on and off lights were also mentioned in two interviews. In one interview a participant said he would like to have a sensor that warns when the lights are still on when leaving the house or going to bed. "It often happens that the lights are still on and I did not see it (...) it would be convenient if there would be some kind of alarm when the lights stay on too long" (i6).

3.2.8. *Posture*

A sensor that can measure posture and can give an alert to encourage the user to stand or sit up straight was discussed in five interviews (especially care givers mentioned this). "Often people (with a visual impairment) are slouching, is it possible to stimulate them to sit or stand up straight with certain sensors?" (i12).

3.2.9. *Sleep*

Sensor applications that can be used to gain insight

Table 3
Other desired sensors applications, frequency

Desired sensor applications	N
Curtains open/close	2
Auditive environment	1
Bathroom occupied	1
(Un) Dressing	1
Multi-sensory stimulation sensor	1
Reminder to not forget things	1
Cooker with alert	1
Memoboards with sensor	1
Windows open/close	1
Smartwatch	1
Temperature bath water	1
Time	1
Bath safety	1
Liquid alert	1
Self-driving car	1

in sleeping patterns of clients were mentioned in five interviews. “Some clients are very silent at night and we wonder if they sleep or not. If you walk in the room often to take a look you can be sure they don’t sleep because you interrupt them. (. . .) A sensor can give a more accurate indication whether someone sleeps or not, and how deep.” (i16).

3.2.10. Other desired sensor applications

The other desired sensors that could not be placed in the categories described above are summarized in Table 3.

3.2.11. Desired sensor applications according to different participants

During the second round of feedback, a list of sensors to be tested in future studies was provided to the participants, who then selected their preference. Different priorities for the future implementation of sensor technology were identified according to different groups of participants. Client representatives indicated lighting (e.g. Philips Hue Lights), posture (e.g. Lumo), and entertainment (e.g. LED curtain) as the sensor applications with highest priority for testing in pilot studies. According to the caregivers, stress and muscle strain were the most important sensor applications that should be tested and implemented. For the developmental psychologists, sensors for understanding behavior had the highest importance for future implementation. For paramedics and physicians, sensors for falling and physical measurements (Bodymetrics Performance Monitor), respectively, were the applications to be implemented.

3.3. Use of sensors in daily practice

The type of sensor and the context in which that sensor was used determined whether the sensor output was used by client representatives, caregivers, or care professionals (Table 4). For example, medical sensor applications were only used by care professionals, while only client representatives mentioned that they used posture sensors. Behavior sensors were the only ones mentioned to be used by caregivers, care professionals, and client representatives.

3.3.1. Display of output and storage of data

According to the participants’ feedback, sensor output should preferably be displayed on an app. In three interviews, medical care professionals mentioned a preference for displaying sensor output on an Apple Watch. Displaying sensor output on a smartphone app was also mentioned in three interviews and an app on an iPad was suggested in one interview. Other ideas to display sensor output were through graphs on a regular computer and through alerts on a land telephone line. Furthermore, it was suggested in three interviews that storage of sensor data should be digital and possibly connected to the care plan of clients. Other ideas included storage on a smartphone or in a database.

3.4. User friendliness

According to three interviews, sensor applications should not be invasive for the client. “From previous experience I know that not all people want something on their body. They just rip it off because they don’t understand it” (i11). Furthermore, the sensor application should be small (two interviews) so that clients are not bothered by it. They should be easy to use (three interviews) and the output should be straight forward (three interviews). “Output should not be complicated, preferably everyone understands it and knows what to do with it.” (i1). Other ideas about user friendliness were that sensor applications should be trendy and incorporated in existing technology. One participant reported: “That it fits in what already exists, people don’t want many different devices. For example, they all have a phone” (i12).

3.5. Reliability

Only one participant mentioned that not all sensor measurements are reliable when used for a person with a visual- or visual-and-intellectual disabilities. This participant said: “Then [for people with behavior hard to interpret and a severe intellectual disability] you cannot use them [sensors] because the re-

Table 4
Sensor application, user, frequency

Sensor application	Use by caregiver	N	Use by care professional	N	Use by client	N
Medical	No	1	Yes	2	No	1
Sleep	Yes	3	Yes	2	–	–
Behaviour	Yes	2	Yes	1	Yes	2
Fall detection	Yes	2	–	–	–	–
Fall prevention	–	–	Yes	1	–	–
Posture	–	–	–	–	Yes	2

sults could be not good, or there are no results at all. For example, someone needs to be able to understand that they have to lie still [for a blood pressure measurement]. When you move only an arm or a leg or the head, it will cause a disturbance [in the results]" (i1).

3.6. *Ethical aspects*

3.6.1. *Clients*

Participants identified putting the interest of the clients first as an important ethical concern for using sensor applications (in fifteen interviews). The client's privacy was the most mentioned issue in this category (in nine interviews). One participant said: "We say every human, whether with or without an intellectual disability, has the right of privacy. If we speak about human rights, they also count for people with an intellectual impairment. It is possibly hard for them to maintain this so we are responsible for that" (i3). Participants reported the importance of storage of sensor data in seven interviews. "It [the data] should be stored while conforming to privacy regulations" (i5) and "You should consider how you manage it [storage of data]. Why would you save it and for how long?" (i7). Furthermore, participants suggested in eight interviews that sensor applications should only be used when there is informed consent from the client or the legal representative of the client. Five participants mentioned that the use of sensor applications should be allowed only if it actually improves the quality of life of clients. In four interviews, it was stated that sensor applications should only be used to benefit the client. "It is nice for us to use as professionals, but if you can improve the life of a client by using sensor technology that would be especially great" (i5). The choice to use a sensor was addressed in three interviews. The client's opinion on the use of sensor technology should be asked (two interviews) and the wishes of the client should be considered (one interview). One participant reported: "I think you should give the choice to the client. We say it is beneficial for the client, but does the client want it?" (i12). Another said: "it is important to consider the wishes of others, what our intentions mean for someone else" (i5). One participant with a visual-and-intellectual disability said he would not want sensor applications to take over his life. In three other interviews, participants said that sensor technology should only be used with an indication.

3.6.2. *Staff versus technology*

In addition to ethical concerns about the interests of clients, participants also reported sensor technology substituting human staff as an important ethical concern. Participants said: "Sensor applications should be complementing or an addition, but never be guiding or determining" (i14) and "Caregivers are trained to do so, and I believe that human care has a better eye than technical gadgets" (i11).

3.6.3. *No ethical concerns*

In two interviews, participants mentioned they did not see any ethical issues concerning the use of sensor technology.

4. Conclusion and discussion

The present study gathered and summarized the opinions of experts, care professionals, and client representatives on the use of sensor applications in the care for individuals with a visual- or visual-and-intellectual disabilities. The main research aim of this study was to explore which sensors are used most and are desired for future implementation. The most used sensors were in the categories of surveillance and health, while the most desired were in the category of behavior. Nevertheless, different sensors were considered most important for future implementation by different groups of participants, such as sensors for lighting, posture, and entertainment. Other important topics were sensor use (display and storage of output) and appearance (user friendliness). Participants underlined that sensors need to be user friendly and the output easy to understand. This is especially important for infrequent caregivers: so they can incidentally and quickly use the sensor without explanation of others. Furthermore, a very important aspect of the use of sensor technology was that sensors should not be invasive for clients. They need to be small and it should be possible to customize them for individual's needs. Also, it is preferable that sensors can be incorporated in existing technology. Finally, ethical concerns on the use of sensor technology were addressed.

According to this study, the most important ethical aspect to consider when using sensor technology is that the interest of the client should be put first. The clients mentioned in this study are vulnerable users and are in one or various ways (partially) dependent on health care workers. Professionals are therefore obligated to ensure their clients have a normal life as much possible: a maximum amount of privacy should be pursued, especially when it comes to surveillance. Bartiméus (the organization where most participants of this study and the authors are affiliated with) has an own privacy consultant in service, who can be asked for advice on privacy related matters. For example, data storage is not always wanted or needed. The 'Smart Sock' gives feedback on the spot and therefore data storage is not needed (www.bioresponsesandcare.nl). Moreover, permission should be asked from clients or their legal representatives. "Critical use" is to be advised: it should not only be about "can it be done?", but also "is it desirable in this particular situation for this client?". Sensors should be used to support, rather than replace, staff.

The use of sensor technology seems to be an opportunity to improve the quality of life of adults and children with visual- or visual-and-intellectual disabilities. For example, sensor applications used to prevent falling can also prevent injuries. Biofeedback sensors, such as the *smart sock*, can help with the understanding of behavior of people with a severe intellectual disability, and subsequently can help care providers to react more appropriately [18]. Sensor technologies used for entertainment and to monitor the activities of adults and children with visual- or visual-and-intellectual disabilities could lead to more exercise and increased pleasure in daily life. The use of robots was also mentioned. It could be interesting to study the role of robots in entertainment and exercise, as well as in improving psychological wellbeing, as in the explorative study by De Groot et al. [19]. Several pilot studies evaluating the efficacy of specific sensor applications for the care of persons with visual- or visual-and-intellectual disabilities could be carried out based of the results of this study. The results provide guidelines for innovations in the field of sensor technology.

The main strength of this exploratory study was that the perspectives of experts and client representatives were considered. In particular, as already shown by the research of the Athena Institute, involving clients with visual- or visual-and-intellectual disabilities as experts in scientific research is important because their unique perspective can supplement the knowledge of scientists and caregivers [1]. The current research confirmed this finding; client representatives mentioned wishes concerning the use of sensor technology that other participants did not, including those regarding lighting and orientation.

This study also has several limitations. First, there was a high possibility of selection bias since participants were selected using a "snowball method". There is the possibility that other experts and client representatives involved in the field of visual- or visual-and-intellectual disabilities were not included. It is also important to underline that there was an imbalance between the larger number of experts and managers involved and the smaller number of client representatives. This disproportion may cause a less reliable representation of the perspective of clients. However, client representatives were the last participants being interviewed and data collection only stopped after data saturation was reached. Therefore, it can be expected that all themes were covered. Another limitation of this study was that participants were selected from heterogeneous clinical settings (e.g. geriatric care, disabled care, developmental care). It is obvious that opinions about the use of sensors collected from experts or care professionals in the field of geriatric care are different from opinions collected by experts or care professionals in developmental care. Children, adolescents, adults, and aged people with visual- or visual-and-intellectual disabilities may have different needs, desires, and problems specific to their developmental phase. However, general themes could be subtracted that seem to be relevant to all clients (like sensors for behavior). Future research including more involvement of client representatives and focusing on more specific applications is necessary. This study highlighted the main topics to be developed in future research applying sensor technology to the care of persons with visual- or visual-and-intellectual disabilities. Future pilot studies should take into account these suggestions to maximize the potential benefits of sensor technology for clients.

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Conflict of interest

The authors have no conflicts of interest to declare.

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