Aus der Klinik für Psychiatrie und Psychotherapie der Medizinischen Fakultät Charité – Universitätsmedizin Berlin

DISSERTATION

Förderung des Einsatzes assistiver Technologien zur Unterstützung der räumlichen Orientierung in der Demenzversorgung

Promoting the adoption of assistive technologies to aid with spatial orientation in dementia care

zur Erlangung des akademischen Grades
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"Any sufficiently advanced technology is indistinguishable from magic."

Clarke's third law, *Profiles of the Future*[1]

[1] Clarke AC. Profiles of the future: an enquiry into the limits of the possible. London: Macmillan; 1962, rev. 1973.

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List of abbreviations

AD	Alzheimer's disease
App	Application
ATs	Assistive technologies
COREQ	Consolidated criteria for Reporting Qualitative research
DCS	Digital Care Support
EUROHIS-QOL	European Health Interview Survey-Quality of Life
GPS	Global Positioning System
GSE	General Self-Efficacy scale
ISONORM	International Organization for Standardization Norm
MMSE	Mini-Mental State Examination
SPSS	Statistical Package for the Social Sciences
TA-EG	Technological affinity scale for electronic products [*Fragebogen zur Technikaffinität - Einstellung zu und Umgang mit Elektronischen Geräten*]
UX	User experience
VODINO	Validation and optimization of the individual benefits of locating systems in home dementia care [*Validierung und Optimierung des individuellen Nutzens von Ortungssystemen bei Demenz*]
Wi-Fi	Wireless fidelity
ZBI	Zarit Burden Interview

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Figure 1 Tablet for care partners and smartphone for persons with dementia displaying the DCS prototype. Extracted from figure 1 found in (31). 13

Abstract

Introduction: In dementia care, locating technologies are a type of assistive technology that hold the potential to improve the quality of life of persons with dementia and their care partners by assisting in the management of spatial orientation impairments and wandering. Although many products are commercially available, their adoption remains low. To better understand how to promote their adoption, we examined user experience and clinical effectiveness resulting from product use and explored barriers to their adoption.

Methods: In a first user experience study, a prototype locating technology was tested for four weeks by 17 dyads composed of persons with dementia and their care partners. In a second user experience study, two similar commercially available locating technologies were tested for four weeks each by another 17 dyads. User experience was examined with ratings of product usability, product functions and product features. Clinical effectiveness, frequency of use, purchase willingness, and product satisfaction were assessed with various scales. In a third qualitative focus group interview study with 22 interdisciplinary professional stakeholders, we explored views on the barriers to their adoption, as well as views on services and information dissemination strategies.

Results: In the first study, the prototype was rated fairly in terms of usability, product functions and product features. However, usability ratings significantly decreased after four weeks. In the second study, ratings of usability, as well as of several product functions and product features were significantly more favourable for one of the two tested commercial products. Clinical effectiveness was not found in either study. In the third study, the main adoption barriers were based on unclear benefits and ethical concerns, as well as limitations in awareness, technology, product characteristics, and capital investments. Key services and information dissemination strategies centred on digital autonomy support, emergency support, information dissemination actors, product acquisition, and product advertising.

Discussion: Results from both user experience studies indicate that focusing on specific product functions and features might substantially improve user experience. This might translate to measurable clinical effectiveness and higher adoption rates. Results from our qualitative study indicate that not only product characteristics and the technology itself impact adoption. Indeed, focusing on services and information dissemination strategies around products warrants closer attention as they might markedly improve adoption.

Zusammenfassung

Einleitung: Ortungssysteme in der Demenzversorgung gelten als eine vielversprechende Art von assistierender Technologie, um die Lebensqualität von Menschen mit Demenz und ihren Pflegepartnern zu verbessern, indem sie dabei helfen räumliche Orientierungsstörungen und Wanderungen zu bewältigen. Ihre Verwendung bleibt jedoch trotz der Verfügbarkeit vieler kommerzieller Produkte gering. Um besser zu verstehen, wie ihre Verwendung gefördert werden kann, haben wir die Nutzererfahrung und klinische Wirksamkeit, die sich aus der Produktnutzung ergeben sowie die Barrieren für ihre Einführung untersucht.

Methoden: In einer ersten Nutzererfahrungsstudie wurde ein Prototyp Ortungssystem vier Wochen lang von 17 Dyaden bestehend aus Menschen mit Demenz und ihren Pflegepartnern getestet. In einer zweiten Nutzererfahrungsstudie wurden zwei ähnliche kommerziell erhältliche Ortungssysteme jeweils vier Wochen lang von weiteren 17 Dyaden getestet. Die Nutzererfahrung wurde mit Bewertungen der Benutzerfreundlichkeit, Produktfunktionen und Produkteigenschaften untersucht. Klinische Wirksamkeit, Nutzungshäufigkeit, Kaufbereitschaft und Produktzufriedenheit wurden mit verschiedenen Skalen bewertet. In einer dritten qualitativen Fokusgruppeninterviewstudie mit 22 interdisziplinären professionellen Stakeholdern untersuchten wir Ansichten zu den Barrieren für ihre Verwendung sowie zu Dienstleistungen und Strategien zur Informationsverbreitung.

Ergebnisse: In der ersten Studie waren die Bewertungen der Benutzerfreundlichkeit, Produktfunktionen und Produkteigenschaften mittelmäßig. Die Bewertung der Benutzerfreundlichkeit ging jedoch nach vier Wochen deutlich zurück. In der zweiten Studie fielen die Bewertungen der Benutzerfreundlichkeit sowie einiger Produktfunktionen und Produkteigenschaften bei einem der beiden getesteten Produkte deutlich besser aus. Klinische Wirksamkeit wurde in keiner der Studien gefunden. In der dritten Studie konzentrierten sich die wichtigsten Einführungsbarrieren auf unklare Vorteile und ethische Bedenken sowie auf bewusstseins-, technologisch-, produktmerkmal- und kapitalinvestitionsbasierte Einschränkungen. Dienstleistungen und Strategien zur Informationsverbreitung konzentrierten sich auf Unterstützung von digitaler Autonomie, Notfallunterstützung, Akteure der Informationsverbreitung, Produktakquisition und Produktwerbung.

Diskussion: Die Ergebnisse beider Studien zur Nutzererfahrung zeigen, dass die Nutzererfahrung durch die Optimierung bestimmter Produktfunktionen und Produkteigenschaften erheblich verbessert werden kann. Dies könnte zu einer messbaren klinischen Wirksamkeit und höheren Verwendung führen. Die Ergebnisse unserer qualitativen Studie zeigen, dass die Verwendung durch mehr als die Produktemerkmale und die Technologie selbst bestimmt wird. Deshalb ist eine gezielte Fokussierung auf Dienstleistungen und Strategien zur Informationsverbreitung rund um Ortungssysteme notwendig, da sie die Verwendung deutlich verbessern könnte.

1. Introduction

The global prevalence of dementia is estimated to be 50 million and will more than triple to reach 152 million by 2050 as the world population ages (1). In Germany, approximately 1.6 million persons were living with dementia in 2018 and this number is projected to increase to around 3 million by 2050 (2). The socioeconomical impact exerted by dementia is enormous and was estimated to be US$ 1 trillion in 2018 (3), making dementia a public health priority worldwide by the World Health Organization (1).

Dementia is a clinical syndrome characterized by a marked decline in the cognitive abilities of an individual that are not due to normal ageing, and that are significant enough to interfere with one's ability to independently carry out activities of daily living (4). There are numerous diseases and brain injuries that cause dementia, the most common cause contributing to 60-80% of cases being Alzheimer's disease (AD) (5). AD is a chronic neurodegenerative disease marked by impairments in episodic memory, attention, planning and judgment, language, and orientation to time and place (5). In addition, behavioural and psychological symptoms are typically present (6). Common symptoms include mood swings, irritability, aggression, confusion, agitation or restlessness, apathy, depressed mood, and wandering (6).

In the absence of a cure for AD and related dementias, it remains imperative to find care solutions that can increase the quality of life of persons with dementia. Considering that approximately 70%-85% of persons with dementia live at home (7, 8), with similar figures found in Germany (9), and that the bulk of the care they receive daily is provided by informal care partners, such as family members or friends (5), it is also of vital importance that care solutions can improve the quality of life of care partners. Indeed, research to date is clear on the mental, physical, and financial stress and burden that caregiving exerts on care partners (5). Besides novel pharmacological interventions, the need for effective and socioeconomically equitable non-pharmacological interventions remains of high importance since pharmacological interventions might not be able to cure AD and related dementias or be affordable by all (10).

In response to this global scenario and limited pharmacological treatment options, a vast amount of effort has been put into the development and deployment of assistive technologies (ATs) for dementia in the last years (11). ATs is an umbrella term used to describe a variety of products and services that utilize information communication technologies (12) to help maintain or enhance the ability of persons with disabilities to carry out activities of daily living by addressing cognitive, behavioural, and/or psychological symptoms (13). One central tenet of ATs for dementia is that their use can also help maintain or enhance the quality of life of care partners (14). Additionally, ATs have the potential to be substantially cost-effective by supporting ageing in place policies that seek to delay the admittance of persons with dementia to long-term care homes (15, 16). To date, a large amount of research on ATs for dementia has focused on the use of so-called locating technologies (17). One central reason for the high focus on locating technologies is because disorientation leading to wandering is one of the most frequent, dangerous, and difficult to manage dementia-related behaviours (18). As their name implies, locating technologies hold the promise of being able to assist persons with dementia to move about safely and independently outside the home environment, and to support care partners by intervening if necessary (19). Germany's 2020 National Dementia Strategy recognizes the utmost importance of supporting the mobility of persons with dementia and highlights the need to develop mobility concepts in its first of four fields of action (20).

While there is no standard definition for dementia-related wandering, Kwak and colleagues (18) define wandering as a "seemingly aimless or disoriented ambulating behaviour of demented persons with dimensions of pattern (lapping, random, or pacing), frequency, boundary transgressions, and deficits in wayfinding" (p. 99). The aetiology of wandering is likely multi-dimensional, where the interplay between impairments in spatial memory and executive functions such as decision-making and planning, combined with inner confusion and restlessness, as well as external stressors such as high-stimulation environments, lead to disorientation and wandering (18). Currently, the Alzheimer's Association estimates that approximately 60% of persons with dementia will wander and get lost even in familiar environments during the course of the disease, and that many are repeat wanderers (21). Wandering exposes persons with dementia and their care partners to risks, ranging from persons with dementia suffering minor superficial cuts and scratches (22), falling and fracturing bones (23), care partners experiencing emotional distress (5) to life-threatening circumstances including death from freezing or drowning (24). To avoid such risks, care partners often have no alternatives at their disposition other than to limit the independent outdoor ambulation of persons with dementia by relying on either sedative, chaperon or even incarceration-type prevention measures (25). Such measures go against a person-centred dementia care approach (1) and can negatively impact the biopsychosocial health of persons with dementia (26). Other therapeutic approaches to help prevent wandering include psychosocial therapy (27, 28) and creating low-stimulation home environments with low noise levels and low light intensities (29) to help regulate emotional well-being and alleviate restlessness. However, the effectiveness of either approach to prevent wandering is not firmly established and both approaches are not able to help when persons with dementia get lost outside the home (30, 31).

In the last years, the number of scientific publications on ATs for dementia, including locating technologies, has grown substantially (13), as has the number of commercially available locating technologies (19). At present, there exists three types of high-tech locating technologies, namely technologies found in mobile locators (e.g., Global Positioning Systems (GPS) and wireless internet (Wi-Fi)), sensors and alarms (e.g., motion sensors with remote alarms), and wayfinding locators (e.g., technologies that offer navigational aid) (32). Most research to date has examined the use of mobile locators for wandering, where persons with dementia wear a GPS product and care partners receive GPS coordinates on a personal computer, tablet, or smartphone (19). For persons with dementia, different types of GPS products are available, including watches, tracking pagers, shoe soles, and necklaces (33, 34). However, the widespread implementation and adoption of locating technologies outside research and clinical environments continues to lag (35, 36). Key reasons for their low adoption likely include the limited number of research on the user experience (UX) of persons with dementia and care partners with locating technologies to better understand their needs and preferences, the almost complete lack of evidence-based findings on clinical effectiveness resulting from product use, and the overall poor understanding of the barriers to their adoption. Indeed, most research to date has focused on examining feasibility and acceptability of use whilst neglecting to examine UX and clinical effectiveness (19). Understanding both is paramount as they contribute to product acceptance and use (19). Of the limited number of studies that have examined UX, most rely on proxy evaluations for persons with dementia by having care partners answer in their place (37). Therefore, there is a lack of clear-cut quality standards regarding what locating technologies should be able to do and what they should look like, as well as not knowing whether their use adds value beyond being accepted and feasible to use. In addition, studies exploring barriers to their adoption are only starting to emerge (33, 38). Of these, none have explored the views of business stakeholders who play a pivotal role in product design, development, and commercialization (39). Plus, recommendations on services and information dissemination strategies are almost non-existent (39) although they can maximize product awareness, positive UX, and product adoption (40, 41).

1.1. Thesis aims and research questions

The overarching aim of the present thesis was to better understand how to promote the adoption of locating technologies for dementia through a deeper understanding of the preferences and needs of persons with dementia and care partners with locating technologies, whether their use can result in clinical effectiveness, and the barriers to their adoption. We first examined UX and clinical effectiveness in two longitudinal user studies with persons with dementia and care partners, and lastly explored barriers to their adoption in a qualitative focus group interview study. In our first user study entitled “Digital Care Support” (DCS) funded by the Investitionsbank des Landes Brandenburg (30, 31), a prototype mobile locator GPS application (app) installed on a smartphone was tested for four weeks at home. The following research questions were examined:

1) How is the prototype rated in terms of its usability?
2) How is the prototype rated in terms of its product functions and design features?
3) Does using the prototype result in clinical effectiveness?
4) Do user characteristics such as age, gender, dementia severity, or care partner stress and burden influence UX?
5) How willing are participants to purchase the prototype?

In our second user study entitled "Validation and optimization of the individual benefits of locating systems in home dementia care" (VODINO) funded by the German Alzheimer Society e. V. (19, 30), two similar commercially available mobile locator GPS watches were tested for four weeks each at home and compared. The following research questions were examined:

1) How is each commercial locating technology rated in terms of its usability?
2) How are their different product functions and design features rated?
3) Does using either product result in clinical effectiveness?
4) Does UX differ between persons with dementia and care partners?
5) Do user characteristics such as age, gender, dementia severity, care partner stress and burden, or technological affinity influence UX?
6) Does product satisfaction differ when rated at home compared to the study centre?

Lastly, in our third qualitative study funded by the Focus Area DynAge of the Freie Universität Berlin and the Charité – Universitätsmedizin Berlin (39), we explored the barriers to the adoption of locating technologies for dementia by conducting focus group interviews with interdisciplinary professional stakeholders from business, healthcare, and research fields. The following research questions were explored:

1) What are professionals' opinions on the use of locating technologies for dementia?
2) What are their personal and professional experiences with these technologies for dementia?
3) What are their opinions on the reasons why locating technologies for dementia have not spread so widely?
4) What services do they recommend to optimize product adoption?
5) What information dissemination strategies do they recommend to optimize product adoption?

2. Methods

2.1. Description of study samples

For the DCS and VODINO user studies, we employed a convenience sampling technique to recruit persons with dementia and care partners from the memory clinic of the Charité – Universitätsmedizin Berlin[2]. To help ensure obtaining a more representative evaluation of UX, participation was open to persons with dementia with differing levels of cognitive impairment. Additionally, information on the number of years since first diagnosis, as well as on current cognitive functioning assessed with the Mini-Mental State Examination (MMSE) (42) no longer than one month prior to study baseline were available for all persons with dementia.

[2] The diagnostic workup of memory clinic patients includes a holistic medical case history, neuropsychological assessments, structural brain imaging with magnetic resonance imaging or computerized tomography, lumbar puncture to obtain cerebrospinal fluid biomarkers, and blood tests.

In the DCS user study, a total of 18 dyads (*n* = 18 persons with dementia, *n* = 18 care partners) were included at baseline. Based on MMSE scores, three (16.7%) persons with dementia were classified as having a mild cognitive impairment, six (33.3%) as having a mild dementia severity, and nine (50%) as having a moderate dementia severity. Twelve (66.7%) had received their first diagnosis three years ago or more and six (33.3%) had received their first diagnosis less than three years ago. Eleven (61.1%) persons with dementia were female and seven (38.9%) were male. Care partners included ten husbands (55.6%), six wives (33.3%) and two daughters (11.1%), summing up to eight (44.4%) care partners being female. On average, persons with dementia were 71.9 years old and care partners were younger at 66.9 years old.

In the VODINO user study, a total of twenty dyads (*n* = 20 persons with dementia, *n* = 20 care partners) were included at baseline. Based on MMSE scores, ten (50%) persons with dementia were classified as having a mild dementia severity and 10 (50%) as having a moderate dementia severity. Eight (40%) had received their first diagnosis three years ago or more and twelve (60%) had received their first diagnosis less than three years ago. Eleven (55%) persons with dementia were female and nine (45%) were male. Care partners were made up of nine wives (45%), ten husbands (50%) and one son (5%), summing up to eleven (55%) care partners being male. On average, persons with dementia were 72.1 years old, and care partners were younger at 68.7 years old.

Lastly, in the qualitative focus group interview study, we purposively contacted seventy professionals from our professional network working in multidisciplinary fields related to gerontology and gerontechnology via personalized e-mail to participate in a half-day focus group interview study held at the memory clinic of the Charité – Universitätsmedizin Berlin (39). As described in Freiesleben et al. (39), professionals were from: (i) "business fields within the technology industry sector (representatives of ATs companies with current gerontechnology focus including company executives and executive associates, marketing analysts, UX designers, and software developers), [(ii)] healthcare fields (representatives of Alzheimer societies, community organizations serving older adults with disabilities and nursing homes including local community representatives, managing directors, healthcare managers, social workers, gerontologist, as well as education and program coordinators), and [(iii)] research fields (research associates, project managers, group leaders, as well as postdoctoral and doctoral researchers from the fields of gerontology, rehabilitation sciences, social work, health services administration, medical sociology and rehabilitation science, nursing sciences, and gerontechnology)" (pp. 2-3). Based on field of work, professionals were separated into a business, healthcare and research group, which allowed to maximize group interaction and homogeneity (43). Data saturation was estimated to be reached with groups of ten to fifteen participants based on group homogeneity (43).

In all three studies, participation was voluntary and all participants provided their written informed consent at study inclusion. The ethics committee of the medical faculty of the Charité – Universitätsmedizin Berlin approved of each study (DCS user study protocol number EA4/033/13; VODINO user study and focus group interview study protocol number (EA4/033/16)). All methods were carried out in accordance with relevant guidelines and regulations.

2.2. Description of study materials

In the DCS user study, a prototype mobile locator GPS app bearing the name of the study was installed on a smartphone and tested. The DCS app was created in an iterative and co-creative product development process with persons with dementia, care partners, healthcare professionals working in the field of dementia, and business professionals including software developers from the company webXells GmbH under the scientific guidance of the memory clinic of the Charité – Universitätsmedizin Berlin. Our research team had performed a short user evaluation with a previous version of the DCS app and found it to be rated positively in terms of acceptability and feasibility of use, which suggested its potential for future development (44). Persons with dementia received a Samsung Galaxy xCover smartphone to test the DCS app, and care partners randomly received a Samsung Galaxy Tab II tablet (*n* = 9) or a Samsung Galaxy Note II smartphone (*n* = 9) based on on-site availability (see Figure 1, p.13; extracted from publication 1). The DCS app was preinstalled on all devices and was the only visible app on the home screen of each device. It included four main functions: (i) location, allowing care partners to locate and display the location of the xCover smartphone on a map), (ii) telephone, allowing two-way telephone communication, (iii) alarm, allowing persons with dementia to send an alarm to care partners, and (iv) service hotline, allowing care partners to view service hotlines, as well as two subfunctions based on geofencing: (v) zone mapping, allowing users to create habitual whereabouts zones of persons with dementia, and (vi) zone sharing, allowing care partners to receive a call or a short message service when persons with dementia enter or exit a zone.

In the VODINO user study, two similar commercially available mobile locator GPS watches marketed for persons with orientation impairments (as described in publication 2, products A and B; see Table 1, p.13; derived from publication 2) were tested by persons with dementia. We selected watches based on recommendations that locating technologies take the form of familiar, everyday objects to optimize adoption (37, 45). Plus, these were the only two mobile locators on the German market at the time of the study that included a location and telephone function, thus allowing for an active versus passive use. Care partners received a study-specific THL T6C smartphone to prevent bias. The apps of product A and B were preinstalled on all smartphones. A main difference between product A and B is that care partners could view the last recognized positions of persons with dementia with product B, whereas only the last recognized position of product A could be viewed by care partners. Also, product A featured five buttons, whereas

product B featured one. By pressing one predefined button of product A or the button of product B, persons with dementia and care partners could come into telephone contact.
In the focus group interview study, no materials were tested with the goal of collecting outcome measures. However, professionals performed a short user test with product A and the study specific THL T6C smartphone of the VODINO study with the aim of stimulating the discussion to help uncover adoption barriers (see Additional file 1, publication 3).

Figure 1 Tablet for care partners and smartphone for persons with dementia displaying the DCS prototype. Extracted from figure 1 found in (31).

Table 1 Product description of GPS watches for persons with dementia

Name	A (HIMATIC GPS Uhr Alpha)	B (ReSOS — Die Notfalluhr)
Picture		
Size/Weight	45.5 mm X 64.5 mm X 17.5 mm/70 grams	43.0 mm X 43.0 mm X 19.0 mm/66 grams
Main colours	Black and blue	Black and red
Buttons	Five (Ø: 0.5 mm)	One (1.8 mm X 0.5 mm)
Band type	Silicone strap	Silicone strap
Battery	Li-ion (3.7 V, 500 mAh)	Li-ion (850 mAh)
Charging	DC 5 V USB charger cable	Charging station with USB cable
Software	Native Android App: HIMATIC GPS Uhr Alpha	Native Android and iOS App: ReSOS-2
Website	https://himaticmobile.de/personenortung.html	http://notfall-uhr.de/

Abbreviations: A, product A; B, product B; GPS, global positioning system; USB, Universal Serial Bus. NOTE. Product A English translation *HIMATIC GPS Alpha watch;* product B English translation *ReSOS-2 –the emergency watch*; size noted as width by length by depth; websites last accessed on August 23, 2018; both watches had a SIM card that allowed for two-way communication and GPS connection. Information derived from table 1 found in (19).

2.3. Description of study designs

The DCS app was tested at home for four weeks from baseline (T1) to the end of the testing period (T2). In the VODINO user study, products A and B were tested for four weeks each at home and compared using a 2X2 crossover design (sequences AB/BA; two study periods: study period one from baseline (T1) to T2.1; second study period from T2.2 (i.e., directly following T2.1) to T3). Both user studies employed a mixed methods design to collect qualitative and quantitative data (46), but only quantitative data were analysed. Throughout, various scales were administered to assess our primary outcome measure UX and our secondary outcome measure clinical effectiveness. Dyads received their products at baseline (i.e., in the VODINO user study, this occurred at T1 and T2.2) during an interactive educational training session based on dementia communication guidelines (47, 48) of approximately thirty minutes that included completing tasks with the products to support product learning (see description of tasks: section 2.3.1., publication 1 and section 2.2., publication 2). Furthermore, dyads received home user diaries in the DCS user study at T1 to provide weekly comments on their ongoing satisfaction with the prototype to be returned at T2. In the VODINO user study, each dyad was asked to rate their overall satisfaction with product A or B at the end of each week at home to compare product satisfaction when rated at the clinic versus at home.

The focus group interview study was based on a qualitative description methodology (49). For healthcare-related research, qualitative description is useful since it allows to perform a holistic exploration of a particular topic and since it can provide pragmatic information on how to improve practice (49). A review of the relevant literature was first performed to identify the topics to be covered in the interview guide (7, 35-37, 49-56). Our final interview guide comprised of three sections, namely (i) exploration of perceptions on value of use, (ii) exploration of adoption barriers, and (iii) exploration of services and information dissemination strategies. A discussion moderator and one or two assistant moderators who kept notes and audio recorded the session lead each group. The interviews lasted approximately three hours.

An overview of the study designs and scales administered in all three studies, as wells as the topics covered in the focus group interviews is presented in detail in Table 2, pp. 15-16. The presented information has been described in (19, 30, 31, 39).

Table 2 Overview of study designs and assessments administered in all three studies, and topics explored in third study

Study one: DCS user study (four-week longitudinal study, mixed-methods, N = 36)

Baseline (T1)	Home user diaries	End of study (T2)
• Demographics, including: - Orientation impairments of persons with dementia (none/mild/moderate/severe) - History of wandering events (never/1-3 times/4-6 times/7 times or more) - Technological experience[1] - Technology Commitment scale[2] • Primary outcome measure UX: - International Standardization Organization Norm (ISONORM) 9241/10 scale[3] • Secondary outcome measure clinical effectiveness: - Zarit Burden Interview (ZBI)[4] - General Self-Efficacy scale (GSE)[5]	• End of each week: participants specified situation(s) in which the prototype was used, described any difficulties experienced, listed the attitude(s) of persons with dementia towards the prototype, and rated their product satisfaction[6].	• Primary outcome measure user experience (UX): - ISONORM 9241/10 - Semi-structured interviews to assess ratings of[7]: (1) product functions (2) product features • Secondary outcome measure clinical effectiveness: - ZBI - GSE - Semi-structured interviews to assess ratings of[7]: (3) subjective frequency of use of the prototype (4) prototype purchase willingness (yes/no) (5) prototype payment willingness

Study two: VODINO user study (eight-week longitudinal study, mixed-methods, N = 40)

Study period one (four weeks)		Study period two (four weeks)	
Baseline (T1)	**T2.1**	**T2.2**	**T3**
• Demographics, including: - History of wandering events (none/1-3 times/4-6 times/7 times or more) • Primary outcome measure UX: - ISONORM 9241/10 scale • Secondary outcome measure clinical effectiveness: - ZBI - European Health Interview Survey-Quality of Life (EUROHIS-QOL)[8] - Orientation impairments[9] - Subjective burden of getting lost[10] • Covariate: - Technological affinity scale for electronic products (TA-EG)[11]	• Primary outcome measure UX: - ISONORM 9241/10 scale - Product functions[12] - Product features[12] - Product satisfaction[13] • Secondary outcome measure clinical effectiveness: - Same as at T1 • Covariates: - Same as at T1 - Subjective frequency of use of the location function[14] • Additional questions: - report of any wandering events - report of any technical difficulties	• Primary outcome measure UX: - ISONORM 9241/10 scale	• Same as at T2.1

Study 3: Focus group interviews with professionals (qualitative description methodology, N = 70 professionals contacted)

Section 1	Section 2	Section 3
Exploration of perceptions on value of use	**Exploration of adoption barriers**	**Exploration of services and information dissemination strategies**
• Demographics, including: - Years of experience with dementia (<2/2-5/5-10/>10)	• Explore views and perceptions on: - Personal experiences	• Explore views and perceptions on:

Table 2 Overview of study designs and assessments administered in all three studies, and topics explored in third study (Continued)

- Years of experience with assistive technologies (ATs) (<2/2-5/5-10/>10) - Pay willingness for a mobile locator based on global positioning technology (once/monthly) - TA-EG • Icebreaker question: - Perceptions on the value of using locating technologies for dementia care written on cards	- Product characteristics - Clinical needs - Clinical expectations	- Needed services around products including customer services and service provision methods - Product promotional methods including product advertising

Abbreviations: DCS, Digital Care Support; VODINO, Validation and optimization of the individual benefits of locating systems in home dementia care; other abbreviations are provided on first mention within the table.

NOTES. [1]. Two self-developed questions: 1) “How much experience do you have with the following products: cellphone without internet; smartphone, tablet, and personal computer?”, and 2) “How often do you use the following functions: short message service, e-mail, telephone, internet, and navigation system?”; four-point Likert scale from 1 = none/never to 4 = a lot/very, range 9-36, scores proportional to technological experience.

[2]. Four selected questions from the German Technology Commitment scale including three questions on acceptance or openness toward technological products, and one question on perceived self-competence with technological products; five-point Likert scale from 0 = not at all true to 4 = completely true, range 0-16, scores proportional to technological acceptance (see reference 23, publication 1).

[3]. Seven-domain Likert scale to assess product usability including: (1) suitability for the task, (2) self-descriptiveness, (3) controllability, (4) conformity with user expectations, (5) error tolerance, (6) suitability for individualization, and (7) suitability for learning; differing Likert ranges per domain ranging from “not at all satisfied” to “very satisfied”, range 0-210, scores proportional to usability (see reference 24, publication 1).

[4]. ZBI-short version; five-point Likert scale from 0 = never to 4 = nearly always, range 0-48, scores proportional to care partner burden (see reference 21, publication 1).

[5]. Four-point Likert scale from 1 = not true at all to 4 = exactly true, range 1-40, scores proportional to higher perceived self-efficacy of care partners when handling stressful situations (see reference 22, publication 1).

[6]. Ratings of product satisfaction on a five-point Likert scale from 0 = not at all satisfied to 4 = very satisfied.

[7]. Product functions (i.e., location, telephone, alarm, and service hotline) and product features (i.e., font style, font size, font colour, overall colours displayed, icons used to represent product functions, and labels given to product functions); five-point Likert scales from 0 = very poor to 4 = very good, scores proportional to more favourable endpoints. Participants could comment on their quantitative ratings to better understand areas of satisfaction and dissatisfaction with the prototype. For subjective frequency of use of the prototype, a five-point Likert scale from 0 = never used to 4 = used very often was employed. For prototype payment willingness, the possible predetermined amounts were 39.99€, 59.99€, 79.99€, and 99.99€.

[8]. Five-point Likert scale from 0 = not at all to 4 = completely, range 0-48, scores proportional to quality of life (see reference 34, publication 2).

[9]-[10]. Self-developed six-point Likert scales from 0 = no impairment/not at all worried to 5 = very impaired/very worried, range 0-5, scores proportional to more negative endpoints.

[11]. Five-point Likert scale from 1 = strongly disagree to 5 = strongly agree, range 19-95, scores proportional to technological affinity (see reference 35, publication 2).

[12]. Product functions (i.e., location and telephone) and product features (i.e., colour, font, size, weight, buttons, and battery life); five-point Likert scales from 0 = not at all good to 4 = very good, scores proportional to more favourable endpoints.

[13]. Same five-point Likert scale as described under 12.

[14]. Five-point Likert scale from 0 = not at all to 4 = very often.

Information described in (19, 30, 31, 40).

2.4. Description of statistical analyses

The Statistical Package for the Social Sciences (SPSS) versions 23 and 24 were used to analyse all quantitative data (57, 58). Statistical significance was set at *P*-value ≤ 0.05.

In both user studies, we first performed normality tests to inspect for outliers, followed by descriptive statistics to analyse demographic data. Pearson's correlations were performed to test for significant relationships between demographic and other baseline data. To examine whether our primary and secondary outcome measures in both user studies significantly changed over time, independent and dependent samples t-tests, as well as chi-square tests were performed, as appropriate. Specifically, in the VODINO user study we performed dependent samples t-tests to analyse primary and secondary outcome measures from persons with dementia and care partners due to the non-independence between persons within a dyad (59). Also, primary outcome measures between products A and B were compared with independent samples t-tests, whereas secondary outcome measures and covariates were examined with Spearman's rank-order correlations and one-way repeated measures analysis of variance, as appropriate. We performed independent samples t-tests to test for any order effect based on whether product A or B was received first.

In the focus group interview study, descriptive statistics were first performed to analyse demographic data. Potential differences between professionals' demographic and other baseline data based on gender or group membership were compared with Kruskal Wallis or Mann-Whitney tests, as appropriate. We also calculated a theme density (i.e., number of times a theme was coded) in the first section as the viewpoints from all professionals were available due to their card answers. Qualitative data were first transcribed verbatim into MAXQDA (60). Transcripts were then thematically analysed using a content analysis, data-driven inductive data analysis methods (61). Hence, we followed a step-by-step process during which emerging patterns and themes from the transcripts were independently identified, chunked, and coded into thematic codes. Thereafter, codes were separated into subthemes and discussed in several group meetings until no additional themes were discovered and team consensus was reached. This ensured that data saturation and reliability were reached in our final coding scheme. We used the COREQ (Consolidated criteria for Reporting Qualitative research) checklist (62) to report our qualitative data (see Additional file 2, publication 3).

3. Results

3.1. First study: DCS user study with a prototype locating technology

Normality tests prior to data analysis revealed no outliers. One dyad dropped out (dropout rate 5.6%) due to reasons unrelated to study involvement, bringing the final sample size to N = 17 dyads. Participant characteristics at baseline are presented in Table 1, publication 1. Not shown in this table are ratings of orientation impairments by care partners, ranging from no impairment (*n* = 3; 17.6%), mild (*n* = 4; 23.5%), moderate (*n* = 7; 41.2%) to severe (*n* = 3; 17.6%). Also not shown are ratings of search history, with most care partners never having to search for persons with dementia (*n* = 15; 88.2%).

Results on UX, our primary outcome measure, indicated that the prototype was rated fairly regarding its usability, product functions and product features, as well as end-users' weekly product satisfaction. However, end-users rated its usability significantly worse by the end of the study, $t(16) = 2.34$, $P = .032$, and the range of ratings varied more at T2 than at T1 (see means and standard deviations: Fig. 2, publication 1 and Table 3, p. 20). Upon closer inspection, the ratings of four usability domains significantly reduced, namely conformity with user expectations, controllability, suitability for individualization and suitability for the task (see dependent samples t-tests: section 3.2.1., publication 1). Product function ratings from most positive to most negative was as follows: location, zone mapping, service hotline, telephone, zone sharing, and alarm. For product features, the following was found: overall colours displayed, labels given to functions, font style, icons used, and font size as well as font colours tied for last position (see means and standard deviations: sections 3.2.2.1. and 3.2.2.2., publication 1). No significant differences between the ratings of different product functions were detected. For product features, a significant difference was found between the ratings of overall colours displayed and font colours, $t(16) = 3.25$, $P = .005$, and font size, $t(16) = 2.64$, $P = .018$. No significant correlation was found between primary outcome measures and relevant participant characteristics at either assessment point. Comments made during the semi-structured interview revealed that five care partners (29.4%) were dissatisfied with the prototype due to technical difficulties leading to a poor reliability of the location function. One care partner mentioned that the prototype had been able to locate their loved one three times during the study.

Results on clinical effectiveness, our secondary outcome measure, revealed no significant changes in ZBI or GSE ratings after four weeks of use (see dependent samples t-tests: section 3.3.1., publication 1). Also, the subjective frequency of use of the prototype was moderate (see mean and standard deviation: section 3.3.2., publication 1). Interestingly, most care partners (*n* = 13; 76.5%) were willing to purchase the prototype, with men more than women, χ^2 (1, N = 17) = 7.46, $P = .029$. Most care partners would be willing to pay 39.99€ (*n* = 8; 47.1%), followed by 59.99€ (*n* = 4; 23.5%), 99.99€ (*n*= 3; 17.6%), and 79.99€ (*n* = 2; 11.8%).

3.2. Second study: VODINO user study with commercial locating technologies

Normality tests prior to data analysis revealed one person with dementia with an MMSE score more than two standard deviations below the mean and was removed from analyses (63). Two dyads who had received different products at T1 dropped out after four weeks stating product dissatisfaction due to technical difficulties (dropout rate 10%; no significant differences compared to remaining dyads), bringing the final sample size to N = 17 dyads. Of these dyads, seven had received product A and ten product B at T1. Participant characteristics at baseline are presented in Table 2, publication 2.

Results on UX, our primary outcome measure, revealed that dyads rated product A and B fairly in terms of usability at all assessments. However, product B was rated significantly better than A at all assessments (see means and standard deviations: Table 3, publication 2 and Table 3, p. 20; see independent samples t-tests: section 3.2. and Additional file 1, publication 2). The information presented in Table 3, p. 20 has been described in (19, 30, 31). Only one significant difference in the usability ratings of persons with dementia compared to care partners was found at T1, sequence AB, with persons with dementia showing less favourable ratings than care partners, $t(6) = -4.77$, $P < .01$. Neither the usability ratings of persons with dementia, care partners, nor of dyads with either product significantly changed after each four weeks of testing periods. For product functions, dyads rated the telephone function of product B significantly better than product A at T2.1, $t(32) = -2.63$, $P < .05$. For product features, several significant differences were found at different assessments, with product B consistently receiving better ratings than product A. Specifically, at T2.1 dyads rated the font and buttons of B better than A, $t(32) = -2.24$, $P < .05$ and $t(32) = -4.03$, $P < .001$, respectively. At T3, they rated the font, buttons, and battery life of product B better than product A, $t(32) = -3.20$, $P < .01$, $t(32) = -2.67$, $P < .05$ and $t(32) = -3.12$, $P < .01$, respectively (see means and standard deviations: section 3.2., publication 2). Differences between the ratings of persons with dementia and care partners revealed that the former rated the overall design features of product A more favourably than the latter at T2.1, $t(6) = 2.44$, $P = .05$, as well as the buttons of product A at T2.1 $t(6) = 2.71$, $P < .05$ and T3, $t(9) = 2.70$, $P < .05$ (see means and standard deviations: section 3.2., publication 2). Primary outcome measures did not correlate with any relevant participant characteristic variable over the course of the study. No significant order effects based on which product was received first were found for any primary outcome measures. Finally, product satisfaction ratings were significantly higher when rated at the clinic versus at home at various assessment points (see dependent samples t-tests: section 3.2., publication 2).

Regarding secondary outcome measures and covariates, no significant changes in ZBI or EUROHIS-QOL ratings were found over the course of the study. However, the TA-EG ratings of persons with dementia and care partners significantly reduced at T3 compared to T1 and T2.1, $F(2, 32) = 16.03$, $P < .001$ and $F(1.11, 17.73) = 23.64$, $P < .001$, respectively. Furthermore, persons with dementia rated themselves significantly more favourable than did care partners in terms of orientation impairments and subjective burden of getting lost at T1, T2.1 and T2, and in terms of EUROHIS-QOL at T1 (see dependent samples t-tests: section 3.3., publication 2).

Lastly, the subjective frequency of use of both products was moderate (see means and standard deviations: section 3.3., publication 2). Product A was able to assist in locating persons with dementia who wandered three times during the study. Location was assisted via the telephone function in two cases and via the location function in one case. In total, eighteen cases of technical difficulties were reported (i.e., problems with battery charging, location, and telephone function), with care partners reporting more difficulties than persons with dementia.

Table 3 Selected primary and secondary outcome measures in both user studies

	ISONORM 9241/10 usability ratings			
Study	**T1**	**T2.1***	**T2.2**	**T3**
DCS, care partners (n = 17)	163.5 ± 28.7§	139.9 ± 46.5§	-	-
VODINO, Sequence AB (n = 7 dyads)†				
Persons with dementia	126 ± 37.3††	116 ± 58.8	170 ± 15.3	168 ± 32.9
Care partners	165 ± 36.2††	147 ± 20.9	179 ± 17.7	155 ± 39.8
VODINO, Sequence BA (n = 10 dyads) †				
Persons with dementia	170 ± 28.2	153 ± 48.8	117 ± 49.6	111 ± 67.0
Care partners	171 ± 28.8	176 ± 21.5	128 ± 36.7	123 ± 56.7
	ZBI ratings			
DCS, care partners (n = 17)	13.4 ± 7.2	12.4 ± 7.6	-	-
VODINO, care partners (n = 17)	14.5 ± 6.4	16.3 ± 9.2	-	17.2 ± 8.5

Abbreviations: A, product A; B, product B; ISONORM, International Standardization Organization Norm; n, number; ZBI, Zarit Burden Interview.
NOTES. Continuous variables are displayed as mean ± standard deviation. Reporting of ISONORM 9241/10 means differed by one decimal point in the VODINO and DCS user study publications. ISONORM 9241/10: range 0-210, scores proportional to usability. ZBI, short version: range 0-48, scores proportional to burden.
* T2 and not T2.1 in the DCS user study.
§ Independent samples t-test for dyads: B rated better than A at all time points.
† Independent samples t-test: prototype rated less favourably by care partners at T2 versus T1, $P < .05$.
†† Dependent samples t-test for within dyad effects: product A rated worse by persons with dementia than by care partners at T1, $P < .01$.
Information described in (19, 30, 31).

3.3. Third study: focus group interviews with interdisciplinary professionals

Of the seventy professionals who were contacted, 35 did not respond, eight were unavailable, and five did not attend (i.e., no-show). The participating twenty-two professionals were separated into a business (n = 7), healthcare (n = 6), and research (n = 9) group (see description of final sample: section Results, Participant characteristics, publication 3). A significant difference between dementia experience and gender was found, Mann-Whitney U = 20.5, z = -2.7, P = .007, mean rank of 14.79 for women and of 7.55 for men. Participant characteristics are presented in Table 1, publication 3. An overview of the themes and subthemes of all three sections of the focus group interviews, as well as illustrative quotes is presented in Table 2, publication 3. Due to space limitations, illustrative quotes are not included here, but can be found within this table and throughout publication 3.

In the first section exploring professionals' perceptions on the value of using locating technologies for dementia, three themes and nine subthemes were identified (see Table 2, Section 1, publication 3). Overall, professionals believed that their use could be beneficial to help: (i) promote the personal security, and (ii) independence of persons with dementia, as well as (iii) reduce care partner stress and burden. Locating technologies could accomplish these outcomes via location finding, risk reduction, autonomous mobility, social engagement, offering peace of mind for care partners via location finding, and by optimizing the use of caregivers' resources. However, potential drawbacks were mentioned for each perceived benefit. Namely, professionals stressed that locating technologies could give end-users a sense of false security if location is inaccurate, that persons with dementia could feel less independent if they feel that they are being tracked, and that care partners might feel an uneasiness about using locating technologies because of their tracking nature. Still, they argued that many care partners believe that they have a moral obligation to monitor and maintained that they may view other methods of monitoring as being less ethical.

In the second section exploring professionals' views on the barriers to the adoption of locating technologies for dementia, six themes and eighteen subthemes were extracted (see Table 2, Section 2, publication 3). First, adoption was viewed as being suboptimal due to awareness limitations, which could be attributed to a low knowledge transfer between stakeholders, limited information on and access to commercial products, and the low technological affinity of end-users. Second, technological limitations due to the location function being unreliable and inaccurate, as well as the limited functionality and poor battery life of products were highlighted. Such technological limitations would cause usage-related difficulties and would not satisfy the perceived benefit that locating technologies could increase quality of life. Third, product characteristic limitations were mentioned. These could be attributed to products being developed with an insufficient focus on end-users, stigmatizing or unsatisfactory aesthetics, and high products costs. Fourth, capital investment limitations were discussed, however only by business professionals. They argued that a lack of funding and low product development follow-through represent major obstacles to the successful commercial deployment of high-quality products. Fifth, unclear benefits were discussed and believed to be due to end-users not recognizing the need to use these product or them relying on other methods of remote location, the limited number of studies reporting on clinical effectiveness from product use, as well as prior negative UX. Lastly, ethical concerns were viewed as hindering adoption by reducing trust in products and by slowing down product development and commercialization. These concerns centred on the balance between control by care partners and autonomous mobility of persons with dementia, data privacy and data security, and the legal right to locate others.

In the third section exploring professionals' opinions on salient services and information dissemination strategies that could optimize adoption, five themes and fifteen subthemes emerged (see Table 2, Section 3, publication 3). For services, (i) digital autonomy support and (ii) emergency support were viewed as essential services to be offered to end-users upon product purchase. Professionals discussed that the digital autonomy of end-users could be better supported by offering installation and product training support, automated technical support, and round-the-clock emergency call centres. However, professionals cautioned about the complex and expensive logistics that are required to put these services in place. For information dissemination strategies, professionals noted the central role played by (iii) information dissemination actors. They highlighted that a multi-actor approach that includes the involvement of memory clinics, medical supply stores, general practitioners, local government, and healthcare insurance companies is key to help increase product awareness. Nevertheless, professionals made it clear that each proposed actor has limitations in terms of financing, time, and lack of follow-up. Professionals also talked about (iv) product acquisition methods in which they advocated for retail options, offering trial periods, and exploring the role of government subsidies. They believed that these proposed product acquisition methods could raise product familiarity by better reaching end-users and could facilitate product financing. Lastly, they discussed the role of (v) product advertising in product promotion. The main recommendations were that advertising materials promote independence and autonomy, that they include a seal of quality from trusted organisations, and that they address the central concerns of end-users such as data security, product characteristics, and service details. Professionals also maintained that using conventional advertising platforms such as magazines, pharmacies and television could help ensure that end-users are reached more effectively. However, business professionals stated that they lack the financial resources required to advertise locating technologies on better suited platforms.

4. Discussion

This thesis reports on three studies that together aimed to provide an in-depth examination on ways to increase the adoption of locating technologies to assist with spatial orientation impairments and wandering in dementia. Results are of high value to various stakeholders such as persons with dementia, care partners, healthcare, researchers and business professional. Indeed, we describe that key adoption enablers and barriers have been overlooked before locating technologies can truly make a difference as a non-pharmacological intervention in dementia care. In two longitudinal user studies, we first examined the UX of persons with dementia and care partners with high-tech locating technologies categorized as mobile locators, as well as clinical effectiveness resulting from use. In the DCS user study, a prototype GPS app installed on a smartphone was tested. In the VODINO user study, two commercially available GPS watches marketed for persons with orientation impairments were tested and compared. Lastly, we performed focus group interviews with interdisciplinary professionals from business, healthcare, and research fields to explore views and opinions on adoption barriers, salient services, and information dissemination strategies.

In both user studies, we found that usability ratings were fair, yet decreased after four weeks of use. Specifically, in the DCS user study, usability ratings decreased significantly after four weeks of use. When we examined in more detail, we found that the ratings of four usability domains out of seven significantly reduced, namely conformity with user expectations, suitability for the task, controllability, and suitability for individualization. In the VODINO user study, usability ratings of product B by dyads were significantly better than ratings of product A at all assessments. No order effects based on which product was received first were found. Importantly, we found that usability ratings in either study were not significantly associated with any relevant participant characteristic such as technological affinity or care partner stress and burden. This finding is important as it suggests that the characteristics of the tested locating technologies rather than participant characteristics led to a significant reduction in this primary outcome measure. Similarly, ratings of product functions and features were not significantly associated with any relevant participant characteristic in either study. Hence, focusing on specific product functions and design features during product design and development might substantially improve usability and other UX outcomes, which in turn could lead to higher adoption rates. Based on our findings in the DCS user study, we recommend placing a special focus on the needs and preferences of end-users with regards to the programming of the alarm function as this function was rated most negatively by participants. Additionally, participants were most dissatisfied with the prototype's font size and font colours. It is possible that the alarm function was viewed as being stigmatizing, and that the font size and font colours were not aesthetically pleasing. The influence of unsatisfactory and stigmatizing aesthetics on product adoption was discussed by professionals in the theme product characteristic limitations. Moreover, participants indicated that they were dissatisfied with the zone mapping function due to its complicated use and low reliability. Others have previously shown that low user-friendliness and technical problems can significantly hamper product acceptance (13, 35). Technological limitations and capital investment limitations that limit the development and deployment of high-quality products were highlighted as key adoption barriers by professionals. In the VODINO user study, we found that dyads preferred the telephone function of product B, as well as its overall design features, its font, number of buttons, and battery life at different assessment points. The more favourable ratings of product B's telephone function could be associated with participants' more favourable rating of its number of buttons. Indeed, product B contained fewer buttons than product A which may have made the use of product B overall more straightforward. The more favourable ratings of product B's font could be explained by the minimal amount of displayed text. This concept of "less is more" was discussed by professionals. Thus, we recommend focusing on all above-mentioned product functions and design features in product design and development to optimize product adoption.

Furthermore, in the VODINO user study we found one significant difference in usability ratings between persons with dementia and care partners at baseline, with more favourable ratings of product A by care partners. At two other assessments, we found that persons with dementia preferred the buttons of product A compared to care partners. Our findings are in-line with previous works that recommend assessing ATs with a dyadic study design to ensure that the voices of persons with dementia are not overlooked (31, 37, 64, 65), a concept that was advocated by professionals. Importantly, factoring in the opinions and recommendations of end-users into product design is associated with a higher satisfaction of end-users when acquiring AT products (66). Better ratings of product A at baseline by care partners suggests that at first glance they viewed product A as being more suitable for daily life use by persons with dementia. Professionals recommended offering trials periods prior to product purchasing to allow end-users to test whether products meet their requirements. Better ratings of product A's buttons by persons with dementia points to the need to design discrete products to avoid stigmatization (64, 67). In a similar vein, professionals critiqued the development of locating technologies for clinically diverse populations using a one-size-fits-all design approach. They argued that there is a need for a narrower focus on the specific needs, desires, and capabilities of persons with dementia and care partners in product development, and that products need to be adaptive by being able to support end-users at different disease stages.

Interestingly, the fair ratings of all three tested locating technologies are at odds with the finding that the products were used only a moderate number of times, as well as with the reported usage-related technical difficulties. It is possible that in the absence of clear alternatives that can offer real-time assistance with spatial orientation impairments and wandering, participants rated suboptimal products fairly because these products held the potential of addressing their central daily living needs for autonomous mobility, social interaction, security, and risk reduction. Indeed, professionals made it clear that they view locating technologies as promising tools to increase end-users' quality of life on physical, social and psychological levels. Unfortunately, technical difficulties with products A and B in the VODINO user study may have also negatively impacted end-users' subjective technological affinity since its rating decreased significantly at the end of the study. Our findings point to the importance of offering ongoing support and product training upon product purchase to help address technological limitations and low technological affinity. Professionals provided several examples of how to offer support to persons with dementia and care partners in real-world scenarios that could mimic educational training sessions typically provided in research settings. Moreover, the finding that product satisfaction in the VODINO user study was consistently higher when rated at the clinic versus at home likewise suggests that ongoing user support is necessary. Differences in product satisfaction ratings may also point to a social desirability bias where participants exaggerated product satisfaction ratings at the clinic to avoid appearing too critical (68). In addition, the moderate number of times all three products were used might explain why clinical effectiveness was not found in either user study. However, it is more likely that the reported technical difficulties had a more significant influence on this non-finding. Indeed, clinical effectiveness was examined by looking at care partner stress and burden and ratings of perceived self-efficacy when dealing with stressful situations. Thus, experiencing technical difficulties could have counteracted our secondary outcome measure.

Regarding information dissemination strategies, professionals stressed that product awareness can be increased by utilizing a multi-stakeholder approach, and recommended placing persons with dementia and care partners at the centre of marketing materials. They argued that doing so could lower the potential for stigmatization and maximize the clear and transparent presentation of data security and other relevant product information. Based on our findings in all three studies, we recommend creating opportunities for collaboration between end-users and different professional stakeholders to help ensure that the perspectives and needs of end-users regarding data security and other ethical concerns such as care partners perhaps feeling uneasy about “tracking” persons with dementia are integral to product development.

Our studies have several strengths. For the first time, smartphone with an installed GPS app was examined in the DCS user study, and two commercially available GPS watches were compared in the VODINO user study using a crossover study design. The widespread use of smartphones and watches as everyday products means that they are recognizable and familiar, which goes hand-in-hand with the recommendation that locating technologies should come in the form of familiar, everyday objects to optimize adoption (36). To our knowledge, only one other recent study has tested a smartphone as a locating technology (69), and no other study has compared commercial GPS watches (19). Our detailed examination of UX and clinical effectiveness is also a leading strength as most studies report on acceptability and feasibility of use (19). Indeed, assessing UX and clinical effectiveness is fundamental since both translate to product acceptance and use (70, 71). Professionals in our third study highlighted that the sparse number of research-validated studies reporting on clinical effectiveness would reasonably discourage healthcare professionals from recommending or introducing locating technologies into care plans, as well as end-users not recognizing the value of using these technologies, ultimately hampering larger societal discussions on their value in dementia. For dementia care policies, scientifically sound findings on clinical effectiveness encourages governments to invest capital in their development and healthcare insurance companies to develop product reimbursement strategies. Furthermore, the inclusion of assessments prior and after product testing in the VODINO user study allowed to compare subjective and objective product appraisals and indicated that trial periods are warranted as product appraisals may change over time. Lastly, the implementation of an interactive educational training session in both user studies helped support product learning, which may be a precondition for the successful adoption of GPS technologies in dementia (33). In our focus group interview study, the inclusion of interdisciplinary professionals is a strength since it allowed to enrich our findings by obtaining a variety of viewpoints. Furthermore, the inclusion of business professionals was novel and highly valuable as their perspectives are lacking from the available literature. Importantly, business professionals substantially helped to uncover business-related hurdles and policy level challenges. Indeed, they were the only group to mention capital investment limitations as a central adoption barrier, as well as the role of government investments in product financing. In addition, they provided more examples of service recommendations. At a policy level, professionals suggested that facilitating harmonization strategies with healthcare insurance companies and governments, as well as finding solutions to regulatory obstacles pertaining to the legal monitoring of others could substantially boost adoption rates. Lastly, exploring services and information dissemination strategies is rare (72) although warranted (40, 41). For information dissemination strategies, we found that there is a large room for improvement with respect to ethically responsible marketing visuals and messaging.

Our studies also have several limitations. First, the sample size of both user studies was small at under twenty dyads, which limits the representativeness and generalisability of our findings. Although our sample sizes are comparable to other studies on ATs in dementia (13), large-scale, randomized controlled clinical trials are needed to determine clinical effectiveness and other relevant outcomes such as product safety. In the VODINO user study, the two dropouts and the decrease in participants' subjective technological affinity, as well as the reported technical difficulties in both user studies indicate that low user-friendliness is a real concern that can exacerbate burden. In addition, although history of wandering behaviours was assessed in both user studies, it was not an inclusion criterion. Hence, it is possible that not all persons with dementia represented target end-users. Still, it is encouraging that participants without a history of wandering viewed a study participation as being beneficial as a proactive way to gain experience with GPS technologies before wandering events potentially occur. Furthermore, we used self-developed scales that are not standardized to assess ratings of product functions and design features (19). Also, we had persons with dementia fill out the ISONORM 9241/10 scale although its psychometrics properties have not been tested with this population (19). Therefore, we created visual aids to simplify its administration (see Additional file 2, publication 2). Also, obtaining objective data on the frequency of use of all tested products was not possible due to technological limitations. In addition, we did not assess preferred product costs in the VODINO user study although product cost influence product acceptability (59). An additional limitation is that we did not sufficiently focus on persons with dementia in the DCS user study (37). Lastly, the crossover design in the VODINO user study lacked a washout period. Therefore, learning effects could have confounded UX outcomes. Encouragingly, order effects were not found, indicating that UX was not influenced by learning effects.

In our focus group interview study, a shortcoming is that our results are limited to the opinions raised by the professionals. Hence, our conclusions are not exhaustive and important topics may have been overlooked. However, professionals came from three different fields of work and from different areas throughout Germany. Also, the use of a purposive sampling technique may have led to a selection bias where participating professionals held more positive views on the use of locating technologies for dementia, especially since twenty-two out of seventy contacted professionals participated. Still, several critiques were put forth by professionals, including business professionals with a vested interest in selling locating technologies, suggesting that the discussion was objective. Plus, it is common for recruitment via e-mail communication to generate low recruitment rates (73). Moreover, appropriate product pricing was not discussed although product costs was mentioned as a central adoption barrier. Limited information on appropriate product pricing has been discussed by others (72), and may point to a larger study limitation. Overall, professionals' quotes in the second and third sections are mostly opinion-based rather than experience-based. This finding may point to a lack of relevant experience on the use of locating technologies for dementia by some of the included business professionals. A lack of experience increases the potential of designing and marketing locating technologies that end-users find stigmatizing (37).

5. Conclusions

The results of the present thesis provide important findings on ways to optimize the adoption of locating technologies to assist with spatial orientation impairments and wandering in dementia. Overall, the open and positive attitudes of the participants in all three studies towards the use of locating technologies despite the raised technological and ethical concerns underscores the potential for the future development of these technologies. An important conclusion of the DCS and VODINO user studies is that improving specific product functions and design features can enhance UX. Doing so might translate to clinical effectiveness and ongoing product satisfaction outside research and clinical settings. To achieve these goals, a multi-stakeholder approach that relies on user-centred design principles appears to be key, as highlighted in our third study. The recent establishment of interdisciplinary and international networks and consortiums (74, 75) that aim to optimize locating technologies for dementia, as well as their adoption, are examples of current advancements being made. Also, a closer examination of the services and information dissemination strategies that end-users find appropriate to help increase digital autonomy and product awareness have been largely overlooked and may be particularly effective (39).

6. References

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Footnote reference

Footnote 1, p. 2: Clarke AC. Profiles of the future: an enquiry into the limits of the possible. London: Macmillan; 1962, rev. 1973.

7. Statutory declaration

“I, Silka Dawn Freiesleben, by personally signing this document in lieu of an oath, hereby affirm that I prepared the submitted dissertation on the topic “Promoting the adoption of assistive technologies to aid with spatial orientation in dementia care”/„Förderung des Einsatzes assistiver Technologien zur Unterstützung der räumlichen Orientierung in der Demenzversorgung“, independently and without the support of third parties, and that I used no other sources and aids than those stated.

All parts which are based on the publications or presentations of other authors, either in letter or in spirit, are specified as such in accordance with the citing guidelines. The sections on methodology (in particular regarding practical work, laboratory regulations, statistical processing) and results (in particular regarding figures, charts and tables) are exclusively my responsibility.

Furthermore, I declare that I have correctly marked all of the data, the analyses, and the conclusions generated from data obtained in collaboration with other persons, and that I have correctly marked my own contribution and the contributions of other persons (cf. declaration of contribution). I have correctly marked all texts or parts of texts that were generated in collaboration with other persons.

My contributions to any publications to this dissertation correspond to those stated in the below joint declaration made together with the supervisor. All publications created within the scope of the dissertation comply with the guidelines of the ICMJE (International Committee of Medical Journal Editors; www.icmje.org) on authorship. In addition, I declare that I shall comply with the regulations of Charité – Universitätsmedizin Berlin on ensuring good scientific practice.

I declare that I have not yet submitted this dissertation in identical or similar form to another Faculty.

The significance of this statutory declaration and the consequences of a false statutory declaration under criminal law (Sections 156, 161 of the German Criminal Code) are known to me.”

Date	Signature

8. Declaration of own contribution to the publications

Silka Dawn Freiesleben contributed the following to the below listed publications:

Publication 1: Megges H, Freiesleben SD, Jankowski N, Haas B, Peters O. Technology for home dementia care: a prototype locating system put to the test. Alzheimer's & Dementia: Translational Research & Clinical Interventions. 2017; 3(3): 332-8. https://doi.org/10.1016/j.trci.2017.04.004

Contribution:

This is a co-authorship in which Silka Dawn Freiesleben has contributed considerably to the published article. Her contributions included conducting the formal statistical analysis and interpretation of the data with co-authors Herlind Megges and Natalie Jankowski. In addition, Silka Dawn Freiesleben played a considerable role in preparing the manuscript for publication. This included assisting in the writing of the original draft with co-author Herlind Megges, performing a review of the relevant literature, and preparing the first drafts of the visual representations of the data found in Table 1 and Fig. 2, which were further refined with co-author Herlind Megges. Afterwards, Silka Dawn Freiesleben assisted in producing several revised versions of the manuscript leading up to the finalised manuscript. All authors reviewed the final manuscript. She also assisted co-author Herlind Megges in proofreading and editing the letter to the editor during manuscript submission, as well as the responses made by co-author Herlind Megges to the peer reviewers during the peer-review submission process.

Publication 2: Megges H, Freiesleben SD, Rösch C, Wessel L, Knoll N, Peters O. User experience and clinical effectiveness with two wearable global positioning system devices in home dementia care. Alzheimer's & Dementia: Translational Research & Clinical Interventions. 2018; 4: 636-44. https://doi.org/10.1016/j.trci.2018.10.002

Contribution:

This is a co-authorship in which Silka Dawn Freiesleben has contributed considerably to the published article. Her contributions included conducting the formal statistical analysis and interpretation of the data with co-authors Herlind Megges and Christina Rösch. In addition, Silka Dawn Freiesleben played a considerable role in preparing the manuscript for publication. This included assisting in the writing of the original draft with co-author Herlind Megges, performing a review of the relevant literature, and preparing the first drafts of the visual representations of the data found in Tables 1, 2, 3, 4 and 5, which were further refined with co-authors Herlind Megges and Christina Rösch. Afterwards, Silka Dawn Freiesleben assisted in producing several revised versions of the manuscript leading up to the finalised manuscript. All authors reviewed the final manuscript. She also assisted co-authors Herlind Megges and Christina Rösch in proofreading and editing the letter to the editor during manuscript submission, as well as the responses made by co-author Herlind Megges to the peer reviewers during the peer-review submission process. Furthermore, Silka Dawn Freiesleben disseminated the final study results in international conferences (e.g., Alzheimer Europe Conference 10/2019 and Alzheimer’s Association International Conference 07/2018) in the form of podium talks and poster presentations. The presentation materials were prepared by her and reviewed by co-authors Herlind Megges, Christina Rösch and Oliver Peters.

Publication 3: Freiesleben SD, Megges H, Herrmann C, Wessel L, Peters O. Overcoming barriers to the adoption of locating technologies in dementia care: A multi-stakeholder focus group study. BMC Geriatrics. 2021; 21(378): 1-17. https://doi.org/10.1186/s12877-021-02323-6.

Contribution:

Silka Dawn Freiesleben is the first author and has contributed substantially to the published article. Her contributions included conceptualizing the study with co-authors Herlind Megges, Lauri Wessel and Oliver Peters by performing a review of the relevant literature to formulate study goals, research questions and hypotheses that would form the basis of the focus group interviews. She also assisted co-authors Herlind Megges, Lauri Wessel and Oliver Peters in securing funding acquisition by proofreading and providing critical feedbacks to the submitted research grant (Focus Area DynAge of the Freie Universität Berlin and Charité Universitätsmedizin Berlin grant number 50000003). Silka Dawn Freiesleben and co-author Herlind Megges developed the first drafts of the methodology, including building and formatting of focus group interview and selection of questionnaires. Silka Dawn Freiesleben acted as an assistant moderator in the focus group interview led by co-author Lauri Wessel. She along with co-authors Herlind Megges and Christina Herrmann are responsible for data curation. She led the formal data analysis, including the verbatim transcriptions of the interviews. All visual representations of the data (i.e., Tables 1 and 2, as well as in Additional files 1 and 2) were created by her. All authors reviewed the final manuscript. Furthermore, she wrote the letter to the editor and the responses to the peer reviewers during the peer-review submission process. Furthermore, Silka Dawn Freiesleben disseminated the final study results in national and international conferences (e.g., Alzheimer Europe Conference 10/2020 and 10/2019, and Deutsche Gesellschaft für Gerontologie und Geriatrie e.V. 09/2018) in the form of a podium talk and poster presentations. The presentation materials were prepared by her and reviewed by co-authors Herlind Megges, Christina Herrmann and Oliver Peters.

Date and stamp	Signature of first supervising university professor
Date	Signature of doctoral candidate

9. Printed copies of selected publications

9.1. Technology for home dementia care: a prototype locating system put to the test

Megges H, Freiesleben SD, Jankowski N, Haas B, Peters O. Technology for home dementia care: a prototype locating system put to the test. Alzheimer's & Dementia: Translational Research & Clinical Interventions. 2017; 3(3): 332-8. https://doi.org/10.1016/j.trci.2017.04.004.
Impact Factor: Scopus Journal Metrics: CiteScore: 9.1; Source Normalized Impact per Paper (SNIP): 1.833; SCImago Journal Rank (SJR): 2.49.*

* Note on the journal listing of Alzheimer's & Dementia: Translational Research & Clinical Interventions in the Institute for Scientific Information (ISI) Web of Knowledge: “TRCI is currently indexed in the Emerging Sources Citation Index (ESCI), which is part of the Web of Science Core Collection. As TRCI was accepted into the ESCI over the summer, the journal is currently in active evaluation by Clarivate to be added to the Science Citation Index Expanded (SCIE) and we should have an update on that by the end of the year.” Email answer from TRCI Managing Editor Phil Jackson on 28.10.2021.

Alzheimer's & Dementia: Translational Research & Clinical Interventions 3 (2017) 332-338

Featured Article

Technology for home dementia care: A prototype locating system put to the test

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Abstract

Introduction: The user experience of persons with dementia and their primary caregivers with locating systems is not firmly established.

Methods: Eighteen dyads used a prototype locating system during 4 weeks. Primary outcome measures were ratings of usability, and product functions and features. Secondary outcome measures were caregiver burden, perceived self-efficacy, frequency of use, and willingness to purchase the prototype. Changes in scores between baseline (T_1) and end of testing period (T_2) were compared by performing independent and dependent samples correlations and descriptive statistics.

Results: Seventeen dyads made up the final sample. Ratings of usability and product functions and features were fair, but usability ratings were significantly reduced after 4 weeks. Although the prototype was used infrequently by majority of the participants, most caregivers would be willing to purchase the prototype, with men more willing than women. No significant change in technological willingness, caregiver burden, or perceived self-efficacy was found between T_1 and T_2. Perceived self-efficacy significantly negatively correlated with willingness to purchase the prototype after 4 weeks.

Discussion: Results highlight the importance of including end users in the research and development phase of locating systems to improve the user experience in home dementia care. Necessary indications for further research are carrying out randomized controlled trials with larger, more representative samples and developing innovative software and hardware solutions.

Keywords: Assistive living technologies; Technology; Caregivers; Dementia; Locating systems; Tracking systems; User experience; Usability

1. Introduction

In 2015, the number of persons diagnosed with dementia (PwD) was estimated at almost 47 million worldwide [1]. By 2050, this number is projected to increase about 135 million owing primarily to aging populations [2]. Currently, most care received by PwD is provided by informal, primary caregivers, such as family members, friends, or others [3]. Research to date has overwhelmingly shown that informal care places a high amount of mental, physical and financial stress, and burden on caregivers, including suffering from anxiety, depression, sleep disturbances, reduced immune function, and job loss [4]. Accordingly, investing in research to develop innovative, promising, as well as equitable care solutions for home and residential dementia care is considered an essential component of a global dementia care plan [2]. To this end, developing assistive living technologies that particularly aid PwD to maintain their ability to

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independently carry out activities of daily living is regarded as a key research area [5], with much research to date focusing on the use of tracking or locating systems.

By using global positioning system (GPS) technology, locating systems make it possible to address one of the first significant sources of stress and burden faced by PwD and caregivers alike in the early stages of dementia, namely disorientation or getting lost while outside the home environment alone [6]. This is done by determining the location of PwD in real time and by providing assistance with orientation to PwD and caregivers when needed. In recent years, research on the user experience of locating systems by PwD and caregivers has gained increasing attention [7,8], yet differences in the definition of user experience between studies make comparing results difficult.

At present, a large number of locating systems, such as watches, tracking pagers, or shoe soles, are commercially available [9]. However, their adoption and long-term use remains low outside research and clinical settings [10,11]. It has been described that methodological limitations such as relying on proxy evaluations of user experience by having caregivers or professionals answer in place of PwD help contribute to the observed underutilization of locating systems [12]. Furthermore, the importance of adequate knowledge on using locating systems was emphasized [13]. Other studies using GPS technology focused on research questions regarding mobility and cognitive impairment. Their results indicated life space parameters may contribute to monitor functional decline in dementia [14], and caregiver burden was closely correlated to challenging walking behavior of PwD [15,16].

Accordingly, the aim of the present study was to evaluate the user experience regarding a prototype locating system in home dementia care to better understand the needs and preferences of PwD and their caregivers. User experience within this study is defined based on the ISONORM 9241/210 [17]. As user experience is a multifaceted construct that comprises users' affective, cognitive, and behavioral attitudes toward a product [17–19], we set out to assess participants' responses to the following variables: usability, ratings of the prototype's functions and features, caregiver burden, perceived self-efficacy, subjective frequency of use, and willingness to purchase the prototype.

2. Methods

2.1. Sample

A total of 18 dyads of PwD and their primary caregivers participated in our user study. Recruitment was done following a convenience sampling technique from eligible patients and their primary caregivers of the Charité University Hospital's Memory Clinic. To ensure having a more representative user evaluation, PwD with different dementia severities were included. In total, three (16.7%) had a mild cognitive impairment, six (33.3%) had a mild disease severity, and nine (50%) had a moderate disease severity based on their Mini–Mental State Examination (MMSE) scores obtained no longer than one month before inclusion, performed by an experienced neuropsychologist. Similarly, primary caregivers were made up of ten husbands (55.6%), six wives (33.3%), and two daughters (11.1%). Participants provided their written informed consent at baseline. Ethics approval was obtained by the Charité Ethics Board, number EA4/033/13.

2.2. Materials

2.2.1. Prototype locating system

The locating system used was a mobile application (app; webXells GmbH, Potsdam, Germany) featuring four main functions: locating, call, alarm, and service hotline, and two sub functions: zone mapping and zone sharing. As the name implies, the locating function allows to remotely locate PwD using GPS technology. In real time, a city map mapping the user's location is created (i.e., zone mapping). Caregivers are able to create individual habitual zones for PwD with the Geofencing function. Should the app locate a PwD as entering or leaving a habitual zone, a notification message can be sent to their caregiver (SMS; i.e., zone sharing). The call function allows users to come into telephone contact, whereas the alarm function allows PwD to call their caregiver when they need more urgent assistance, and the service hotline function enables users to obtain ongoing technological assistance. Our team selected this prototype as we have previously conducted a user study with an earlier version of the prototype with caregivers [20]. In short, the prototype was positively rated overall, suggesting its promising future research and development potential.

2.2.2. Additional products

To use the app, PwD received a Samsung Galaxy xCover smartphone with the prototype preinstalled. We recommended to wear the smartphone in an adjustable waistband, but depending on individual preferences, any other kind of wearing the device nearby and safely secured within clothing or handbag was optional. Caregivers received either a Samsung Galaxy Tab II tablet personal computer (PC; $n = 9$) or a Samsung Galaxy Note II smartphone ($n = 9$) with the prototype preinstalled. These products were selected as they feature a touch screen with a large display and are devoid of unnecessary functions. Fig. 1 shows the tablet PC and the smartphone, both with the installed prototype.

2.3. Study design

2.3.1. Baseline (T_1)

The entire testing period lasted for 4 weeks from baseline (T_1) to the end of the testing period (T_2). All questionnaires at T_1 and T_2 were completed by caregivers.

Fig. 1. Tablet PC for caregiver and smartphone for PwD, both with the installed prototype.

During the first meeting, caregivers completed a demographics questionnaire, the short version of the Zarit Burden Interview (ZBI) [21], and the General Self-Efficacy (GSE) scale [22]. The ZBI short version contains 12 questions, each scored on a five-point Likert scale ranging from 0 = never to 4 = nearly always. Total scores range from 0 to 48, where higher scores indicate higher subjective burden. The GSE scale was used to measure how caregivers perceive themselves when handling stressful situations. Questions follow a four-point Likert scale ranging from 1 = not true at all to 4 = exactly true. Total scores range from 1 to 40, with higher scores indicating higher perceived self-efficacy. The demographics questionnaire included questions on PwD's walking behavior, impairments in orientation, and the number of times caregivers had to search PwD outside the home environment. Two questions also assessed subjective technological experience, namely: (1) "How much experience do you have with the following products: cell phone without Internet, smartphone, tablet PC, and computer?" and (2) "How often do you use the following functions: SMS, e-mail, telephone, Internet, navigation system?" Each question used a four-point Likert scale ranging from 1 = none/never to 4 = a lot/very often, and total scores ranged from 9 to 36, with higher scores indicating a higher subjective technological experience. To measure technological commitment, four select questions of the German Technology Commitment Scale were used [23]. The questions specifically measured acceptance or openness toward technological products ($n = 3$) and perceived self-competence with regards to using such tools ($n = 1$) on five-point Likert scales ranging from 0 = not at all true to 4 = completely true. Final scores range from a possible 0 to 16, with higher scores indicating higher subjective technological commitment.

Dyads then participated in an interactive educational training session of 30 minutes during which they received their products and information on how to use them. Depending on preexisting technological experience, the training sessions lasted longer or were even shorter than 30 minutes. To verify whether the provided information was understood, caregivers completed these four tasks: (1) use the locating function to locate PwD; (2) use zone mapping function to map out the location of PwD; (3) use the call function to call PwD; and (4) call the service hotline. Afterward, caregivers completed the ISONORM 9241/10 questionnaire [24] to assess their usability rating of the prototype. This questionnaire measures seven areas of usability, including the following: (1) suitability for the task, (2) self-descriptiveness, (3) controllability, (4) conformity with user expectations, (5) error tolerance, (6) suitability for individualization, and (7) suitability for learning. Answers follow a seven-point Likert scale ranging from 1 = not at all satisfied to 7 = very satisfied, and the maximum number of points a person can obtain is 210. To examine whether dyads used the prototype on a regular basis, and to assess their ongoing experience, they received a user diary. Dyads were asked to specify a situation where they had used the prototype, describe any difficulties experienced, list the attitudes of the PwD toward the prototype, and report on how satisfied they were with the prototype overall on a scale ranging from 0 = not at all satisfied to 4 = very satisfied.

2.3.2. *End of testing period (T_2)*

Caregivers completed the ZBI, GSE, and ISONORM 9241/10 a second time to assess any possible changes from baseline. Furthermore, dyads completed a 40-minute semistructured interview to rate the prototype's product functions and features. The product functions and the main product features (i.e., font style, font size, font color, overall colors displayed, icons used to represent product functions, and labels given to product functions), were rated on a five-point Likert scale ranging from 0 to 4, with higher numbers indicating more positive ratings (0 = very poor, 1 = poor, 2 = fair, 3 = good, 4 = very good). Furthermore, caregivers reported their subjective frequency of use of the prototype on a scale ranging from 0 = never used to 4 = used very often. In addition, participants commented on their quantitative ratings within the interview. To examine whether caregivers' ability to use the prototype had improved over the 4 weeks, the same four practical tasks at baseline were readministered. Finally, the caregivers were asked if they would purchase the prototype (0 = yes, 1 = no) and for the maximum amount of money they would spend for a system covering all individual needs. Possible answers covered the amounts of 39.99€, 59.99€, 79.99€, and 99.99€.

2.4. Statistical analysis

SPSS Statistics 23 was used to analyze data. T_1 and T_2 results were compared by performing independent samples t-tests, paired samples t-tests, Pearson's correlations, chi-square tests, and descriptive statistics.

3. Results

3.1. Participant characteristics

Before data analysis, data were inspected for outliers and were not detected. Of the 18 dyads included at T_1, one dyad dropped out for reasons unrelated to study involvement (dropout rate: 5.6%). Unless otherwise specified, the reported results are from these 17 dyads. Participant characteristics at baseline are presented in Table 1.

As expected, MMSE scores correlated with baseline caregiver burden scores, $r = -0.53$, $P = .024$. No other significant findings between other demographic variables were found at baseline. Regarding PwD's walking behavior, the majority were able to walk outside alone at study inclusion ($n = 14$; 82.4%), but several were rated as displaying impairments with orientation, ranging from none ($n = 3$; 17.6%), mild ($n = 4$; 23.5%), moderate ($n = 7$; 41.2%), to severe ($n = 3$; 17.6%). Almost all caregivers never had to search PwD outside the home environment ($n = 15$; 88.2%), and only one caregiver (5.9%) had used a locating system in the past.

3.2. Primary outcome measures

3.2.1. Usability

The total usability rating of the prototype declined significantly from T_1 to T_2, $t(16) = 2.34$, $P = .032$. The variation in range of scores is also larger at T_2, indicating that caregivers' usability rating was more similar at T_1 and more widespread at T_2. Results are displayed in Fig. 2. Concerning the seven usability subcategories, all scores decreased from T_1 to T_2, with categories one (i.e., suitability

Table 1
Participant characteristics at baseline (T_1)

Characteristic	PwD (n = 18)	Caregivers (n = 18)
Gender ratio (male/female)	7/11	10/8
Age (years); range	71.94 ± 5.01; 62–82	66.89 ± 10.65; 41–78
MMSE score (out of 30)	18.89 ± 7.49 (5–29)	
MCI (cutoff 28)	3	—
Mild (cutoff < 28 > 20)	7	—
Moderate (cutoff ≤ 20)	8	—
Number of years diagnosed with dementia		
Two or less	6	—
Three or more	12	—
Educational attainment		
High school	—	5
College	—	2
University	—	11
Living with PwD	—	16
Technological experience (out of 36)	—	23.1 ± 6.0 (9–32)
TCS (out of 16)	—	9.9 ± 3.3 (5–16)
GSE (out of 40)	—	29.7 ± 4.8 (19–36)
ZBI (out of 48)	—	13.4 ± 7.2 (0–28)

Abbreviations: PwD, persons diagnosed with dementia; MMSE, Mini–Mental State Examination; MCI, mild cognitive impairment; Technological experience, higher scores indicate higher technological experience; TCS, Technology Commitment Scale—higher scores indicate higher technological commitment; GSE, General Self-Efficacy Scale—higher scores indicate higher perceived self-efficacy; ZBI, Zarit Burden Interview—higher scores indicate higher burden.

NOTE. Continuous variables are displayed as mean value ± standard deviation, with minimum and maximum scores in parentheses.

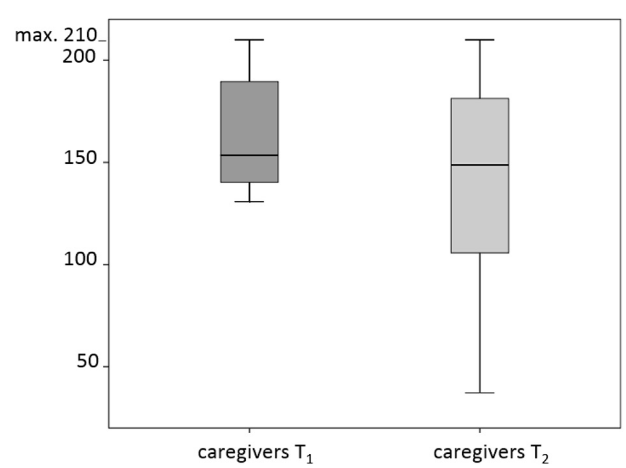

Fig. 2. Total usability evaluation of the prototype with the ISONORM 9241/10: scores ranging from 0 to 210; higher scores indicate better usability ratings. T_1: M = 163.5 ± 28.7; min/max = 130.75/210. T_2: M = 139.94 ± 46.5; min/max = 37.25/210. Continuous variables are displayed as mean value ± standard deviation. Abbreviations: min, minimum; max, maximum; M, mean value.

for the task), three (i.e., controllability), four (i.e., conformity with user expectations), and six (i.e., suitability for individualization) significantly reducing, where $t(16) = 2.37$, $P = .031$; $t(16) = 2.27$, $P = .037$; $t(16) = 2.17$, $P = .045$; and $t(16) = 2.12$, $P = .05$, respectively. Usability rating at T_1 or T_2 did not correlate with any relevant variable at either time point.

3.2.2. Ratings of product functions and features

3.2.2.1. Product functions

Overall, the prototype was rated fairly with respect to product functions (M = 2.4; standard deviation [SD] = 0.9; min/max = 0/4). Of the functions to be rated, the locating function was rated most positively (M = 2.8; SD = 1.1; min/max = 0/4), followed by the zone mapping function (M = 2.6; SD = 1.2; min/max = 0/4), the service hotline function (M = 2.4; SD = 1.3; min/max = 0/4), the call function (M = 2.3; SD = 1.2; min/max = 0/4), and the zone sharing function (M = 2.2; SD = 1.5; min/max = 0/4). The alarm function was rated most negatively (M = 2.0; SD = 1.7; min/max = 0/4). No significant differences between function ratings were found. Comments made by participants identified three specific areas of dissatisfaction with the zone mapping function, namely the number of steps needed to take to map zones ($n = 3$; 17.6%), the complexity of these steps ($n = 3$; 17.6%), and the reliability of this function ($n = 4$; 23.5%). In addition, five caregivers (29.4%) explicitly stated the overall functioning of the prototype as unreliable due to technological problems. In general, they complained about the complex functions and lacking reliability. In detail, they criticized the not precisely working Geofencing. One caregiver mentioned that the prototype had helped them locate the PwD three times during the study.

3.2.2.2. Product features

Similarly, the prototype's product features were fairly rated (M = 2.3; SD = 0.9; min/max = 0/4). Of the features to be rated, the overall colors displayed received the best rating (M = 2.9; SD = 0.9; min/max = 1/4), followed by the labels given to the different product functions (M = 2.7; SD = 0.7; min/max = 2/4), the font style (M = 2.6; SD = 0.9; min/max = 1/4), and the icons used (M = 2.5; SD = 0.9; min/max = 1/4). The font size and font colors were rated equally least positively (M = 2.1; SD = 1.1; min/max = 0/4; min/max = 1/4, respectively). A significant difference was found between the overall colors displayed and the font colors, $t(16) = 3.25$, $P = .005$, as well as with font size, $t(16) = 2.64$, $P = .018$. Some participants (n = 4; 23.5%) would have preferred to wear the prototype integrated into a watch or another small device avoiding to stigmatize the PwD.

Ratings of the product functions or features did not correlate with any relevant variable at T_1 or T_2, and dyads' overall weekly satisfaction ratings of the prototype furthermore show that it was fairly rated each week ($M_{range} = 1.83–2.3$; $SD_{range} = 0.82–1.2$; $min/max_{range} = 0/3$), with no significant difference found between any given week. Further reports from the user diary revealed a list of difficult situations while using the prototype. One caregiver reported on removal of the smartphone from the waistband by the PwD. The locating device was temporarily lost and by this caused additional burden. In terms of the acceptance of the PwD to constantly wear the device, $n = 4$ (23.5%) reported overall positive and $n = 2$ (11.8%) negative attitudes. If the caregiver received a tablet PC or a smartphone did neither influence the primary outcome measures nor the time to complete tasks.

3.3. Secondary outcome measures

3.3.1. Caregiver burden and perceived self-efficacy

No significant difference in caregiver burden from T_1 (M = 13.4; SD = 7.2; min/max = 0/28) to T_2 (M = 12.4; SD = 7.6; min/max = 0/28) or in perceived self-efficacy from T_1 (M = 29.7; SD = 4.8; min/max = 19/36) to T_2 (M = 28.3; SD = 4.8; min/max = 18/38) was found.

3.3.2. Subjective frequency of use and time to complete tasks

Dyads believed to have used the prototype a moderate number of times during the testing period (M = 2.3; SD = 1.1; min/max = 1/4), and most mentioned having used it when going for a walk ($n = 8$; 47.1%), visiting family and friends ($n = 5$; 29.4%), and for grocery shopping ($n = 5$; 29.4%). Although the time required to complete the four practical tasks decreased from T_1 (M = 5:24 minutes; SD = 4:27; min/max = 1:17/19:24) to T_2 (M = 3:45 minutes; SD = 2:05; min/max = 0:37/9:15), no significant difference between both time points was found.

3.3.3. Willingness to purchase the prototype

Most caregivers ($n = 13$; 76.5%) mentioned being willing to purchase the prototype, and results of our chi-square test show that men were more willing than women, χ^2 $(1, N = 17) = 7.46$, $P = .029$. Concerning the pricing for a system that covers all needs, the largest proportion of participants chose 39.99€ ($n = 8$; 47%) as suitable. Followed by 23.5% ($n = 4$), who would pay up to 59.99€, 11.8% ($n = 2$) up to 79.99€, and 17.6% ($n = 3$) up to 99.99€. In addition, a significant negative correlation between perceived self-efficacy at T_2 and willingness to purchase the prototype was found, $r = -0.483$, $P = .049$.

4. Discussion

The present study reports on the user experience with a prototype locating system in home dementia care. As expected, baseline MMSE and caregiver burden scores were significantly correlated. Regarding user experience, usability ratings show that the prototype was rated fairly at both time points, although surprisingly ratings significantly decreased over time. This indicates several experienced technical deficiencies affecting usability and underlines the importance of reliable systems (e.g., regarding GPS accuracy and Geofencing). Other studies already stated challenges concerning complex GPS-locating systems [25]. Reliability and user-friendliness are of highest importance, especially for the caregiver, but also for the PwD. In addition to this, our results show that potential users have to be trained. This indicates the need to develop training manuals and programs for users with few technological experience, also stated by other authors [13].

Furthermore, we found that four subcategories of usability (i.e., suitability for the task, controllability, conformity with user expectations, and suitability for individualization) significantly diminished after time. Focusing on these four areas of usability when developing locating systems may contribute toward improving usability scores, especially after users acquire more experience. This suggestion seems particularly relevant given that usability ratings were not significantly associated with any other variable, implying that the inherent characteristics of the prototype influenced usability ratings rather than the external characteristics of participants (e.g., caregiver burden, or technological experience and commitment). The fair ratings of the product's functions and features reported here are encouraging, considering that the locating system was merely a prototype. Although these results are largely descriptive, this type of information regarding usability is surprisingly limited in the available literature, which limits our knowledge on the needs and preferences of potential users. As expected, participants preferred the locating function, but no function was rated significantly better than another.

In any case, the fair ratings of the prototype are at odds with the finding that it was used infrequently by most of the participants. One way to interpret this discrepancy is that PwD and caregivers are open to the idea of receiving additional forms of support in home dementia care and accordingly rated the prototype fairly overall. Other studies suggest the high potential of assistive technologies in home dementia care similarly [25], in particular, the positive effects of locating systems for caregivers were mentioned [6]. Interestingly, we additionally found that most caregivers, men more than women, would be willing to purchase the prototype. Those who rate themselves as handling stressful situations well are more inclined to purchase a locating system. This is reflected by a significant negative correlation between self-efficacy at T_2 and willingness to purchase the prototype.

The statistical power of this study is limited by the small sample size. Furthermore, PwD were not directly in focus of our research, which might be a methodological limitation [12]. Nevertheless, aiming to explore the dyad as an entity, we gathered some interesting insights on PwD indirectly. Because the assessment of the user experience of cognitively impaired is a challenge, we recommend to focus on qualitative methods, such as problem-centered interview [26] and participatory design approaches [27]. Including dyads in early development would additionally support recommendations with the aim to provide a person-centered approach for dementia care [28]. A further limitation of our study is the lack of data with respect to the frequency of use, which was caused by a technological limitation of the tested system. Also other small user studies have experienced challenges, leading to comparable limitations [6,25]. Finally, it can be speculated that the duration of our study was too short and PwD were not sufficiently impaired to investigate the usefulness of the tested system in depth.

In summary, our study could be seen rather as a pilot study in this very young research area, focusing on implications for further research obtainable from these findings. Thus, developing innovative software solutions for caregivers and hardware solutions for PwD is one relevant implication. In this context, future experiments should also focus on locating systems already available and evaluating their current quality. Nevertheless, the most important conclusion is the high relevance of carrying out randomized controlled trials with larger, more representative samples in a real environment. This recommendation was also stated by other authors [12,29]. Proposed suitable outcome measures in earlier studies were "time spent searching" and "days until long-term admission" [29] as well as caregivers' well-being and quality of life [15]. Because technological limitations often inhibit to investigate the usefulness of assistive technology, we recommend to focus on the usability, until these kinds of limitations have been overcome. In addition, future studies that include different stakeholders will likely help us gain more insights into how to better address the needs and preferences of PwD and caregivers to improve their user experience with locating systems. As this kind of research addresses many disciplines such as business, design, gerontology, neurology, and psychiatry, focusing on interdisciplinary research is required.

Taken together, our findings highlight the importance of including end users in the research and development phase of locating systems to improve user experience of locating systems in home dementia care.

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RESEARCH IN CONTEXT

1. Systematic review: The authors reviewed the literature (e.g., PubMed) and meeting abstracts and presentations. Although a number of locating systems exist, their adoption in home dementia care remains low, and the inclusion of persons with dementia in user experience studies is limited. These relevant citations are appropriately cited.
2. Interpretation: Our findings highlight the importance of including persons with dementia and their primary caregivers in the research and development phase of locating systems to improve use experience in home dementia care.
3. Future directions: Recommendations to improve user experience are provided based on ratings of usability, and product functions and features. Future studies more heavily involving persons with dementia, as well as different stakeholders, are welcomed.

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9.2. User experience and clinical effectiveness with two wearable global positioning system devices in home dementia care

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Impact Factor: Scopus Journal Metrics: CiteScore: 9.1; Source Normalized Impact per Paper (SNIP): 1.833; SCImago Journal Rank (SJR): 2.49.*

* Note on the journal listing of Alzheimer's & Dementia: Translational Research & Clinical Interventions in the Institute for Scientific Information (ISI) Web of Knowledge: “TRCI is currently indexed in the Emerging Sources Citation Index (ESCI), which is part of the Web of Science Core Collection. As TRCI was accepted into the ESCI over the summer, the journal is currently in active evaluation by Clarivate to be added to the Science Citation Index Expanded (SCIE) and we should have an update on that by the end of the year.” Email answer from TRCI Managing Editor Phil Jackson on 28.10.2021.

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Featured Article

User experience and clinical effectiveness with two wearable global positioning system devices in home dementia care

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Abstract

Introduction: The user experience and clinical effectiveness with wearable global positioning system (GPS) devices for persons with dementia (PwDs) and caregivers (CGs) remain unclear although many are available.
Methods: Using a crossover design, 20 dyads tested two similar commercial GPS watches (products A and B) at home for 4 weeks each. Usability, product functions, design features and product satisfaction at home and the clinic were investigated. Caregiver burden and quality of life assessed clinical effectiveness.
Results: The final 17 dyads rated the usability, telephone function, overall design features, font, buttons, and battery life of B significantly better than A. PwDs rated the overall design features and buttons of A significantly better than CGs. Product satisfaction with both products was significantly lower at home. Clinical effectiveness was not found.
Discussion: User experience can be improved by optimizing specific product details. This might translate to clinical effectiveness. Social desirability bias may explain different product satisfaction ratings.

Keywords: Assistive technology; Caregiving; Clinical effectiveness; Dementia; GPS; Home dementia care; Locating systems; Monitoring; Product satisfaction; Tracking systems; Usability; User experience; Wandering; Wearables

1. Introduction

Assistive technologies intended to aid persons with dementia (PwDs) and their primary caregivers (CGs) can be seen as promising, potentially cost-effective tools that could help optimize the amount of care provided in informal care settings [1,2]. "Tracking" or locating systems are specific assistive technologies that enable the location of PwDs through a global positioning system (GPS) technology. Accordingly, GPS devices aim to promote the safety of PwDs who exhibit wandering behaviors [3,4]. Therefore, these products can also reduce the stress and burden experienced by PwDs and CGs that is typically associated with wandering behaviors [5,6].

To date, studies on prototype and commercial GPS devices in dementia care have used different product types with similar functions and design features. Typically, products are small (e.g., pager sized or watch sized), discrete or nonvisible (e.g., worn around the waist, neck, wrist, or

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placed inside a pocket or shoe sole), have two to six main functions (e.g., location, telephone, geofencing, alarm, fall detection, and speed alert), no buttons (i.e., passive systems) or one to three buttons (i.e., active systems), and are lightweight [5–11]. These functions and features are in line with most expert recommendations [7,12].

However, research has also shown that assistive technologies for dementia care lack clear-cut quality standards regarding their design. Moreover, these technologies are rarely developed using techniques of user-centered design [13,14]. It is therefore likely that most products exhibit a suboptimal design, which impedes technology acceptance and long-term use [7,13]. This may partly explain why commercial GPS devices for dementia are rarely used outside clinical research settings [7,10,15], although many are commercially available [14,16]. Furthermore, most studies on GPS devices focus on feasibility, acceptability, and usability [5–10,17,18] without providing a more holistic understanding of end users' experience with such devices. In addition, it is unclear whether the use of such products results in clinical effectiveness [14,19,20]. As it stands, findings pertaining to the clinical effectiveness of assistive technologies are shockingly sparse [13,21,22]. For GPS devices, it is not clear whether they provide measurable aid in home dementia care beyond being accepted and feasible.

For these reasons, this study is based on the construct of user experience (UX), which is typically defined as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service" [23]. In other words, it is a multidimensional construct that includes affective, cognitive, and behavioral dimensions that users exhibit before, during, and after product use [24,25]. The theoretical background of UX overlaps with key aspects of the technology acceptance model [26], as a recent review analyzed [27]. In short, this model states that perceived ease of use and usefulness of a product, as well as external factors (e.g., technological affinity) contribute to actual acceptance and use. In contrast, UX focuses more on specific product characteristics and their associations with outcomes, including satisfaction or acceptance, which are moderated by specific usage situations [28].

Therefore, the central aim of this study was to perform an in-depth comparison of the UX of PwDs and their informal CGs with two similar commercial GPS watches in home dementia care. To date, only three studies have compared more than one commercial GPS device, yet the product types differed [5,11,18]. Of these studies, one did not collect data from PwDs [11], one did not focus on UX [5], and the other focused on acceptability without describing the devices used [18]. A direct comparison of GPS watches is particularly warranted given that it has been recommended that products take the form of familiar, everyday objects (e.g., watch) to help ensure their adoption [7,10]. Furthermore, comparing commercial GPS products could provide additional information on their possible effectiveness [14] and on functions and features that lead to a more favorable UX. In addition, we examined whether product satisfaction differs when reported at home versus a clinical setting. One could hypothesize that PwDs and CGs report a more positive product satisfaction in clinical settings based on a social desirability bias [29,30]. A second aim was to examine whether product use would result in clinical effectiveness for PwDs and CGs.

2. Methods

2.1. Sample

Twenty dyads ($n = 20$ PwDs, $n = 20$ CGs) were recruited following a convenience sampling technique from memory clinic patients in 2016. PwDs who could move about outside the home were included. Years since diagnosis and a Mini-Mental State Examination score assessed up to 1 month before baseline were available for all PwDs. All participants provided their written informed consent for participation in this UX study.

2.2. Materials

Two similar commercial GPS watches marketed for people with orientation impairments (hereafter products A and B) were selected (see Table 1). These were the only two GPS watches on the German market with a location and telephone function. In combination with products A and B CGs received a study-specific smartphone to prevent bias with two native Android applications preinstalled to be able to locate PwDs. By pressing one defined button of product A or the button of product B, a call is sent out to the smartphone and PwDs could accept an incoming call by pressing this button. With both smartphone applications, CGs could view the last recognized position of product A or positions of product B on an online map. To support product learning, we developed a 60-minute technological training session based on dementia communication guidelines [31,32]. This included hands-on exercises by having PwD practice calling and accepting a call from CG, and CG calling and locating PwD on a map.

2.3. Study design

Products A and B were compared using a 2 $\times$ 2 cross-over design (sequences AB|BA, two study periods, four assessment points). Each product was tested at home for 4 weeks. The first study period lasted from baseline at T1 to T2.1, and the second study period lasted from T2.2 to T3.

2.3.1. First study period

At T1, standard demographic data were measured. Also, CGs and PwDs were independently asked to report on a history of wandering events. Then, four secondary

Table 1
Product description of GPS watches for PwDs

	A	B
Product name	HIMATIC GPS Uhr Alpha [*HIMATIC GPS Alpha watch*]	ReSOS-2—Die Notfalluhr [*ReSOS-2–the emergency watch*]
Product picture		
Size	45.5 mm × 64.5 mm × 17.5 mm	43.0 mm × 43.0 mm × 19.0 mm
Weight	70 g	66 g
Main colors	Black and blue	Black and red
Buttons	Five (Ø: 0.5 mm)	One (1.8 mm × 0.5 mm)
Band type	Silicone strap	Silicone strap
Battery	Li-ion (3.7 V, 500 mAh)	Li-ion (850 mAh)
Charging method	DC 5 V USB charger cable	Charging station with USB cable
Software/application	Native Android App: HIMATIC GPS Uhr Alpha	Native Android and iOS App: ReSOS-2
Website	https://himaticmobile.de/personenortung.html	http://notfall-uhr.de/

Abbreviations: A, product A; B, product B; GPS, global positioning system; PwDs, persons with dementia; USB, Universal Serial Bus.
NOTE. Size noted as width by length by depth; websites last accessed on August 23, 2018; both watches have a SIM card that allows for two-way communication and GPS connection.

outcome measures assessed clinical effectiveness: CG burden (Zarit Burden Interview, range 0–48) [33], quality of life of PwDs and CGs (European Health Interview Surveys-quality of life, range 0–48) [34], orientation impairments, and subjective burden of getting lost (self-developed six-point Likert scales ranging from 0 = no impairments/not at all worried to 5 = very impaired/very worried, with CGs appraising PwDs). Higher scores represent more negative endpoints, except for the European Health Interview Surveys-quality of life. The covariate technological affinity was assessed for PwDs and CGs with the technological affinity scale for electronic products (TA-EG, range 19–95) [35]. Dyads then randomly received their first product and completed the technological training session. The primary outcome measure usability was then assessed with the International Standardization Organisation Norm (ISONORM) 9241/10 scale (range 0–210) [36,37]. This scale relies on principles of the International Standardization Organisation [38] and is recommended for UX studies [39]. The scale measures seven usability domains, including suitability for the task, self-descriptiveness, controllability, conformity with user expectations, error tolerance, suitability for individualization, and suitability for learning. For the TA-EG and ISONORM 9241/10 scales, higher scores represent more positive endpoints.

At T2.1, dyads returned to the clinic and first performed the same tasks as at T1 during the technological training session as a way to control product learning, followed by a reassessment of usability with the ISONORM 9241/10 scale. Thereafter, dyad members rated two further primary outcome measures, namely the main product functions (i.e., telephone and location) and design features (i.e., color, font, size, weight, buttons, and battery life) on five-point Likert scales ranging from 0 = not at all good to 4 = very good. Font ratings assessed the font's typeface, size, and color, and ratings of buttons measured amount, size, sound, haptic feedback, and color. Then, dyads jointly rated their overall product satisfaction using the same five-point Likert scale. In addition, the covariate subjective frequency of use of the location function was assessed by CGs on a five-point Likert scale ranging from 0 = not at all to 4 = very often. All custom items are displayed in Supplementary Table 1. Also, secondary outcome measures and the TA-EG were readministered. Finally, participants were asked whether any wandering events and technical difficulties with the product had occurred.

2.3.2. *Second study period*

T2.2 directly followed T2.1. Here, dyads received their second product and completed the technological training session, followed by filling out the ISONORM 9241/10 scale. At T3, dyad members' UX with the second product was assessed following the same methodological procedure as at T2.1.

2.3.3. *Home assessments*

At the end of each week, dyads jointly rated their overall weekly product satisfaction with product A or B at home with the same question as at the clinic.

2.4. Statistical analysis

Data were analyzed using Statistical Package for the Social Sciences Statistics 24. Because of the nonindependence between PwDs and CGs within a dyad [40], PwDs and CGs data were analyzed with paired samples t tests for primary and secondary outcome measures. Independent samples t tests between products were additionally performed for primary outcome measures. Furthermore, secondary outcome measures and covariates were analyzed with Spearman's rank-order correlations and one-way repeated measures analysis of variances. Potential order effects between sequences AB and BA were examined with independent samples t tests.

3. Results

3.1. Participant characteristics

Baseline data were first inspected for outliers, and one dyad with a PwD Mini-Mental State Examination score more than 2 SDs (standard deviations) below the mean was excluded [41]. Two dyads dropped out at T2.1 (dropout rate 10%) stating product dissatisfaction because of technical difficulties, with no other significant differences compared with nondropouts, and both dyads received different products. In the final sample of 17 dyads (n = 17 PwDs, n = 17 CGs), seven received product A and 10 received product B at T1 and vice versa at T2.2. Ten CGs and three PwDs reported a history of wandering events. All participant characteristics are displayed in Table 2.

3.2. Primary outcome measures

Results of the ISONORM 9241/10 usability scale for both products were fair to good and are presented in Table 3 and Supplementary Fig. 1. Independent samples t tests showed that dyads rated product B better than A at all assessments. At T1, $t(32) = -2.11$, $P < .05$ ($M_A = 146$, SD = 40.7, $M_B = 171$, SD = 27.7); at T2.1, $t(32) = -2.29$, $P < .05$ ($M_A = 131$, SD = 45.5, $M_B = 164$, SD = 38.6); at T2.2, $t(32) = -4.32$, $P < .001$ ($M_A = 123$, SD = 42.9, $M_B = 175$, SD = 16.6); and at T3, $t(32) = -2.47$, $P < .05$ ($M_A = 117$, SD = 60.7, $M_B = 162$, SD = 35.7). To assess differences between PwD and CG ratings, paired samples t tests revealed only one significant result at T1 for sequence AB, where the ratings of PwDs were lower than those of CGs: $t(6) = -4.77$, $P < .01$. Paired samples t tests to test changes in usability scores over time revealed that neither the usability ratings of PwDs and CGs nor of dyads with either product differed after each study period.

Results concerning product function and design feature ratings are presented in Table 4 and Fig. 1. Independent samples t tests revealed a significant difference in dyads' rating of the telephone function at T2.1 between products, where $t(32) = -2.63$, $P < .05$ ($M_A = 2.1$, SD = 1.0, $M_B = 3.0$, SD = 0.8). For overall design features, dyads rated product A worse than B at T3, where $t(32) = -3.18$, $P < .01$ ($M_A = 13.7$, SD = 4.3, $M_B = 18.4$, SD = 4.4) and CGs at T2.1, where $t(15) = -2.28$, $P < .05$, similar to PwDs at T3, where $t(15) = -2.56$, $P < .05$. Concerning individual design features, dyads rated the font and buttons of product A worse than those of B at T2.1, $t(32) = -2.24$, $P < .05$ ($M_A = 2.4$, SD = 0.7, $M_B = 3.1$, SD = 0.9) and $t(32) = -4.03$, $P < .001$ ($M_A = 1.9$, SD = 1.2, $M_B = 3.3$,

Table 2
Participant characteristics at baseline (T1)

Characteristics	PwDs (n = 17)	CGs (n = 17)
Age, mean ± SD [range]	71.7 ± 6.9 [56–80]	67.7 ± 8.0 [51–77]
Gender ratio (% female)	8/9 (53)	9/8 (47)
Education		
High school, n (%)	7 (41)	7 (41)
College, n (%)	2 (12)	1 (6)
University, n (%)	8 (47)	9 (53)
MMSE score, mean ± SD [range]	18.2 ± 4.3 [12–25]	—
Mild dementia (20–25), n (%)	8 (47)	—
Moderate dementia (12–19), n (%)	9 (53)	—
Years since diagnosis		
>1, n (%)	1 (6)	—
1–2, n (%)	5 (29)	—
2–3, n (%)	4 (24)	—
3–4, n (%)	2 (12)	—
>5, n (%)	5 (29)	—
History of wandering events		
None, n (%)	14 (82)	7 (41)
1–3 times, n (%)	3 (18)	8 (47)
4–6 times, n (%)	0	2 (12)
>7 times, n (%)	0	0
TA-EG (19–95)	71.2 ± 7.3 [58–85]	74.1 ± 6.1 [63–83]

Abbreviations: CGs, caregivers; MMSE, Mini-Mental State Examination; PwDs, persons with dementia; SD, standard deviation; TA-EG, technological affinity scale for electronic products.
NOTE. Percentages rounded to the nearest whole number.

Table 3
ISONORM 9241/10 usability ratings over the course of the study

	Study period 1		Study period 2	
Sequence	T1	T2.1	T2.2	T3
AB (n = 7 dyads)*				
PwDs	126 ± 37.3†	116 ± 58.8	170 ± 15.3	168 ± 32.9
CGs	165 ± 36.2†	147 ± 20.9	179 ± 17.7	155 ± 39.8
BA (n = 10 dyads)*				
PwDs	170 ± 28.2	153 ± 48.8	117 ± 49.6	111 ± 67.0
CGs	171 ± 28.8	176 ± 21.5	128 ± 36.7	123 ± 56.7

Abbreviations: A, product A; B, product B; CGs, caregivers; PwDs, persons with dementia; ISONORM, International Standardization Organisation Norm; SD, standard deviation.
NOTE. Continuous variables are displayed as mean value ± SD.
*Independent samples t tests for dyads: B rated better than A at all time points, P value <.05.
†Paired samples t tests for within-dyad effects: PwDs rated A worse than CGs, P value <.01.

$P < .05$), respectively. At T3, the font, $t(32) = -3.20$, $P < .01$ ($M_A = 2.6$, SD = 1.0, $M_B = 3.6$, SD = 0.7), buttons, $t(32) = -2.67$, $P < .05$ ($M_A = 2.2$, SD = 1.5, $M_B = 3.4$, SD = 0.8), and battery life, $t(32) = -3.12$, $P < .01$ ($M_A = 1.1$, SD = 1.1, $M_B = 2.4$, SD = 1.3) of product A were rated worse than those of B by dyads. Independent samples *t* tests for CGs at T2.1 revealed significant differences in the ratings of font, $t(15) = -2.70$, $P < .05$ and buttons, $t(15) = -3.76$, $P < .01$, and at T3 for buttons, $t(15) = -3.03$, $P < .01$, all in favor of product B. Likewise, ratings of PwDs at T2.1 were significantly different for buttons, $t(15) = -2.38$, $P < .05$, and at T3 for font, $t(15) = -2.71$, $P < .05$, size, $t(15) = -2.41$, $P < .05$, and battery life, $t(15) = -2.73$, $P < .05$. Furthermore, paired samples *t* tests showed that the overall design features of product A were rated worse by CGs than by PwDs at T2.1, where $t(6) = 2.44$, $P = .05$. For individual design features, PwDs rated the buttons of product A better than CGs at T2.1, $t(6) = 2.71$, $P < .05$ and at T3, $t(9) = 2.70$, $P < .05$. To test potential order effects based on receiving product A or B first, independent samples *t* tests were performed and yielded nonsignificant differences in primary outcome measures.

Finally, results of paired samples *t* tests for product satisfaction ratings at the clinic versus home revealed several significant differences, with consistently higher ratings at the clinic. Specifically, a significant difference was found for product A at T3, where $t(19) = -5.08$, $P < .001$ ($M_{clinic} = 2.2$, SD = 1.0, $M_{home} = 1.1$, SD = 0.9) and for product B at T2.1, $t(19) = -2.90$, $P < .01$ ($M_{clinic} = 2.8$, SD = 0.8, $M_{home} = 2.1$, SD = 1.0) and at T3, $t(13) = -3.31$, $P < .01$ ($M_{clinic} = 2.3$, SD = 1.4, $M_{home} = 1.1$, SD = 1.0).

3.3. Secondary outcome measures and covariates

Secondary outcome measures and covariates obtained over the course of the study are presented in Table 5. At baseline, Spearman's rank-order correlations revealed that quality of life and subjective burden of getting lost significantly correlated ($r_s = 0.40$, $P < .05$), and that the latter significantly correlated with orientation impairments ($r_s = 0.73$, $P < .001$) and age ($r_s = -0.36$, $P < .05$). Furthermore, paired samples *t* tests for secondary outcome measures were performed to test any within-dyad effects between PwDs and CGs. Significant results were found for orientation impairments at T1, $t(16) = 4.01$, $P < .001$, T2.1, $t(16) = 3.85$, $P < .001$, and T3, $t(16) = 2.31$, $P < .05$, as well as for subjective burden of getting lost at T1, $t(16) = 12.26$, $P < .001$, T2.1, $t(16) = 4.82$, $P < .001$, and T3, $t(16) = 5.13$, $P < .001$. A significant difference was also found for the European Health Interview Surveys-quality of life at T1, $t(16) = -2.21$, $P < .001$. In all cases, PwDs rated themselves significantly better than CGs.

Examination of clinical effectiveness with one-way repeated measures analysis of variances revealed no significant changes over the study duration. For the covariate TA-EG, a significant main effect of time for PwDs, F (2, 32) = 16.03, $P < .001$ and for CGs, F (1.11, 17.73) = 23.64, $P < .001$ was found, where scores at T1

Table 4
Product function and design feature ratings over the course of the study

	T2.1				T3			
	A (*n* = 7 dyads)		B (*n* = 10 dyads)		A (*n* = 10 dyads)		B (*n* = 7 dyads)	
Variables	PwDs	CGs	PwDs	CGs	PwDs	CGs	PwDs	CGs
Product functions								
Telephone*	2.1 ± 0.9	2.1 ± 1.1	3.0 ± 0.8	2.9 ± 0.9	2.1 ± 1.0	2.7 ± 1.1	2.7 ± 1.1	2.9 ± 1.2
Location	—	2.9 ± 0.9	—	2.7 ± 1.2	—	2.7 ± 0.8	—	2.9 ± 0.7
Design features								
Overall†,‡,§	16.3 ± 4.2¶	12.0 ± 4.3¶	17.2 ± 4.2	16.4 ± 3.6	14.4 ± 3.7	12.9 ± 4.8	19.4 ± 4.4	17.4 ± 4.5
Color	3.0 ± 0.8	2.4 ± 1.3	2.8 ± 0.9	2.9 ± 0.9	2.6 ± 1.0	2.9 ± 0.7	3.0 ± 0.8	3.0 ± 0.8
Font*,†,‡,§	2.7 ± 0.5	2.1 ± 0.7	3.0 ± 1.1	3.1 ± 0.7	2.8 ± 0.8	2.4 ± 1.2	3.7 ± 0.5	3.4 ± 0.8
Size§	3.0 ± 1.2	2.3 ± 0.8	2.4 ± 1.2	2.5 ± 0.7	2.5 ± 1.1	2.3 ± 1.1	3.6 ± 0.5	2.4 ± 1.3
Weight	2.9 ± 0.7	2.4 ± 1.0	3.3 ± 0.8	2.9 ± 1.0	2.6 ± 1.2	2.8 ± 1.1	3.3 ± 1.1	3.0 ± 0.8
Buttons*,†,‡,#,**	2.6 ± 0.5††	1.1 ± 1.2††	3.3 ± 0.7	3.2 ± 1.0	2.7 ± 1.3††	1.6 ± 1.7††	3.1 ± 1.1	3.6 ± 0.5
Battery life†,§	2.1 ± 1.2	1.6 ± 1.5	2.4 ± 1.1	1.8 ± 1.1	1.2 ± 1.1	0.9 ± 1.1	2.7 ± 1.1	2.0 ± 1.5

Abbreviations: CGs, caregivers; PwDs, persons with dementia; SD, standard deviation.
NOTE. Continuous variables are displayed as mean value ± SD (range 0–5); overall stands for mean of all design features (range 0–24).
*Independent samples *t* tests for dyads: B rated better than A at T2.1.
†Independent samples *t* tests for dyads: B rated better than A at T3.
‡Independent samples *t* tests for PwDs and CGs: B rated better than A by CGs at T2.1 (*P* value <.01 for buttons. All other *P* values <.05).
§Independent samples *t* tests for PwDs and CGs: B rated better than A by PwDs at T3.
¶Paired samples *t* tests for within-dyad effects: A rated better by PwDs than CGs.
#Independent samples *t* tests for PwDs and CGs: B rated better than A by CGs at T3.
**Independent samples *t* tests for PwDs and CGs: B rated better than A by PwDs at T2.1.
††Paired samples *t* tests for within-dyad effects: A rated better by PwDs than CGs.

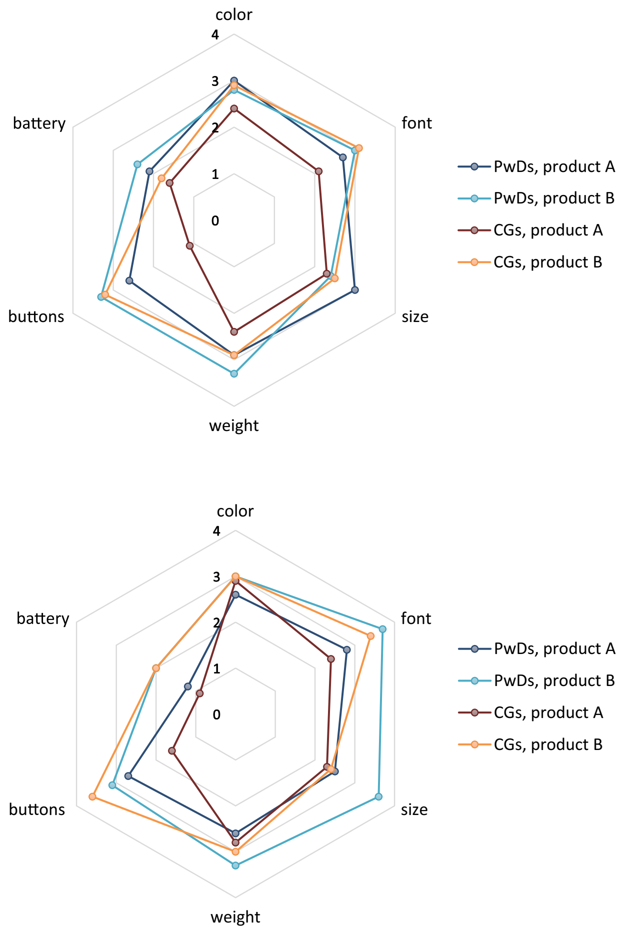

Fig. 1. Radar charts for design feature ratings at T2.1 (top) and T3 (bottom). Product A rated by seven dyads at T2.1 and by 10 dyads at T3, and vice-versa for product B. Abbreviations: CGs, caregivers; PwDs, persons with dementia.

and T2.1 were significantly higher than T3 scores. Finally, results of CGs' subjective frequency of use of the location function of product A or B showed that CGs used it a moderate amount of times at T2.1 (M_A = 3.0, SD = 1.4, M_B = 2.6, SD = 1.1) and T3 (M_A = 2.4, SD = 0.8, M_B = 2.6, SD = 1.6).

Over the course of the study, product A was able to assist in locating PwD in three wandering events (i.e., lost during shopping outing, lost during hiking, and lost during walk out of home). In two cases, the telephone function assisted and in the third case the PwD was located with the location function. Regarding technical difficulties, nine cases were reported for each product (i.e., problems with the charging cable or dock, the software, and the telephone function). Of these 18 cases, CGs reported more difficulties than PwDs (i.e., CGs: n = 7 for A, n = 6 for B; PwDs: n = 2 for A, n = 3 for B).

4. Discussion

The present study reports on the UX with and the clinical effectiveness resulting from the use of two similar commercial GPS watches used for a period of 4 weeks each in home dementia care. Although the selected products were similar, usability ratings by dyads of product B were significantly better than ratings of product A throughout the study. Differences in ratings of usability and design features within dyads are in line with previous studies, which have suggested that the needs and preferences of PwDs and CGs with GPS devices need to be taken into consideration as they may differ [7,8,42,43]. Also, the finding that usability ratings with both products decreased after 4 weeks of use, but not significantly, seems to imply that users' expectations could not be fully met, but that they were not entirely dissatisfied. The finding that end users' subjective technological affinity significantly decreased at the end of the study may be indirectly associated with decreased usability ratings. Indeed, it is possible that dissatisfaction with either product left users to rate themselves as being less technologically savvy. Furthermore, technical difficulties may have also contributed to the decrease in

Table 5
Secondary outcome measures and covariates over the course of the study, PwDs (n = 17) and CGs (n = 17)

Variables	T1	T2.1	T3
ZBI (0–48), CGs	14.5 ± 6.4 [3–25]	16.3 ± 9.2 [2–41]	17.2 ± 8.5 [5–36]
EUROHIS-QOL (0–48)			
PwDs	10.2 ± 6.6 [1–27]†	11.9 ± 9.1 [2–33]	10.3 ± 8.5 [0–34]
CGs	14.7 ± 5.7 [6–23]†	14.4 ± 6.6 [5–26]	14.6 ± 6.2 [6–28]
TA-EG (19–95)*			
PwDs	71.2 ± 7.3 [58–85]	72.2 ± 10.0 [46–87]	58.7 ± 7 [43–71]
CGs	74.1 ± 6.1 [63–83]	74.7 ± 7.0 [58–82]	56.7 ± 10.7 [38–75]
Orientation impairments (0–5)			
PwDs	1.4 ± 1.3 [0–5]†	1.5 ± 0.9 [0–3]†	1.9 ± 1.1 [0–5]†
CGs	3.0 ± 1.1 [1–4]†	3.1 ± 1.5 [0–5]†	2.7 ± 1.5 [0–5]†
Subjective burden of getting lost (0–5)			
PwDs	0.5 ± 0.8 [0–3]†	1.1 ± 1.5 [0–5]†	1.1 ± 1.4 [0–4]†
CGs	3.6 ± 1.0 [1–5]†	3.4 ± 1.2 [1–5]†	3.5 ± 1.2 [1–5]†

Abbreviations: CGs, caregivers; EUROHIS-QOL, European Health Interview Surveys-quality of life; PwDs, persons with dementia; SD, standard deviation; TA-EG, technological affinity scale for electronic products; ZBI, Zarit Burden Interview.

NOTE. Continuous variables are displayed as mean value ± SD, with minimum and maximum scores in brackets.

*One-way repeated measures analysis of variances: PwDs and CGs ratings at T1 and T2.1 higher than at T3, P value <.001.

†Paired samples t tests for within-dyad effects: CGs ratings higher than PwDs (P value <.05 for orientation impairments at T3. All other P values <.001).

ratings of usability and technological affinity, and are often cited as factors for low product acceptance and use [15,44].

Regarding product functions, we expected CG to prefer the location function of product B since the last visited positions of PwD could be viewed. However, it is possible that users viewed this extra information as nice-to-have, but not essential or too infringing on their personal privacy. Ethical considerations regarding privacy constraints, data protection, autonomy, and personal dignity need to be taken into account when it comes to product development and use [45,46]. The finding that dyads preferred product B's telephone function could be associated with end users' more favorable ratings of the buttons of product B. On the other hand, at all assessments, PwDs preferred the buttons of product A compared with CGs. This may speak to the need to design discrete wearable devices to avoid stigmatization of PwDs [42,47]. Dyads' better ratings of product B's font might be best explained by the concept of "less is more."

It is important to note that product functions and design features were assessed with non-standardized self-developed Likert scales. Currently, no standardized measures exist to assess these variables, except for parts of the QUEST 2.0 questionnaire [48]. However, this scale focuses on satisfaction with assistive technologies. Also, the use of the ISONORM 9241/10 scale with PwDs is debatable, as the psychometric properties of this scale have not been evaluated with PwDs.

Encouragingly, we did not find any order effects. Thus, receiving product A or B first did not significantly influence ratings of the second product received. The comparison of product satisfaction at home versus the clinic showed that users may bias their answers in clinical settings to avoid appearing too critical [30]. Note, however, that only one question assessed product satisfaction, and dyads jointly rated this variable. Future studies may benefit from the implementation of standardized home assessments with digital or paper-based user diaries [39].

Clinical effectiveness was not found. The short study duration and the small sample size might explain this finding. Nevertheless, this assessment is an overarching goal in research on assistive technologies, with too little information currently available [19,21]. In practice, no established guidelines on GPS devices exist, which makes it difficult for end users to select and for clinicians to recommend any GPS technology. Nonetheless, recommendations that support the decision-making process for professionals in an ethically responsible manner [45] and that define who will more likely benefit from such technologies [47] exist. Also, the results on differences between PwD and CG ratings of orientation impairments and burden of getting lost could be associated with anosognosia in PwDs and needs to be addressed sensitively.

A central limitation is the small sample size and the two dropouts after 4 weeks. It should be noted that most studies on intelligent assistive technologies have a sample size of less than 20 participants [13]. Nonetheless, the two dropouts, as well as the reported technical difficulties and the decrease in participants' technological affinity suggest that low product satisfaction and adoption are real concerns and may add an additional burden on end users. Also, the selected products were not specifically designed for PwDs and CGs, but rather for a heterogeneous population, which is typical for most commercial GPS devices. Proactive ways to address these issues include designing products that are adaptive to the changing needs of specific end users and that are tested in large, randomized controlled studies that follow a user-centered design [8,20,43]. We also did not focus on the cost of either product, although this has been found to influence product acceptability [49]. Furthermore, history of wandering behavior, which frequently occurs in later disease stages [50], but that can happen at any disease stage [51], was not an inclusion criterion. Indeed, most CGs reported PwDs as having a history of wandering behavior. Another limitation was the lack of objective data on users' frequency of use. Finally, the crossover design did not include a washout period to avoid having carryover effects (e.g., learning effects) confound outcome measures. However, no order effects were detected, which indicates that potential learning effects did not influence UX.

Study strengths include the dyadic design, pre-assessments and post-assessments, and the development and implementation of a technological training session. Furthermore, the assessment of the telephone function was deemed important as devices featuring this function are less passive, making them likely better suited for PwDs in earlier disease stages. Two of three PwDs who wandered were located by using the telephone function. Also, self-developed Likert scales were visualized to make them easier to understand. Overall, the detailed UX findings highlight the need to perform in-depth and dyadic analyses.

In conclusion, the results presented here support specific design recommendations for GPS watches in home dementia care. Specifically, devices should contain few buttons, display a clear font with parsimonious text, and have a battery life of at least 24 hours. Indeed, "for any kind of product or service, it's the little things that count" [52]. In spite of the mentioned limitations, this study provides a starting point for research on UX and clinical effectiveness with wearable GPS devices. Future studies using a randomized mixed-method dyadic approach with standardized and validated outcome measures are needed [43,53].

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Supplementary data

Supplementary data to this article can be found online at doi.org/10.1016/j.trci.2018.10.002.

RESEARCH IN CONTEXT

1. Systematic review: The authors reviewed all relevant publications on the user experience and clinical effectiveness with wearable global positioning system (GPS) devices for persons with dementia (PwDs) and caregivers (CGs) using PubMed, meeting abstracts, and presentations. This is the first user experience study comparing two commercial GPS watches in home dementia care with data from PwDs and CGs, and reporting on clinical effectiveness resulting from product use.
2. Interpretation: Our results support specific design recommendations for GPS watches in home dementia care. Namely, devices should contain few buttons, display a clear font with limited text, and have a battery life of at least 24 hours. Addressing these recommendations may contribute to measurable clinical effectiveness.
3. Future directions: Given the number of commercially available GPS watches and their low use in home dementia care, our results highlight the importance of optimizing products. Future studies with a randomized mixed-method dyadic approach and with standardized and validated outcome measures are warranted.

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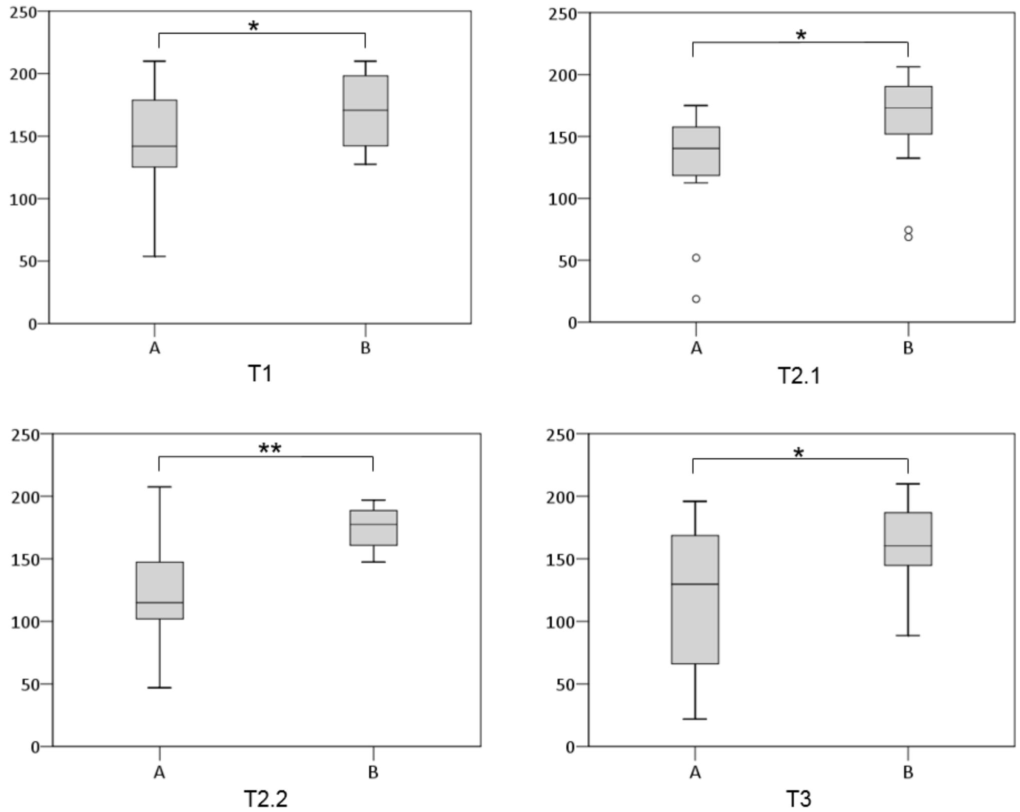

Additional file 1, Figure 1. ISONORM 9241/10 usability ratings by dyads over the course of the study, N = 34; ** p < .001 and * p < .05, B rated better than A by sample at all time points.

Additional file 2, publication 2

Additional file 2, Table 1. Visualization of questions at T2.1 and T

not at all good 0	poor 1	fair 2	good 3	very good 4
not at all 0	rarely 1	sometimes 2	often 3	very often 4

Product functions (asked separately): How much did you like the: (1) telephone; (2) location function?
Design features (asked separately): How much did you like the: (1) color; (2) font; (3) size; (4) weight; (5) buttons; (6) battery life of the product?
How satisfied were you with the product overall?
How often did you use the product overall?

NOTE. The location function was assessed by caregivers only.

9.3. Overcoming barriers to the adoption of locating technologies in dementia care: a multi-stakeholder focus group study

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Gesamtanzahl: 36 Journale

Rank	**Full Journal Title**	**Total Cites**	**Journal Impact Factor**	**Eigenfactor Score**
1	JOURNALS OF GERONTOLOGY SERIES A-BIOLOGICAL SCIENCES AND MEDICAL SCIENCES	21,215	5.236	0.025410
2	JOURNAL OF THE AMERICAN GERIATRICS SOCIETY	33,158	4.180	0.034050
3	JOURNALS OF GERONTOLOGY SERIES B-PSYCHOLOGICAL SCIENCES AND SOCIAL SCIENCES	9,435	3.502	0.009930
4	AMERICAN JOURNAL OF GERIATRIC PSYCHIATRY	7,144	3.393	0.009920
5	GERONTOLOGIST	11,196	3.286	0.011530
6	BMC Geriatrics	6,492	3.077	0.015830

Accessed November 15, 2021 at:

https://intranet.charite.de/fileadmin/user_upload/microsites/sonstige/medbib/Impact_Faktoren_2019/ISI-WEB-Liste-Kategorie-Gerontology.pdf

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RESEARCH Open Access

Overcoming barriers to the adoption of locating technologies in dementia care: a multi-stakeholder focus group study

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Abstract

Background: Locating technologies are a subtype of assistive technology that aim to support persons with dementia by helping manage spatial orientation impairments and provide aid to care partners by intervening when necessary. Although a variety of locating devices are commercially available, their adoption has remained low in the past years. Several studies have explored barriers to the adoption of assistive technologies from the perspective of professional stakeholders, but in-depth explorations for locating technologies are sparse. Additionally, the inputs of business professionals are lacking. The aim of this study was to expand knowledge on barriers to the adoption of locating technologies from a multi-stakeholder professional perspective, and to explore strategies to optimize adoption.

Methods: In total, 22 professionals working in business ($n = 7$), healthcare ($n = 6$) and research ($n = 9$) fields related to gerontology and gerontechnology participated in our focus group study. Perceptions on the value of using locating technologies for dementia care, barriers to their adoption, as well as salient services and information dissemination strategies were explored. After verbatim transcription, transcripts were analysed following an inductive data-driven content analysis approach in MAXQDA.

Results: Six key adoption barriers centering on: (1) awareness-, (2) technological-, (3) product characteristic- and (4) capital investment-based limitations, (5) unclear benefits, as well as (6) ethical concerns emerged. The interplay between barriers was high. Five core themes on services and information dissemination strategies centering on: (1) digital autonomy support, (2) emergency support, (3) information dissemination actors, (4) product acquisition, and (5) product advertising were extracted.

Conclusions: Our study with interdisciplinary stakeholders expands knowledge on barriers to the adoption of locating technologies for dementia care, and reinforces recommendations that an interdisciplinary strategy is needed to optimize adoption. Also, our findings show that focusing on services to increase digital autonomy and on information dissemination strategies has been largely overlooked and may be particularly effective.

Keywords: Alzheimer's disease, Assistive technology, Adoption, Barriers, Dementia, Focus group, Locating technology, Services, Stakeholders, Surveillance

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Background

The development and deployment of assistive technologies (ATs) represents an opportunity to reshape dementia care on a global and socioeconomically diverse scale at potentially low costs [1]. Several types of ATs exist to compensate for a multitude of cognitive and physical deficits in persons with Alzheimer's disease (AD) and related dementias [2]. In the literature, locating, or 'monitoring', 'surveillance', 'tracking', or 'wayfinding' ATs that use satellite-based positioning technology such as global position systems (GPS) have received considerable attention [3, 4]. Indeed, spatial orientation impairments in AD develop early [5], are common [6, 7], and can cause significant stress and burden for persons with dementia and their care partners [8]. Prevalence rates of persons with dementia getting lost even in familiar environments range from 17% [6] to 75% [7] depending on definitions and reporting measures used, which exposes persons with dementia to risks that can result in life-threatening circumstances [9]. To avoid such risks, care partners often limit independent outdoor ambulation by opting for chaperon, sedative or incarceration-type prevention measures [10] although these measures can negatively impact biopsychosocial health [11]. By contrast, locating devices can promote the independence and safety of persons with dementia by helping manage spatial orientation impairments and by supporting care partners to intervene when necessary [12].

To date, acceptability studies with different stakeholders including persons with dementia and care partners (hereafter end-users), as well as with healthcare and research professionals report favorable perceptions on the appropriateness and openness of using locating technologies for dementia care [13, 14]. Yet, outside research environments, end-users generally have little awareness of the existence of these technologies [15, 16]. Consequently, adoption rates remain low [17, 18] despite the increasing availability of commercial products [12]. Similar findings have been reported for the broader category of ATs [15], which has resulted in the exploration of adoption barriers by these stakeholders [13, 14, 19]. Predominant ATs adoption barriers include awareness-, translational-, effectiveness-, ethical-, and structural-based barriers [14], as well as cost factors [20]. However, very few studies have specifically focused on locating technologies. As such, key factors affecting their adoption might be overlooked [21]. For example, to our knowledge at least one community-based Norwegian study has examined the factors affecting the successful deployment of GPS technologies for public dementia care services, and reports that early adoption in the course of AD is critical [22]. Early adoption has also been highlighted as a central factor affecting product usability and long-term adoption in a Canadian-based study [23]. Certainly, additional studies in different cultural backgrounds are warranted. Also, successful adoption might not strongly depend on early intervention for other ATs.

In addition, existing studies have largely overlooked the voices of business stakeholders intimately involved in product design, development, and commercialization although their inclusion has been recommended [24]. The low involvement of business professionals in past research could help explain the paucity of recommendations on which services [25] should be offered to end-users and which information dissemination approaches such as marketing strategies [26] should be utilized to help maximize end-user awareness, positive user experience (UX), and product adoption [26, 27]. Examples of services such as customer support including product training and technical support in emergency situations have been identified as central needs by end-users [19, 28]. In research settings, these needs are also recognized by researchers as end-users typically receive study-developed product manuals and product training. Still, it remains unclear how to effectively reach and support end-users outside research settings.

Using insights from focus groups with key stakeholders from business, healthcare and research fields, the current study complements existing research by providing an in-depth exploration of the adoption barriers, and recommendations for salient services and information dissemination strategies for locating technologies for dementia care. The goal was to identify ways to optimize the adoption of locating technologies for end-users.

Methods

Participants and setting

We utilised a purposive sampling technique to recruit professionals working in fields related to gerontology and gerontechnology from our work network. In total, seventy professionals were contacted via personalized e-mail to partake in a half-day focus group study held at the Memory Clinic of the Charité Universitätsmedin Berlin, Germany, in May 2016. Invitations outlined the study purpose, methodology and organizational details. Specifically, professionals were from business fields within the technology industry sector (representatives of ATs companies with current gerontechnology focus including company executives and executive associates, marketing analysts, UX designers, and software developers), healthcare fields (representatives of Alzheimer societies, community organisations serving older adults with disabilities and nursing homes including local community representatives, managing directors, healthcare managers, social workers, gerontologist, as well as education and program coordinators), as well as research fields (research associates, project managers, group leaders, as well as postdoctoral and doctoral researchers from the fields of gerontology, rehabilitation sciences, social work, health services administration, medical sociology and rehabilitation science, nursing sciences, and gerontechnology). To maximize group homogeneity and interaction [29], professionals were separated into groups based on their professional field. We estimated that sample sizes per group of approximately ten to fifteen would be sufficient to reach data saturation based on sample homogeneity [29]. All professionals who participated provided their written informed consent, and the ethics committee of the medical faculty of the Charité Universitätsmedizin Berlin approved of the study (protocol number EA4/033/16). Participation was voluntary, there were no exclusion criteria, and no incentives for participation were provided. To help ensure that professionals felt comfortable when sharing their thoughts and experiences, discussion moderators indicated that each participant would be given a unique identification number known only to the research team when coding raw data. All methods were carried out in accordance with relevant guidelines and regulations.

Study design

A qualitative study in the form of focus groups to obtain information from various viewpoints [30] was performed. To inform the study design, we employed a qualitative description methodology [31]. Qualitative description is particularly helpful to gain an in-depth understanding of healthcare-related topics and useful "because of its ability to provide clear information on how to improve practice" (p. 2) [31]. To identify topics and structure the focus group, an interview guide based on a review of the relevant literature was developed [13–20, 28, 30–32]. The final guide comprised of three sections detailed below. Each group was led by a discussion moderator (HM, OP, LW) and one or two assistant moderators (SDF, VL, RS, GÖ, FK) who kept notes and audio recorded the discussion. All moderators and assistant moderators were provided with the interview guide prior to the focus groups. Also, a dry run of the interview guide was performed to allow for adjustments in wording or placement of questions, and to ensure familiarity and consistency with the guide between groups. Focus groups lasted approximately three hours, which included the administration of informed consent and filling out of questionnaires.

Section 1: exploration of perceptions on value of use

Professionals first filled out a standard demographic questionnaire which also assessed years of experience (i.e., professional or personal) with dementia and ATs, as well as one-time and monthly pay willingness for a locating device from the perspective of end-users (i.e., proxy measurement). Also, technological affinity was assessed with the Technological Affinity for Electronic Products questionnaire (TA-EG; Likert scale 19–95, scores proportional to affinity) [33]. The TA-EG assesses key aspects of the technology acceptance model which provides information on technology acceptance and use [34]. Then, professionals' perceptions on the value of using locating technologies for dementia care were explored by having them write down and discuss at least two keywords or phrases they associate with their use. Exploring perceptions served as an icebreaker [32] to allow professionals to acclimatise to their group before moving onto the next sections.

Section 2: exploration of adoption barriers

Thereafter, obstacles to the adoption of locating technologies by end-users were explored by examining views on personal experience, product characteristics, and clinical needs and expectations. To supplement the discussion, a GPS watch marketed for persons with orientation impairments and a smartphone with a pre-installed native android application to locate the watch were presented. These products were available due to our concurrent UX study with persons with dementia and care partners [12], and are displayed in more detail [see Additional file 1].

Section 3: exploration of services and information dissemination strategies

Lastly, views on salient services and information dissemination strategies, including recommendations for customer services, service provision methods, and promotional methods such as product advertising were discussed. To supplement the discussion, the flyers of two commercially available GPS watches marketed for persons with orientation impairments [12], which included the GPS watch shown in the previous section, were presented.

Data analysis

Audio data were digitally recorded, and transcribed verbatim (SDF, HM, CH) into MAXQDA [35]. Afterwards, transcripts were cross-checked with the recordings to ensure validity (SDF, HM, CH). Transcripts were thematically analysed (SDF, HM, CH) using content analysis that followed a data-driven inductive data analysis method [36]. First, common patterns and themes were independently identified and chunked into thematic codes while staying as close to the transcripts as possible. Any unclear quotes and counter-arguments were also noted. Then, codes were further refined into subthemes, and lastly discussed during multiple meetings until team consensus (SDF, HM, CH) was reached to ensure reliability. Data saturation was also assumed to be reached, as no new information could be added to the codes. All authors reviewed and discussed the final codes.

Written perceptions from the first section of the focus groups provided the opportunity to obtain opinions from all participants. As such, a theme density (i.e., number of times a theme arose), supplemented by contributions in the open discussion, was calculated for this section. Reporting of qualitative data using the COREQ (COnsolidated criteria for REporting Qualitative research) Checklist [37] is displayed in more detail [see Additional file 2]. Quantitative data were analysed by performing descriptive statistics. Potential group differences based on group membership or gender were compared with Kruskal Wallis or Mann-Whitney tests, as appropriate. Statistical significance was set at P-value $\leq$ 0.05 using IBM SPSS Statistics, version 23 [38].

Results

Participant characteristics

In total, 22 professionals out of the 70 contacted participated ($n = 35$, no response; $n = 8$, unavailable; $n = 5$, no-show). The final groups were: (i) business ($n = 7$, with n = 3 company executives, $n = 1$ executive associate, $n = 1$ software developer, $n = 1$ marketing analyst, and $n = 1$ UX designer) (ii) healthcare ($n = 6$, with $n = 1$ social worker, $n = 1$ gerontologist, n = 2 managing directors of AD societies, and $n = 2$ healthcare managers of community organisation serving older adults with disabilities), and (iii) research ($n = 9$, with $n = 1$ postdoc (gerontology), $n = 3$ PhD students (gerontology, rehabilitation sciences, and medical sociology and rehabilitation science), $n = 3$ project managers (health services administration, and two gerontology), and $n = 2$ research associates (both gerontechnology). No significant group membership differences were found. One significant difference between gender and dementia experience was found, Mann-Whitney $U = 20.500$, $z = -2.681$, $P = .007$, with a mean rank of 7.55 for males and 14.79 for females. Participant demographics are presented in Table 1.

Perceptions of value of use

We identified three recurrent themes on perceptions on value of use and nine subthemes, displayed in Table 2,

Table 1 Descriptive characteristics of the participants

Variables	Business ($n = 7$)	Healthcare ($n = 6$)	Research ($n = 9$)	All ($n = 22$)[a]
Age	44.3 ± 10 [32–55]	46.7 ± 12.9 [28–62]	37.1 ± 11.1 [27–62]	42 ± 11.5 [27–62]
Gender, m/f (female)	5/2 (29)	2/4 (67)	3/6 (67)	10/12 (55)
Education, n				
High school	1 (14)	1 (17)	–	2 (9)
College	1 (14)	1 (17)	–	2 (9)
Any university[b]	5 (71)	4 (67)	9 (100)	18 (82)
Dementia exp. yrs., n				
< 2 yrs	1 (14)	–	4 (44)	5 (23)
2–5 yrs	4 (57)	1 (17)	–	5 (23)
5–10 yrs	2 (29)	2 (33)	2 (22)	6 (27)
> 10 yrs	–	3 (50)	3 (33)	6 (27)
ATs exp. yrs., n				
< 2 yrs	1 (14)	1 (17)	4 (44)	6 (27)
2–5 yrs	3 (43)	2 (33)	1 (11)	6 (27)
5–10 yrs	3 (43)	2 (33)	4 (44)	9 (41)
> 10 yrs	–	1 (17)		1 (5)
Pay willingness, once	235.6 ± 134.6 [99–500]	255 ± 193.8 [100–600]	211.7 ± 176.6 [20–500]	231.1 ± 162.3 [20–600]
Pay willingness, monthly	16.3 ± 8.2 [5–30]	20.5 ± 8.1 [10–30]	17.9 ± 17.6 [0–50]	18.1 ± 12.5 [0–50]
TA-EG (range 19–95)	76.6 ± 8.7 [59–83]	64.7 ± 6.7 [58–74]	68 ± 9.9 [57–83]	69.7 ± 9.7 [54–83]

Abbreviations: *ATs* assistive technologies, *exp.* experience, *m/f* male/female, *n* number, *TA-EG* Technological Affinity for Electronic Products, *yrs.* years
Continuous and discrete variables are displayed as mean ± standard deviation [range].
Standard deviations are rounded to nearest decimal point. Percentages are rounded to nearest whole number. TA-EG scores are proportional to technological affinity. Pay willingness in Euros.
[a]Business group: $n = 3$ company executives, $n = 1$ executive associate, $n = 1$ software developer, $n = 1$ marketing analyst, and $n = 1$ UX designer; healthcare group: $n = 1$ social worker, $n = 1$ gerontologist, $n = 2$ managing directors of AD societies, and $n = 2$ healthcare managers of community organisation serving older adults with disabilities; research group: $n = 1$ postdoc (gerontology), $n = 3$ PhD students (gerontology, rehabilitation sciences, and medical sociology and rehabilitation science), $n = 3$ project managers (health services administration, and two gerontology), and $n = 2$ research associates (both gerontechnology).
[b]For education, "any university": one business, healthcare and research professional, respectively, obtained a Master's degree, and four business, three healthcare and eight research professionals obtained a PhD degree.

Table 2 Overview of themes and subthemes illustrated with quotes per focus group section

Section 1: Exploration of perceptions on value of use			
Themes	**Subthemes**	**Illustrative quotes**	**Theme density (%)**[a]
Promote security for persons with dementia	• Location finding	P2, Business, Company executive: *“Security is guaranteed by the product since for example, when persons with dementia do not come home at a specific time, they can be located.”*	$n_b = 5$ (71) $n_h = 3$ (50) $n_r = 6$ (67)
	• Risk reduction	P2, Business, Company executive: *“A lot of people have been saved with these products from freezing, drowning,* etc.*”*	
Counterargument	• *False sense of security*	P15, Research, PhD student (gerontology)*: “I can see with the app where a person with dementia is, on which street corner, but I can’t see whether s/he is crossing at a red light or not.”*	*$n_b = 0$ (0) $n_h = 0$ (0) $n_r = 1$ (11)*
Promote independence for persons with dementia	• Autonomous mobility	P15, Research, PhD student (gerontology): *“These products can also help maintain or increase the freedom of movement and independence of persons with dementia.”* P6, Business, Company executive: *“If you don’t have such a system, then you have someone telling persons with dementia: “Stop” Stay put! Where are you going again?”*	$n_b = 3$ (43) $n_h = 4$ (67) $n_r = 6$ (67)
	• Social engagement	P15, Research, PhD student (gerontology): *“Yeah I mean like when you can see a daily profile of persons with dementia—where one likes to go, spend their time, what they find interesting in their neighbourhood.”*	
Counterargument	• *Feeling tracked*	P5, Business, Marketing analyst*: “The persons that wears the product can feel like they are being tracked, and that’s not a good feeling.*	*$n_b = 2$ (29) $n_h = 2$ (33) $n_r = 2$ (22)*
Reduce stress and burden for care partners *Counterargument*	• Assistance with remote location • Efficient resource utilization • *Uneasiness about tracking*	P2, Business, Company executive: *“It makes me feel more secure because I’m worried that my [fictitious] dad might not find his way back home although he might be able to… We have clients come up to us and say: ‘Thank you, thank you, thank you! We can let our father, uncle,* etc. *walk alone again.”* P6, Business, Company executive: *I see monitoring also positively. There are a lot of people in professional care settings or care partners who feel responsible in providing this monitoring.”* P22, Research, Research associate (gerontechnology): *“To make it easier to care for persons with dementia… It might be more comfortable for formal care settings because they can save on personnel or invest less time in these [locating] task.”* P5, Business, Marketing analyst*: “But also care partners that use the product can feel uneasy because they are tracking persons with dementia.”*	$n_b = 2$ (29) $n_h = 2$ (33) $n_r = 5$ (56) *$n_b = 1$ (14) $n_h = 0$ (0) $n_r = 0$ (0)*
Section 2: Exploration of adoption barriers			
Themes	**Subthemes**	**Illustrative quotes**	
Awareness limitations	• Low knowledge transfers between stakeholders • Limited information on, and access to commercial products • Low technological affinity of end-users	P14, Research, Postdoc (gerontology): *“I can’t use what I don’t know exists. That’s the main problem I learned after conducting 105 interviews [with persons with dementia and care partners].”* P11, Healthcare, Managing director of AD society: *“From the perspective of end-users, this is a product that I don’t know, that is unfamiliar… Product awareness is still largely inadequate.”* P2, Business, Company executive: *“My personal opinion: Way too early. End-users don’t know that these products exist.”* P21, Research, Research associate (gerontechnology): *“General practitioners don’t have an overview of all commercially available products. The same goes for nursing facilities.”* P4, Business, Software developer: “*If care partners need it [GPS technology], where do they go? Where can you buy it? You won’t find it in a supermarket or media store! You first have to research it and if you’re not from this line of work, it’s hard [to find information].”* P14, Research, Postdoc (gerontology): *“Some [persons with dementia and care*	

Table 2 Overview of themes and subthemes illustrated with quotes per focus group section *(Continued)*

		partners] say: 'I've read or heard about this, but I don't know where I can buy these products. I guess online'." P18, Research, Project manager (gerontology): *"There are certainly older adults that are good with technologies, which have smartphones. But there are some older adults that have no experience—that are technology skeptic."* P13, Healthcare, Healthcare manager: *"We are talking about the age group 70 plus, right? The next generation will be more familiar with these technologies."*
Technological limitations	• Unsatisfactory reliability and accuracy of location function • Limited functionality	P16, Research, PhD student (rehabilitation science): *"If it's in the name, it has to work!"* P14, Research, Postdoc (gerontology): *"If it [location] doesn't work reliably, it won't reduce care partners stress and burden."* P22, Research, Research associate (gerontechnology): *"When one enters an underground parking lot or a building, then you can often pretty much forget about location. The product has to be more than 150% reliable. If not, you can forget it!"* P22, Research, Research associate (gerontechnology): *"It should be low maintenance… You should be able to locate immediately, without having to wait for updates. And if there's a discrepancy of a few meters and I'm in the pedestrian zone and there are a lot of people around, it could be that I don't find someone who is two meters away."* P16, Research, PhD (rehabilitation science): *"The location of two minutes ago might not be valid."* P11, Healthcare, Managing director of AD society: *"For the battery, there's a signal notifying you when you are running low on power. Of course, the question is when you receive a notification. Because it's totally annoying if the product starts to beep when you are alone. This might lead to more disorientation."* P5, Business, Marketing analyst: *"Geofencing is one aspect. I would program other intelligent functions, such as integrated temperature recognition. There are maybe other things at persons with dementias' location that could active an alarm. So I would program intelligent systems."* P7, Business, UX designer: *"I would like a product that notifies me when my [fictitious] mom leaves her home without the product."*
		P22, Research, Research associate (gerontechnology): *"And then an emergency recognition, so that when persons with dementia fall down or stumble on something, that the system recognizes this.*
	• Poor battery performance	P3, Business, Executive associate: *"If I need a GPS product all day, maybe it won't last all day. And cellphones [for care partners] either."*
		P1, Business, Company executive: *"How long does the battery last? Since our latest update, max two days…"* [P4, Business, Software developer: *"Max? Yeah, that's a problem."*]
Product characteristic limitations	• Low end-user focus and product customizability in product development	P10, Healthcare, Managing director of AD society: *"A decisive factor is how easy the different functions are to understand… Regarding product functions, less is more."* P12, Healthcare, Healthcare manager: *"There is a person with dementia who lives in our nursing facility. He doesn't leave the grounds without his fanny pack. If you could put the product in his fanny pack and it would still work, that would be ideal."* P16, Research, PhD (rehabilitation science): *"Individual configuration... to set up a custom area 'from this crossroad to here'."* P9, Healthcare, Gerontologist: *"I find it good that there are different functions, such as the emergency and two-way communication. But these functions should be individually customizable, looking at actual severity level and other factors."* P3, Business, Executive associate: *"What dementia severity does the person have? A one-size-fits-all product won't work."* P9, Healthcare, Gerontologist: *"Persons developing the technology don't involve end-users. First of all to ask: 'What do you want from your product? What should the product look like?'"* P2, Business, Company executive: *"Persons with dementia and care partners are not our primary market group."* P6, Business, Company executive: *"I think I've realized that we have to think a lot more from the perspective of end-users. This should always be the starting point and then think about hardware and so forth."*
	• Unsatisfactory and stigmatizing aesthetics	P11, Healthcare, Managing director of AD society: *"Most products are not aesthetically pleasing for females."* P10, Healthcare, Managing director of AD society: *"For the design, yeah, there's black, but I would think of offering products in more colors. This should be possible."*

Table 2 Overview of themes and subthemes illustrated with quotes per focus group section *(Continued)*

		P1, Business, Company executive: *"The products are too big! We would gladly reduce the size if the technology would allow it… The problem is that you need space for a better battery, for power, for… And so that it's comfortable to wear, particularly if it's to be worn on the wrist."* P1, Business, Company executive: *"Some products have security straps. But no one wants to walk around with such a thing!"*
	• Product costs	P1, Business, Company executive: *"The biggest barrier is always the price."* P10, Healthcare, Managing director of AD society: *"There's a cost problem at the moment. Can I afford this? Are there any additional costs once I use it? Products are simply too expensive."* P8, Healthcare, Social worker: *"Cost is a big factor. Do I purchase it or not for the last phase of my life?"*
Capital investment limitations	• Lack of funding	P1, Business, Company executive: *"There's no one here [in the other groups] that I know was involved in product development, right? There's a big discrepancy. We could all say how products should be and what could be done. But you have to have the money to do this…you first have to have the money to invest."*
	• Low product development follow-through	P1, Business, Company executive: *"There are too many products that are not developed to the end."*
Unclear benefits	• Unclear perceived need by • end-users	P11, Healthcare, Managing director of AD society: *"Persons with dementia do not see that they need it [locating device]. At most, care partners recognize a need."* P6, Business, Company executive: *"I can imagine that my fictitious father might need such a product. But whether he sees a need? There might be no recognized need."* P2, Business, Company executive: *"No end-user purchases it out of prevention. All buy it because something has already happened."*
		P8, Healthcare, Social worker: *"It [using a locating technology] of course depends on dementia severity.*
	• Reliance on other trusted locating methods	P5, Business, Marketing analyst: *"I [care partners] might pragmatically get more involved with the [local] community."*
	• Lack of studies and unclear clinical effectiveness	P21, Research, Research associate (gerontechnology): *"End-users should be more involved [in research and development]. They should test products and then we will better understand what needs to be improved."* P1, Business, Company executive: *"We need the Charité and the German Alzheimer Society to come out with studies. Then there will be a bigger discussion."* P2, Business, Company executive: *"There are dementia severities, and then it's always the question: 'How long can I [care partners] let persons with dementia move about and use the product [without studies with persons with dementia with different AD severities]?"* P19, Research, Project manager (gerontology): *"I can't evaluate products as a lay person. Do I need it? Does it work?"*
	• Previous negative user experience	P1, Business, Company executive: *"The technology is constantly changing. And those [end-users] who did test it three-four years ago… they had bad experiences. And if it doesn't work on the first attempt: Next! Forget it!"*
Ethical concerns	• Balance between autonomous mobility of persons with dementia and control by care partners • Unclear information on data privacy and security	P19, Research, Project manager (gerontology): *"As a person with dementia, I have my autonomy, I have my rights. I might not know that I am being located at a particular time. But for care partners, that's really not a problem because they have a sense of security. There's a big difference between medical professionals and care partners, where medical professionals say: 'That's an infringement on personal freedom', and care partners say: 'I don't care. I have to know where [person with dementia] is!'"* P13, Healthcare, Healthcare manager: *"There are also data security aspects, so basically the fear of being watched or controlled."* P3, Business, Executive associate: *"I think of tracking firms that collect large amounts of data, secretly collecting information on movement profiles… Do we reduce independence or increase security?"*
• Unclear legal rights on location of others		P6, Business, Company executive: *"We are very involved with this at the moment. How many movement profiles can be programmed and saved, under which conditions,* etc.*? This is a very difficult situation at the moment for all businesses involved."* P15, Research, PhD student (gerontology): *"There are a lot of decisions at the moment on what is allowed regarding locating others."* P2, Business, Company executive: *"Ultimately, it's a legal problem with too many unknowns. Are we allowed to do this, to do that? This hinders commercialization. First get approval from a court of law. The external framework could be better. This*

Table 2 Overview of themes and subthemes illustrated with quotes per focus group section *(Continued)*

		is one of the main reasons why it [GPS technologies] has not spread so quickly."
Section 3: Exploration of services and information dissemination strategies		
Themes	**Subthemes**	**Illustrative quotes**
Digital autonomy support	• Installation and product training support	P15, Research, PhD student (gerontology): *"A support that's really tailored to end-users. Particularly to help set up and configure the product."*
		P3, Business, Executive associate: *"If I use it for the first time, I would like to have an installation assistance on how to use the app that I can maybe turn on and off."* P17, Research, Project manager (health services administration): *"That you really have an on-location support that also makes house calls to help one get started with the product."* P5, Business, Marketing analyst: *"Case-management service support… If I have a person with deficits, with a certain problem severity, then I can also offer other attractive service support features."*
	• Automated technical support	P6, Business, Company executive: *"…for example, that telephone numbers are listed on a website, that frequent questions such as 'How to install the program',* etc. *are provided."*
Counterargument	• *Unclear affordability of services for end-users*	P2, Business, Company executive: *"But these services have to be affordable and there are simply too many older adults that do not have the financial capacity."*
Emergency support	• Emergency call centers	P10, Healthcare, Managing director of AD society: *"At a minimum [for emergency situations], there has to be a hotline."* P17, Research, Project manager (health services administration): *"It's important to have an emergency support call service that answers whatever question you might have."*
Counterargument	• *Lack of personnel and financial resources*	P6, Business, Company executive: *"When an alarm is set out, because you have personnel changes every 24 h, you have to have a lot of people that do this [job]. Who does it on the weekends?"* P22, Research, Research associate (gerontechnology): *"Support that is available 24/7…but this has to be financed. That's also really expensive!"*
Information dissemination actors	• Multi-actor approach: memory clinics, medical supply stores, general practitioners, local government, and healthcare insurance companies	P9, Healthcare, Gerontologist: *"You could involve memory clinics."* P?, Healthcare: *"It would be really easy to involve medical supply stores."* P17, Research, Project manager (health services administration): "*I think that general practitioners should be involved because they are typically the starting point. There's a trust-based relationship there."* P19, Research, Project manager (gerontology): *"There's a pilot project in [German city], where the government has set up a counselling center also for technology for older adults…They can advise you there…You can go to them, but they can also go to you."*
		P5, Business, Marketing analyst: *"What we need is support from an established healthcare insurancecompany that creates a 'service-support platform'."*
Counterargument	• *Financial, time and lack of follow-up limitations of proposed actors*	P9, Healthcare, Gerontologist: *"But persons with dementia come here [memory clinic] at max every six months…"* P22, Research, Research associate (gerontechnology): *"If my general practitioner talks to me about such products, I'd feel like they are trying to sell me something. I don't go to my general practitioner for that."* P19, Research, Project manager (gerontology): *"GPs are saying: 'What else are we also supposed to do?' Who pays for this extra work?"*
Product acquisition	• Retail options	P19, Research, Project manager (gerontology): *"At the moment, most products can be bought online. So there's a lack of vendors with whom older adults can talk to. I think personal talks are extremely important."*
	• Trial periods	P8, Healthcare, Social worker: "I might see an ad for such a product and think: 'Oh, that's cool!' But I still have no experience with the product. Experience is elementary. If I don't have experience, I won't use the product." P12, Healthcare, Healthcare manager: *"For me, it would be a requirement that I can test the product first for two to three weeks without having to pay a big amount for this. Maybe a little fee, but not the entire amount."* P16, Research, PhD (rehabilitation science): *"For many, it's important to be able to experience the product, to touch it, feel it. Maybe offer a trial purchase."*
	• Government subsidies	P5, Business, Marketing analyst: *"In nursing care, there are a lot of government care grants…different financial plans, how you can use these various services."*
Product advertising	• Promotion of independence and autonomy	P2, Business, Company executive: *"We are trying to erase the word tracking."* P3, Business, Executive associate: *"We've replaced the word tracking with guardian*

Table 2 Overview of themes and subthemes illustrated with quotes per focus group section *(Continued)*

		angel."
		P10, Healthcare, Managing director of AD society (flyer-feedback): *"And particularly in old age, the importance of remaining independent without sacrificing comfort and safety."* P11, Healthcare, Managing director of AD society (flyer-feedback): *"I prefer the description on this flyer. It's simple and contains all you need to know. I see security, quality of life, liberty. The visual presentation is good, and the font size is nice and large. This other flyer is not directed toward persons with dementia, but rather only toward care partners."* P19, Research, Project manager (gerontology; flyer feedback): *"This picture is a no-no for the current generation of older adults."*
	• Seal of quality from trusted organisations	P1, Business, Company executive: *"There have to be institutions. That's why I'm here today… In the end, the Charité or similar is missing. The stamp from ISO does not suffice. When Charité or German Healthcare Ministry is visible, then there's a completely different quality level that is achieved."*
	• Addressing concerns of end-users: data security, product characteristics, and service details	P20, Research, PhD (medical sociology and rehabilitation science): *"It could be a marketing problem… for example, that it's not clear that it can be avoided that everyone sees my data and locate me. If I don't know that, I don't buy it."* P10, Healthcare, Managing director of AD society: *"This aspect [data security] has to be covered in product advertising."*
		P16, Research, PhD (rehabilitation science): *"I really think that there is a general lack of clear information on data security. It's really important that data security is communicated and mentioned and that it's theoretically possible for a third party to access data sensitive information. So that people know what to do in such situations."* P5, Business, Marketing analyst (flyer feedback): *"What I still don't know is whether I have to take the watch off every day and charge it."* P6, Business, Company executive: *"Let's say I receive a message at 4 am about my mother and this happens three nights in a row. I'll be woken up and I can't really help… What happens then?"*
	• Conventional advertising platforms: television, magazines, pharmacies	P14, Research, Postdoc (gerontology): *"There are probably people that don't check online for this [GPS product], but rather watch TV. So maybe use TV ads to multiply information."* P22, Research, Research associate (gerontechnology): *"I saw an ad in [free magazine with large older adult readership] about a high blood pressure product. I thought that was really good. A magazine that a lot of older adults read—not just persons with dementia and care partners. And the magazines are free. You can just take one."* P14, Research, Postdoc (gerontology): *"Maybe there should just be ads placed in pharmacy windows."*
Counterargument	• *Financial limitations*	P1, Business, Company executive: *"I don't produce million-dollar TV ads."*

Abbreviations: *n* number; n_b business, n_h healthcare, n_r research
Percentages in parentheses rounded to nearest whole number
[a]Theme density calculated based on professionals' written keywords or phrases and supplemented by contributions in the open discussion

Section 1. No differences in theme density between groups were found. The shared perception was that using locating technologies could result in increasing end-users' quality of life on psychological, social, and physical levels by: (i) promoting the personal security and (ii) independence of persons with dementia, and by (iii) reducing stress and burden experienced by care partners. These benefits could be achieved due to location finding, risk reduction, supporting autonomous mobility and social engagement, by offering peace of mind for care partners by assisting with remote location, and by improving caregiving resource utilization.

P2, Business, Company executive: *"A lot of people have been saved with these products from freezing, drowning, etc."*

P15, Research, PhD student (gerontology): *"Yeah I mean like when you can see a daily profile of persons with dementia—where one likes to go, spend their time, what they find interesting in their neighbourhood."*

P2, Business, Company executive: *"It makes me feel more secure because I'm worried that my [fictitious] dad might not find his way back home although he might be able to … We have clients come up to us and say: 'Thank you, thank you, thank you! We can let our father, uncle, etc. walk alone again."*

P22, Research, Research associate (gerontechnology): *"To make it easier to care for persons with dementia … It might be more comfortable for formal care settings because they can save on personnel or invest less time in these [locating] task."*

Still, professionals expressed mixed feelings for each perceived benefit. In particular, products could represent a sense of false security due to inaccurate location.

P15, Research, PhD student (gerontology): *"I can see with the app where a person with dementia is, on which street corner, but I can't see whether s/he is crossing at a red light or not."*

Also, persons with dementia might view product use as reducing their independence due to feelings of being tracked. Similarly, care partners could feel uneasy when using products due to their tracking nature.

P5, Business, Marketing analyst: *"The persons that wears the product can feel like they are being tracked, and that's not a good feeling.*

P5, Business, Marketing analyst: *"But also care partners that use the product can feel uneasy because they are tracking persons with dementia."*

However, professionals pointed out that most care partners feel morally responsible to monitor and that devices offer more ethical forms of monitoring compared to alternative methods such as restricting ambulation.

P6, Business, Company executive: *I see monitoring also positively. There are a lot of people in professional care settings or care partners who feel responsible in providing this monitoring."*

P6, Business, Company executive: *"If you don't have such a system, then you have someone telling persons with dementia: "Stop" Stay put! Where are you going again?"*

Adoption barriers

We identified six recurrent adoption barrier themes and 18 subthemes, displayed in Table 2, Section 2.

(i) ***Awareness limitations.*** A key theme centered on the low awareness of the existence of locating technologies by end-users. This could be attributed in part to poor knowledge transfers between end-users and professional stakeholders. Business professionals indicated product marketing issues leading to low awareness, such as products being released "*way too early*".

P14, Research, Postdoc (gerontology): *"I can't use what I don't know exists. That's the main problem I learned after conducting 105 interviews [with persons with dementia and care partners]."*

P2, Business, Company executive: *"My personal opinion: Way too early. End-users don't know that these products exist."*

Also, the lack of a readily available overview of commercial products, and limited retail access to products leading to complex purchasing processes for end-users were highlighted.

P21, Research, Research associate (gerontechnology): *"General practitioners don't have an overview of all commercially available products. The same goes for nursing facilities."*

P4, Business, Software developer: *"If care partners need it [GPS technology], where do they go? Where can you buy it? You won't find it in a supermarket or media store! You first have to research it and if you're not from this line of work, it's hard [to find information]."*

Furthermore, the low technological affinity of most end-users was expressed by research and healthcare professionals.

P18, Research, Project manager (gerontology): *"There are certainly older adults that are good with technologies, which have smartphones. But there are some older adults that have no experience—that are technology skeptic."*

(ii) ***Technological limitations.*** Technological limitations causing usage-related difficulties also lead to low adoption by not satisfying the expectation that use could help increase quality of life. Research professionals reported on their experience with products that do not provide reliable and accurate location based on poor network communication issues, frequent hiccups, and product maintenance updates.

P22, Research, Research associate (gerontechnology): *"When one enters an underground parking lot or a building, then you can often pretty much forget about location. The product has to be more than 150% reliable. If not, you can forget it!"*

P22, Research, Research associate (gerontechnology): *"It should be low maintenance … You should be able to locate immediately, without having to wait for updates. And if there's a discrepancy of a few meters and I'm in the pedestrian zone and there are a lot of people around, it could be that I don't find someone who is two meters away."*

Furthermore, the limited functionality of available products and poor battery performance were reported as central technological barriers for all groups.

P5, Business, Marketing analyst: *"Geofencing is one aspect. I would program other intelligent functions, such as integrated temperature recognition. There are maybe other things at persons with dementias' location that could active an alarm. So I would program intelligent systems."*

P1, Business, Company executive: *"How long does the battery last? Since our latest update, max two days … "* [P4, Business, Software developer: *"Max? Yeah, that's a problem."*].

(iii) ***Product characteristic limitations.*** Regarding the presented locating device, all groups showed high approval for a watch design. However, professionals emphasized that discrepancies between end-users' needs and available products would discourage adoption.

P6, Business, Company executive: *"I think I've realized that we have to think a lot more from the perspective of end-users. This should always be the starting point and then think about hardware and so forth."*

P2, Business, Company executive: *"Persons with dementia and care partners are not our primary market group."*

Specifically, they expressed the concept of "less is more", and the lack of individual configurations that can adapt to changing healthcare needs with advancing disease severity.

P12, Healthcare, Healthcare manager: *"There is a person with dementia who lives in our nursing facility. He doesn't leave the grounds without his fanny pack. If you could put the product in his fanny pack and it would still work, that would be ideal."*

P9, Healthcare, Gerontologist: *"I find it good that there are different functions, such as the emergency and two-way communication. But these functions should be individually customizable, looking at actual severity level and other factors."*

In addition, they stressed that unsatisfactory and stigmatizing aesthetics due to developing products for heterogeneous populations using a one-size-fits-all design approach or due to technological limitations hinder adoption.

P11, Healthcare, Managing director of AD society: *"Most products are not aesthetically pleasing for females."*

P1, Business, Company executive: *"The products are too big! We would gladly reduce the size if the technology would allow it … The problem is that you need space for a better battery, for power, for … And so that it's comfortable to wear, particularly if it's to be worn on the wrist."*

Moreover, product affordability and insufficient information on additional costs upon purchase were pivotal barriers.

P1, Business, Company executive: *"The biggest barrier is always the price."*

P10, Healthcare, Managing director of AD society: *"There's a cost problem at the moment. Can I afford this? Are there any additional costs once I use it? Products are simply too expensive."*

(iv) ***Capital investment limitations.*** Business professionals were the only group to express that capital investment limitations impacted the successful development and deployment of high-quality products. They criticized the collection of viewpoints on optimal product characteristics without also advocating for higher capital investments to successfully translate viewpoints to product development.

P1, Business, Company executive: *"There's no one here [in the other groups] that I know was involved in product development, right? There's a big discrepancy. We could all say how products should be and what could be done. But you have to have the money to do this … you first have to have the money to invest."*

Moreover, they argued for a better follow-through from research and development phases to product commercialization.

P1, Business, Company executive: *"There are too many products that are not developed to the end."*

(v) ***Unclear benefits.*** Several unclear benefits on the value of using locating technologies were discussed. These included end-users not recognizing the need to use products that can aid with spatial orientation deficits, utilizing more trusted locating methods such as involving social network members, and the limited number of studies using a user-centered design to better understand end-users' needs and preferences with unclear information on clinical effectiveness.

P11, Healthcare, Managing director of AD society: *"Persons with dementia do not see that they need it [locating device]. At most, care partners recognize a need."*

P5, Business, Marketing analyst: *"I [care partners] might pragmatically get more involved with the [local] community."*

P21, Research, Research associate (gerontechnology): *"End-users should be more involved [in research and development]. They should test products and then we will better understand what needs to be improved."*

P2, Business, Company executive: *"There are dementia severities, and then it's always the question: 'How long can I [care partners] let persons with dementia move about and use the product [without studies with persons with dementia with different AD severities]?"*

Also, previous negative experiences with devices could yield persistent negative perceptions and hinder adoption despite rapidly improving technological innovations.

P1, Business, Company executive: *"The technology is constantly changing. And those [end-users] who did test it three-four years ago … they had bad experiences. And if it doesn't work on the first attempt: Next! Forget it!"*

(vi) ***Ethical concerns.*** The balance between products being able to both heighten the autonomous mobility and infringe on the personal privacy of persons with dementia via ubiquitous location control by care partners or third-party tracking firms was at the core of the discussion.

P3, Business, Executive associate: *"I think of tracking firms that collect large amounts of data, secretly collecting information on movement profiles … Do we reduce independence or increase security?"*

However, professionals mentioned that care partners' sense of moral responsibility to provide security for persons with dementia might encourage the adoption of a security-at-all-costs viewpoint, even if information on the collection of movement data by third parties is confusing due to unclear data security and privacy aspects.

P19, Research, Project manager (gerontology): *"As a person with dementia, I have my autonomy, I have my rights. I might not know that I am being located at a particular time. But for care partners, that's really not a problem because they have a sense of security. There's a big difference between medical professionals and care partners, where medical professionals say: 'That's an infringement on personal freedom', and care partners say: 'I don't care. I have to know where [person with dementia] is!'"*

In addition, research and business professionals added that changing laws pertaining to legal rights on the location of others hinder adoption via slow product development and commercialization.

P6, Business, Company executive: *"We are very involved with this at the moment. How many movement profiles can be programmed and saved, under which conditions, etc.? This is a very difficult situation at the moment for all businesses involved."*

P2, Business, Company executive: *"Ultimately, it's a legal problem with too many unknowns. Are we allowed to do this, to do that? This hinders commercialization. First get approval from a court of law. The external framework could be better. This is one of the main reasons why it [GPS technologies] has not spread so quickly."*

P15, Research, PhD student (gerontology): *"There are a lot of decisions at the moment on what is allowed regarding locating others."*

Services and information dissemination strategies

We identified five recurrent themes on salient services and information dissemination strategies and 15 subthemes, displayed in Table 2, Section 2.

(i) ***Digital autonomy support.*** Efforts to support end-users' digital autonomy upon product purchase was a key theme. Discussed ways to support digital autonomy included offering installation and product training support. Specific examples included providing at-home installments, product education, web-based automated technical support to allow end-users to search for answers to frequently asked questions and customer support telephone numbers, as well as offering case-management support, where a case manager develops and coordinates a comprehensive plan of services based on end-users' needs.

P17, Research, Project manager (health services administration): *"That you really have an on-location support that also makes house calls to help one get started with the product."*

P5, Business, Marketing analyst: *"Case-management service support … If I have a person with deficits, with a certain problem severity, then I can also offer other attractive service support features."*

P6, Business, Company executive: *" … for example, that telephone numbers are listed on a website, that frequent questions such as 'How to install the program', etc. are provided."*

However, professionals questioned how the suggested services could be cost-effectively financed.

P2, Business, Company executive: *"But these services have to be affordable and there are simply too many older adults that do not have the financial capacity."*

(ii) ***Emergency support.*** A second type of service that was discussed centered on support in emergency situations. Professionals in all groups agreed that round-the-clock, external emergency call centers should be available to provide real-time assistance should a person with dementia goes missing or if end-users have more pressing questions.

P17, Research, Project manager (health services administration): *"It's important to have an emergency support call service that answers whatever question you might have."*

Still, professionals made it clear that providing quality call centers is fraught with challenges. They cautioned that such services are notoriously expensive to manage and that they require a large personnel base.

P6, Business, Company executive: *"When an alarm is set out, because you have personnel changes every 24 hours, you have to have a lot of people that do this [job]. Who does it on the weekends?"*

P22, Research, Research associate (gerontechnology): *"Support that is available 24/7 … but this has to be financed. That's also really expensive!"*

(iii) ***Information dissemination actors.*** Professionals also discussed the role of several key actors who could help increase product awareness. Taken together, a multi-actor approach including memory clinics, medical supply stores, general practitioners, governments, and healthcare insurance companies was proposed.

P9, Healthcare, Gerontologist: *"You could involve memory clinics."*

P?, Healthcare: *"It would be really easy to involve medical supply stores."*

P17, Research, Project manager (health services administration): *"I think that general practitioners should be involved because they are typically the starting point. There's a trust-based relationship there."*

P19, Research, Project manager (gerontology): *"There's a pilot project in [German city], where the government has set up a counselling center also for technology for older adults … They can advise you there … You can go to them, but they can also go to you."*

P5, Business, Marketing analyst: *"What we need is support from an established healthcare insurance company that creates a 'service-support platform'."*

However, healthcare and research professionals cautioned about the lack of regular follow-ups at memory clinics, as well as time limitations of general practitioners and potentially harming patient–doctor trust relationships.

P9, Healthcare, Gerontologist: *"But persons with dementia come here [memory clinic] at max every six months … "*.

P22, Research, Research associate (gerontechnology): *"If my general practitioner talks to me about such products, I'd feel like they are trying to sell me something. I don't go to my general practitioner for that."*

P19, Research, Project manager (gerontology): *"GPs are saying: 'What else are we also supposed to do?' Who pays for this extra work?"*

(iv) ***Product acquisition.*** Furthermore, professionals discussed which product acquisition methods would allow to best reach end-users, increase product familiarity, and facilitate product financing. Main ideas included promoting retail versus online sales, offering trial periods at low or no cost, and exploring the role of government subsidies in product financing.

P19, Research, Project manager (gerontology): *"At the moment, most products can be bought online. So there's a lack of vendors with whom older adults can talk to. I think personal talks are extremely important."*

P12, Healthcare, Healthcare manager: *"For me, it would be a requirement that I can test the product first for two to three weeks without having to pay a big amount for this. Maybe a little fee, but not the entire amount."*

P5, Business, Marketing analyst: *"In nursing care, there are a lot of government care grants … different financial plans, how you can use these various services."*

(v) ***Product advertising.*** Lastly, the role of promotional activities centering on product advertising was explored. Key recommendations included ensuring that advertising messaging and visuals are non-stigmatizing and that they utilize a end-user focus. For example, this could be achieved by emphasizing the value of using products to help with optimizing the autonomous mobility of persons with dementia rather than focusing on tracking features.

P11, Healthcare, Managing director of AD society (flyer-feedback): *"I prefer the description on this flyer. It's simple and contains all you need to know … I see security, quality of life, liberty. The visual presentation is good, and the font size is nice and large. This other flyer is not directed toward persons with dementia, but rather only toward care partners."*

P3, Business, Executive associate: *"We've replaced the word tracking with guardian angel."*

Another suggestion included displaying a seal of quality from respected research institutions on product advertisements to optimize end-users' trust in products.

P1, Business, Company executive: *"There have to be institutions. That's why I'm here today … In the end, the Charité or similar is missing. The stamp from ISO does not suffice. When Charité or German Healthcare Ministry is visible, then there's a completely different quality level that is achieved."*

Professionals also expected that advertising materials transparently address key concerns that end-users might have centering on data security, product characteristics such as battery life, and service details such as assistance with emergency situations.

P20, Research, PhD (medical sociology and rehabilitation science): *"It could be a marketing problem … for example, that it's not clear that it can be avoided that everyone sees my data and locate me. If I don't know that, I don't buy it."*

P5, Business, Marketing analyst (flyer feedback): *"What I still don't know is whether I have to take the watch off every day and charge it."*

P6, Business, Company executive: *"Let's say I receive a message at 4am about my mother and this happens three nights in a row. I'll be woken up and I can't really help … What happens then?"*

Furthermore, several examples of advertising platforms that were viewed as being able to reach end-users more effectively were mentioned. Identified platforms were television, magazines, and pharmacies.

P14, Research, Postdoc (gerontology): *"There are probably people that don't check online for this [GPS product], but rather watch TV. So maybe use TV ads to multiply information."*

P22, Research, Research associate (gerontechnology): *"I saw an ad in [free magazine with large older adult readership] about a high blood pressure product. I thought that was really good. A magazine that a lot of older adults read—not just persons with dementia and care partners. And the magazines are free. You can just take one."*

P14, Research, Postdoc (gerontology): *"Maybe there should just be ads placed in pharmacy windows."*

However, business professionals commented on the lack of financial resources to promote products on platforms that might better reach end-users.

P1, Business, Company executive: *"I don't produce million-dollar TV ads."*

Discussion

This study reports on key barriers to the adoption of locating technologies for use in dementia care, as well as on services and information dissemination strategies to increase adoption. Results are relevant for researchers, healthcare and business professionals, including product designers and developers as they highlight that adoption involves more than the technology and products themselves.

Overall, the professionals in our sample held positive views on the use of locating technologies as a way to increase end-users' quality of life. However, these technologies also raised ethical concerns since they could be seen as restricting the independence of persons with dementia. Therefore, professionals argued for clear and transparent information on how the data and movement profiles of persons with dementia are saved. These findings resonate with previous publications [14, 22, 39]. The mention of these ethical concerns from business professionals is encouraging as others have argued that ATs developers pay too little attention to the needs of end-users or the "human factor" (p. 77) [40]. Also, participants believed that the need for independence of persons with dementia and care partners' need to locate their loved ones might outweigh data security concerns, a sentiment expressed by end-users themselves [41]. This finding reinforces the importance of creating opportunities for collaborations between business professionals and end-users to ensure that data security and end-user perspectives are integral to product development.

The discussion of adoption barriers revealed that the interplay between barriers is high. For example, low awareness of the existence of locating technologies by end-users could in part be attributed to unsuccessful communication across relevant stakeholders, with limited research on clinical and cost-effectiveness as a driving factor behind this association. In turn, limited research-validated studies on clinical effectiveness discourages healthcare professionals from recommending locating technologies, and hampers larger societal discourses on their value. Regarding product characteristics, the role of technological innovations to maximize individualization and reduce the risk of stigmatization were stressed. Although not explicitly mentioned by professionals, we add that technological innovations that incorporate prominent patterns of AD-related spatial orientation deficits, such as "dimensions of pattern (lapping, random, or pacing), frequency, [and] boundary transgressions" (p. 99) [8] could help ensure that locating technologies better respond to end-users' needs, desires, and capabilities.

When discussing services, professionals highlighted that supporting the digital autonomy of end-users to help counteract low technological affinity, as well as building trusting relationships with service providers are essential for adoption. Efforts to support digital autonomy to help persons with dementia age-in-place is a timely topic [42], and several examples on ways to optimize digital autonomy were provided. We maintain that services can address end-users' low technological experience in real-world scenarios by mimicking clinical study environments where products are typically explained and shortly tested before being used for longer periods of time. Furthermore, while discussing information dissemination strategies, professionals provided several recommendations for promotional activities to increase product awareness. Taken together, they indicated that a multi-stakeholder approach is key and advocated the concept of "meeting consumers where they are" by using traditional sources of information dissemination. Also, they mentioned that offering trial periods could help end-users gain experience with a product and enable UX feedback. Indeed, studies show that end-users are more satisfied with the acquisition of ATs when their opinions are factored into device recommendations [43]. Feedback on the presented advertisement flyers indicated that product marketing has a large room for improvement in terms of content and visuals that can be achieved by creating marketing tools in a process of co-creation between persons with dementia, their care partners and business stakeholders. Similar to recent studies [44, 45], professionals' stressed the importance of placing end-users at the center of marketing activities to reduce stigmatizing keywords and visuals, as well as to ensure that information on functionality and data security are transparently and adequately addressed.

This study has some limitations. First, although asking professionals about their views on the use of locating technologies for dementia care might have resulted in findings reported elsewhere [20, 46], the perspectives of business professionals are largely lacking in the literature. Second, the use of a convenience sampling technique, which was used to ensure that professionals have sufficient knowledge on the use of locating technologies for dementia care, might have resulted in the collection of viewpoints from persons more positively biased toward the use of these technologies. However, other professional stakeholders [14, 20] similarly report high openness toward the use of ATs in dementia care. Still, the possibility of a positive bias cannot be conclusively ruled out, particularly since 22 out of the 70 professionals contacted agreed to participate. However, as previously mentioned, the focus groups generated rich and diverse viewpoints and low recruitment rates using e-mail is typical [47]. Third, the finding that recommendations regarding product pricing were not explicitly discussed in the third section although purchase cost was mentioned as a pivotal barrier for product adoption can be seen as a limitation. This limitation is not unique to our work, and past research with end-users also generally reports a high range of acceptable purchase costs which typically range from 20 to 100 dollars [44]. Still, the fact that product pricing was not explicitly discussed is one example that points to a larger limitation of this study. Upon closer analysis of professionals' quotes in the second and third sections of the focus group interview, we find that they are largely opinion-based rather than experience-based. Given that we used purposive sampling and that we encouraged professionals to report on their own experiences, this finding suggests that some of the included professional stakeholders may have limited experience on the use of locating technologies for dementia care. Quite revelatory is that at least one business professional explicitly mentioned that persons with dementia and their care partners are not their primary market group. The development and marketing of locating technologies for dementia care that meets end-users' needs, preferences and values requires a fundamental paradigm shift insofar as this will take time, and will require a end-user focus and a process of co-creation between end-users and professional stakeholders to optimize long-term product adoption. As mentioned by one business professional, dynamic individuals with the financial capital and drive to embark on this quest are needed. Also, a lack of relevant professional expertise, particularly by business professionals, increases the risk of developing and marketing products that end-users perceive as being stigmatizing. Finally, the fact that the discussion took place a few years ago may be seen as a limitation to the present findings. Yet, from what could be found from the scientific literature, no significant changes in the uptake of locating technologies by end-users has occurred since the study was performed, suggesting that adoption barriers have not been adequately addressed.

The strengths of the present study include its qualitative nature to allow for an in-depth exploration of a complex and multifaceted topic [30], as well as its interdisciplinary nature by bringing together stakeholders with different areas of expertise. While others have argued that "multiple stakeholders with differing philosophical viewpoints slow the development, commercialization and deployment of geriatric technologies" (p. 80) [48], our results do not support this view. A key recommendation based on the results of the current study is to provide opportunities for collaborations between end-users and interdisciplinary stakeholders to support the development and commercialization of scientifically-validated, clinically effective locating technologies for dementia care [49]. Also, and to our knowledge, the inclusion of business professionals is new. Business professionals proved to be particularly helpful in understanding business-related topics and hurdles since they provided more examples of service recommendations, were the only group to mention the role of government subsidies in product financing, as well as capital investment limitations impacting the development and deployment of high-quality products. In addition, studies addressing marketing strategies for locating technologies for dementia care are rare [44] even though marketing aspects play a central role in product adoption [26, 27]. Lastly, the focus on locating technologies can be viewed as a strength as viable solutions to increase adoption are still largely limited to extrapolating findings from a broad range of ATs with various applications.

Conclusions

In conclusion, this paper resonates with past findings on adoption barriers, and identifies services and information dissemination factors that remain to be adequately addressed before the implementation of locating technologies can truly make a difference in dementia care. The need to improve locating solutions and their adoption has been highlighted by the recent creation of international and interdisciplinary consortiums and networks [50, 51]. Moving forward, collaborations between end-users and professional stakeholders that examine what services end-users find appropriate to increase digital autonomy, and what information dissemination strategies to utilize to effectively reach end-users are steps in the right direction.

Abbreviations

AD: Alzheimer's disease; ATs: Assistive technologies; GPS: Global Positioning System; UX: User experience

Supplementary Information

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Additional file 1. Product description of GPS watch and smartphone presented to professionals. Table presenting a description of the GPS watch and smartphone presented to professionals during the focus groups, including product name, picture, dimensions, weight, battery, charging, software, and website of product.

Additional file 2. COREQ (COnsolidated criteria for REporting Qualitative research) Checklist. Table presenting information of the focus groups following COREQ Checklist reporting style.

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Authors' contributions

All authors contributed to the preparation of the manuscript. SDF, HM, LW, and OP designed the study. HM, LW, and OP moderated one focus group each. SDF, HM, and CH transcribed, coded, and analyzed the data. SDF drafted the manuscript. All authors have read and approved the final version of the manuscript.

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Availability of data and materials

The authors confirm that the data supporting the findings of this article are available within the article.

Declarations

Ethics approval and consent to participate

This study obtained the ethical approval of the ethics committee of the medical faculty of the Charité—Universitätsmedizin Berlin (protocol number EA4/033/16). A written informed consent was obtained from all participants before taking part in the focus group. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Additional file 1. Product description of GPS watch and smartphone presented to professionals.

Name	HIMATIC GPS Uhr Alpha [Himatic GPS watch Alpha]	Thl T6C smartphone
Picture		
Dimensions	45.5mm X 64.5mm X 17.5mm	71.6mm X 143.9mm X 8.2mm
Weight	70g	160g
Battery	500 mAh, Li-Ion	1900mAh, Li-Ion
Charging	DC 5V USB charger cable	2.0 Micro USB
Software	Native Android App: HIMATIC GPS Uhr Alpha	Android 5.1 Lollipop
Website	https://himaticmobile.de	https://www.thlphone.com/

Abbreviations: GPS, global positioning system; UX, user experience.
NOTE. GPS watch has five buttons and contains a location and telephone function technology. The smartphone application displays the last recognized position of the GPS watch on an online map when prompted. Displayed are two GPS watch apps used in our concurrent user experience study [REF], a Google Maps application, a telephone icon, a contacts icon, and a home button.

Additional file 2, publication 3

Additional file 2. COREQ (COnsolidated criteria for REporting Qualitative research) Checklist.

Topic	Description
Domain 1: Research team and reflexivity	
Personal characteristics	
Interviewer/facilitator	HM, OP, LW.
Credentials	MSc (Gerontology) / Dr. med. (German medical doctoral degree) / Dr. rer. pol. (German equivalent to PhD in Business Administration).
Occupation	Research associate / Senior physician and academic researcher / Full professor of Information Management and Digital Transformation.
Gender	Female / Male / Male.
Experience and training	Experience in quantitative and qualitative research on assistive technologies, dementia diagnostics, and clinical drug trials in Alzheimer’s disease / Experience in quantitative research, dementia diagnostics, and clinical drug trials in Alzheimer’s disease/ Experience in qualitative research on health-IT and business model innovations.
Relationship with participants	
Relationship established	Conducted previous research with one of the participants in the business group and collaborated with several of the participants in previous Alzheimer’s disease research projects and events / Conducted previous research with one of the participants in the business group and collaborated with several of the participants in previous Alzheimer’s disease research projects and events / No prior knowledge or relationship with any of the participants.
Participant knowledge of the interviewer	Participants received the information that the authors were conducting a research project on assistive technologies in the field of dementia care with a special focus on locating technologies. The communicated goal was to explore the needs of persons with dementia and their caregivers with regards to locating technologies, as well as to explore how these needs could be effectively meet through business model designs.
Interviewer characteristics	Participants received the information that the authors were interested in exploring potential barriers to the adoption of assistive technologies, including locating technologies, in dementia care.
Domain 2: Study design	
Theoretical framework	
Methodological orientation and theory	Qualitative description.
Participant selection	
Sampling	Purposive sampling.
Method of approach	Personalized e-mail.
Sample size	22 professionals separated into groups based on their professional field (business, n = 7, healthcare, n = 6, and research, n = 9).
Non-participation	70 professionals were contacted to participate (n = 35, no response, n = 8, unavailable for various reasons, and n = 5, no-show—i.e., agreed to participate, but were not present for the focus group).
Setting	
Setting of data collection	Memory Clinic of the Charité Universitätsmedizin Berlin. Participants were gathered in a conference room to receive a welcome reception and information on organizational details prior to the focus groups, and then separated into one of three rooms for the focus groups.
Presence of non-participants	Silka Dawn Freiesleben (SDF), Valentina Lüdtke (VL), Robert Sonneschein (RS), Gökhan Ozer (GO) and Florian Konwischer (FK) acted as assistants to the researchers.
Description of sample	Yes—see Table 1.
Data collection	
Interview guide	SDF, HM, OP and LW wrote the questions included in the interview guide, and prompts were given during the interviews if needed. No pilot testing.
Repeat interviews	No.
Audio/visual recording	Audio recording performed by SDF, VL; RS, GO and FK, and verbatim transcription performed by SDF, HM, Christina Herrmann (CH).
Field notes	Yes.
Duration	Approximately three hours (including administration of informed consent and filling out of questionnaires).
Data saturation	Assumed to be reached with a sample size of ten to fifteen participants per group based on sample homogeneity.

Transcripts returned	No.
Domain 3: Analysis and findings	
Data analysis	
Number of data coders	Three (SDF, HM and CH).
Description of the coding tree	Three main themes and nine subthemes reported in the first section of the focus groups, six main themes and eighteen subthemes reported in the second section of the focus groups, and five main themes and fifteen subthemes reported in the third section of the focus groups—see Table 2.
Derivation of themes	Using content analysis, data-derived themes were identified following an inductive data analysis approach.
Software	MAXQDA.
Participant checking	No.
Reporting	
Quotations presented	Yes, quotations were identified and are presented—see Table 2.
Data and findings consistent	Yes.
Clarity of major themes	Yes—three, six, and five main themes are reported in the first, second, and third sections of the focus groups, respectively.
Clarity of minor themes	Yes—nine, twenty-two, and twenty-three subthemes are reported in the first, second, and third sections of the focus groups, respectively.

NOTE. The information displayed under the header "*Personal characteristics*" regarding credentials, occupation, experience and training, and relationship established reflect the information available at the time of the study.

10. Curriculum vitae

My curriculum vitae does not appear in the electronic version of my paper for reasons of data protection.

Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht.

11. Complete list of publications

Publications in peer-reviewed journals

Fuentes-Casañ M, Schipke CG, **Freiesleben SD**, Klostermann A, Peters O. Presenilin 1 gene mutation (M139V) in a German family with early-onset Alzheimer's disease: a case report. Arch Clin Neuropsychol. 2021; 24(acab070): 1-10. https://doi.org.10.1093/arclin/acab070. Impact Factor: Scopus Journal Metrics: CiteScore: 4.0; Source Normalized Impact per Paper (SNIP): 1.132; SCImago Journal Rank (SJR): 0.909.

Freiesleben SD, Megges H, Herrmann C, Wessel L, Peters O. Overcoming barriers to the adoption of locating technologies in dementia care: a multi-stakeholder focus group study. BMC Geriatr. 2021; 21(378):1-17. https://doi.org/10.1186/s12877-021-02323-6. Impact Factor: Scopus Journal Metrics: CiteScore: 4.5; Source Normalized Impact per Paper (SNIP): 1.758; SCImago Journal Rank (SJR): 1.414.

Ballarini T, van Lent DM, Brunner J, Schröder A, Wolfsgruber S, Altenstein S, Brosseron F, Buerger K, Dechent P, Dobisch L, Düzel E, Ertl-Wagner B, Fliessbach K, **Freiesleben SD**, Frommann I, Glanz W, Hauser D, Haynes JD, Heneka MT, Janowitz D, Kilimann I, Laske C, Maier F, Metzger CD, Munk M, Perneczky R, Peters O, Priller J, Ramirez A, Rauchmann B, Roy N, Scheffler K, Schneider A, Spottke A, Spruth EJ, Teipel SJ, Vukovich R, Wiltfang J, Jessen F, Wagner M, DELCODE study group. Mediterranean diet, Alzheimer disease biomarkers and brain atrophy in old age. Neurology. 2021; 96(24): e2920-32. https://doi.org/10.1212/WNL.0000000000012067. Impact Factor: Scopus Journal Metrics: CiteScore: 9.6; Source Normalized Impact per Paper (SNIP): 2.476; SCImago Journal Rank (SJR): 2.91.

Menne F, Schipke CG, Klostermann A, Fuentes-Casañ M, **Freiesleben SD**, Bauer C, Peters O. Value of neuropsychological tests to identify patients with depressive symptoms on the Alzheimer's disease continuum. J Alzheimers Dis. 2020; 78(2): 819-26. https://doi.org/10.3233/JAD-200710. Impact Factor: Scopus Journal Metrics: CiteScore: 6.9; Source Normalized Impact per Paper (SNIP): 1.145; SCImago Journal Rank (SJR): 1.677.

Sannemann L, Schild A-K, Altenstein S, Bartels C, Brosseron F, Buerger K, Cosma NC, Fliessbach K, **Freiesleben SD**, Glanz W, Heneka MT, Janowitz D, Kilimann I, Kobeleva X, Laske C, Metzger CD, Munk MHJ, Perneczky R, Peters O, Polcher A, Priller J, Rauchmann B, Rösch C, Rudolph J, Schneider A, Spottke A, Spruth EJ, Teipel S, Vukovich R, Wagner M, Wiltfang J, Wolfsgruber S, Duezel E, Jessen F for the DELCODE Study Group. Neuropsychiatric symptoms in at-risk groups for AD dementia and their association with worry and AD biomarkers—results from the DELCODE study. Alz Res Therapy. 2020; 12(131): 1-11. https://doi.org/10.1186/s13195-020-00701-7. Impact Factor: Scopus Journal Metrics: CiteScore: 9.3; Source Normalized Impact per Paper (SNIP): 1.657; SCImago Journal Rank (SJR): 2.802.

Herdick M, Dyrba M, Fritz H-CJ, Altenstein S, Ballarini T, Brosseron F, Buerger K, Cetindag AC, Dechent P, Dobisch L, Duezel E, Ertl-Wagner B, Fliessbach K, **Freiesleben SD**, Frommann I, Glanz W, Haynes JD, Heneka MT, Janowitz D, Kilimann I, Laske C, Metzger CD, Munk MH, Peters O, Priller J, Roy N, Scheffler K, Schneider A, Spottke A, Spruth EJ, Tscheuschler M, Vukovich R, Wiltfang J, Jessen F, Teipel S, Grothe MJ. Multimodal MRI analysis of basal forebrain structure and function across the Alzheimer's disease spectrum. Neuroimage: Clin. 2020; 28(102495): 1-11. https://doi.org/10.1016/j.nicl.2020.102495. Impact Factor: Scopus Journal Metrics: CiteScore: 7.0; Source Normalized Impact per Paper (SNIP): 1.369; SCImago Journal Rank (SJR): 1.772.

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Megges H, **Freiesleben SD**, Jankowski N, Haas B, Peters O. Technology for home dementia care: a prototype locating system put to the test. Alzheimers Dement (N Y). 2017; 3(3): 332-8. https://doi.org/10.1016/j.trci.2017.04.004. Impact Factor: Scopus Journal Metrics: CiteScore: 9.1; Source Normalized Impact per Paper (SNIP): 1.833; SCImago Journal Rank (SJR): 2.49.

Freiesleben SD, Furczyk K. A systematic review of agomelatine-induced liver injury. J Mol Psychiatry. 2015; 3(1): 1-12. https://doi.org/10.1186/s40303-015-0011-7. Impact Factor: not available as journal is now closed.

Publication in conference proceedings

Freiesleben SD, Megges H, Rösch C, Peters O. Promoting the adoption of GPS technologies in dementia care: key lessons from focus group interviews with business, research and healthcare professionals. Poster presentation, conference 30th Alzheimer Europe Conference, virtual conference, 10/2020.

Freiesleben SD, Megges H, Rösch C, Peters O. Promoting the adoption of GPS watches in the field of dementia care: from professionals to end users. Poster presentation, conference 29th Alzheimer Europe Conference, The Hague, The Netherlands, 10/2019.

Freiesleben SD, Megges H, Rösch C, Peters O. User experience and clinical effectiveness with two wearable locating systems in home dementia care. Podium presentation, conference29th Alzheimer Europe Conference, The Hague, The Netherlands, 10/2019.

Rösch C, Megges H, **Freiesleben SD**, Peters O. How dyadic interactions influence the user experience of persons with dementia and their caregivers with GPS watches. Poster presentation, conference 29th Alzheimer Europe Conference, The Hague, The Netherlands, 10/2019.

Megges H, **Freiesleben, SD**, Rösch C, Peters O. The digital value of social media platforms: Alzheimer's disease and other dementias on Facebook. Poster presentation, conference 29th Alzheimer Europe Conference, The Hague, The Netherlands, 10/2019.

Megges H, **Freiesleben SD**, Rösch C, Peters, O. Ortungssysteme auf dem Prüfstand- Ergebnisse des Projekts „Validierung und Optimierung des individuellen Nutzens von Ortungssystemen bei Demenz – VODINO". Podium presentation, conference Deutsche Alzheimer Gesellschaft e.V., Weimar, Germany, 10/2018.

Megges H, **Freiesleben SD**, Rösch C, Wessel L, Peters O. Kleinigkeiten machen den Unterschied: Eine Nutzerstudie mit GPS-Geräten in der häuslichen Pflege bei Demenz.

Poster presentation, conference Deutsche Gesellschaft für Gerontologie und Geriatrie e.V., Cologne, Germany, 09/2018.

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Rösch C, Megges H, **Freiesleben SD**, Peters O. Dyadische Interaktionen beeinflussen die Nutzererfahrung mit GPS-Geräten in der häuslichen Pflege bei Demenz. Podium presentation, conference Deutsche Gesellschaft für Gerontologie und Geriatrie e.V., Cologne, Germany, 09/2018.

Rösch C, Megges H, **Freiesleben SD**, Peters O. How relationship dynamics between persons with dementia and caregivers regarding subjective technological affinity with locating systems play out over time. Poster presentation, conference Alzheimer's Association International Conference, Chicago, USA, 07/2018. Published in: Alzheimers Dement; 14(7):188. https://doi.org/10.1016/j.jalz.2018.06.2021. Impact Factor: ISI-Web Journal Citation Report 2017: 12.74.

Freiesleben SD, Megges H, Rösch C, Peters O. User experience study with two locating systems in home dementia care. 2018. Podium presentation, conference Alzheimer's Association International Conference, Chicago, USA, 07/2018. Published in: Alzheimers Dement; 14(7):189. https://doi.org/10.1016/j.jalz.2018.06.2024. Impact Factor: ISI-Web Journal Citation Report 2017: 12.74.

Megges H, **Freiesleben SD**, Lüdtke V, Rösch C, Peters O. A longitudinal user study testing two locating systems in home dementia care. 2017. Podium presentation, conference Alzheimer's Association International Conference, London, UK, 07/2017. Published in: Alzheimers Dement; 13(7):165-6. https://doi.org/10.1016/j.jalz.2017.06.2614. Impact Factor: ISI-Web Journal Citation Report 2017: 12.74.

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Megges H, **Freiesleben SD**, Lüdtke V, Peters O. Validierung und Optimierung des individuellen Nutzens von Ortungssystemen bei Demenz – VODINO. Podium presentation, conference Deutsche Alzheimer Gesellschaft e.V., Saarbrücken, Germany, 09/2016.

Megges H, **Freiesleben SD**, Lüdtke V, Peters O. Eine vergleichende Anforderungsanalyse zu Ortungssystemen bei Demenz mit Betroffenen, Angehörigen und Experten. Podium presentation, conference Deutsche Gesellschaft für Gerontologie und Geriatrie e.V., Stuttgart, Germany, 09/2016.

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