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Rik Wesselink
University of Twente; Windesheim University of Applied Sciences

Geke Ludden
University of Twente

Marike Hettinga
Windesheim University of Applied Sciences

Berry Eggen
Eindhoven University of Technology

Citation

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Rik Wesselink[ab]*, Geke Ludden[a], Marike Hettinga[b], Berry Eggen[c]

[a] University of Twente, The Netherlands
[b] Windesheim University of Applied Sciences, The Netherlands
[c] Eindhoven University of Technology, The Netherlands

*corresponding e-mail: r.r.wesselink@utwente.nl

Abstract: Designing for people with dementia requires a tailored approach that addresses the specific complexities related to dementia. Design principles can provide guidance for designing in this complex context. Work in this field discusses recommendations, guidelines, or principles to design for dementia. However, this information is scattered and a clear overview of design principles, that designers can apply, is missing. In this paper we propose a set of design principles that is grounded in existing literature on designing for people with dementia. We first explore and analyse design recommendations that are described in related work. Next, we merge them into 10 design principles. Finally, we discuss the different roles of these principles, and how they are interconnected. This results in a tool for researchers and designers to use in designing for people with dementia: the *Wheel of Design Principles*.

Keywords: Dementia; Design Principle; Product Design; Recommendation

1. Introduction

Dementia affects the lives of millions of people worldwide. The WHO estimates that currently 55 million people live with dementia, and that this number will grow to 78 million within 10 years (WHO, 2021). Among older people, dementia is one of the main causes of disability and dependency. This hinders independent living at home, which is what elderly generally prefer (Chernbumroong, Cang, Atkins, & Yu, 2013), and puts great stress on the healthcare system.

Technology can play an important role in supporting independent living for people with dementia (PwD) (Evans, Brown, Coughlan, Lawson, & Craven, 2015). Most assistive technologies currently focus on supporting activities of daily living, monitoring safety, and assisting healthcare (Evans et al., 2015). Washing aids, fall-prevention devices and medication reminders are examples of such products. In their study, however, Evans et al. conclude that the acceptance of these products is low. This underscores the importance of

well-designed products that are accepted by PwD and their social context. Moreover, it points out the complexity of designing for this context and the importance of looking beyond functionality itself.

As the dementia progresses, using everyday products becomes increasingly challenging due to both cognitive and physical decline. These challenges vary from person to person and range from having trouble pressing a small button due to tremors, to not understanding the sequence of actions, not recognizing the product at all, or the loss of initiative. Designing products for PwD, fitting their unique capabilities and limitations, therefore requires a tailored approach (Ramos, Miller, & van den Hoven, 2020). And although design for dementia is a growing topic in HCI research, well-structured information on how to design for this vulnerable user group is still limited.

Related work on design for dementia generally provides process-related recommendations and often does not discuss design-related ones. Researchers stress, for example, the importance of the participation of PwD in the process (Kenning & Brankaert, 2020). Studies that do specifically discuss design-related recommendations often describe them as lessons learned from their research and design process (Donaldson, 2018; Mayer & Zach, 2013). A few studies show a clearer focus on design recommendations and link their work to design principles from related areas such as Universal Design (Outi & Päivi, 2009). All in all, recommendations on how to design for PwD are available, but they are limited and scattered.

Please note that, next to the term recommendations, different terms are used, such as guidelines, or principles. The different terms are usually not well defined and often seem interchangeable. In our view, recommendations can be both specific and general, guidelines suggest a prescription on how something should be done, and principles describe more fundamental ideas and considerations. Because of their fundamental nature, design principles are more generic and can therefore be applied in a variety of contexts. They need to be applied with discretion and require careful consideration of the context, to thereby facilitate the tailored approach designing for PwD requires.

In this paper, we aim to create an overview of design principles that can inform design for PwD. First, we explore related literature. Then, we describe how we extracted insights from these studies and merged them into a set of 10 design principles. Finally, we discuss how these design principles are interconnected and affect one another. In this final step, we provide a tool for researchers and designers to use in designing for PwD.

2. Approach

This study was structured in three steps. We first explored and analysed literature related to guidelines, principles, and recommendations, on design for dementia. In this paper, we use the term *recommendations* for all the guidelines, principles, and recommendations we found in related work.

Second, we merged overlapping design recommendations into a set of unique design principles that we defined. And third, we reflected on how these final design principles affect one another, which we visualized in the *Wheel of Design Principles* (Figure 1).

2.1 Step 1: Exploring and analysing related work

To find related work on recommendations for design for dementia, we explored three databases. The *ACM Digital Library* was used for its large HCI-related database and full-text search option, *Scopus* was used because its multidisciplinary database broadens our search, and finally Google Scholar was used to find relevant work that is not published in the previous databases. We searched for *recommendations*, *guidelines*, and *principles*, all in the area of design and dementia. This led to the search strings as described in Table 1. We used snowballing to expand on the search results.

Table 1.   Databases and search strings used

Database	Search within	Other filters	Search string	Nr. of results
The ACM Full – Text collection	Anywhere	No	(guideline* OR recommendation* OR principle*) AND design* AND dementia	753
Scopus	Title-Abs-Key	Subject area COMP or ENGI, only include conference papers and articles	(guideline* OR recommendation* OR principle*) AND design* AND dementia	123
Google Scholar	Uncheck 'patents and 'cites'	No	design principle dementia	95,900

Table 1 shows there were many results. We filtered the results through sorting by relevance and we excluded literature on design processes, environment design or interior design. We only included work that specifically lists recommendations related to product design for PwD, which resulted in a selection of seven studies (see section 3). Please note that our aim was to create a good overview of the state-of-the-art. Although we performed a careful search, we do not claim to have included all related work on this topic.

From the selected literature, we extracted the design recommendations. We analysed them looking for differences and commonalities, and identified categories based on their underlying goals.

2.2 Step 2: Merging & defining design principles

We grouped the design recommendations in principles that emerged from an inductive analysis. The first author executed the analysis of the design recommendations and proposed overarching principles. The overarching principles were further defined based on

the underlying design recommendations from the related literature. These principles and definitions were reviewed by, and discussed with, the second author until agreement was reached.

2.3 Step 3: Reflecting on design principles

Once the final set of design principles was defined, we reflected on how they affect one another when they are applied. We visualised the relations between the principles in the *Wheel of Design Principles* (Figure 1)*.* This visualisation can be used as a tool for design and reflection by other researchers and designers.

3. Exploring and analysing related work

Exploring related work resulted in seven related studies (Blackler, Chen, Desai, & Astell, 2020; Brankaert, 2016; Donaldson, 2018; Hyry, Yamamoto, & Pulli, 2011; Mayer & Zach, 2013; Outi & Päivi, 2009; Wesselink, Hettinga, Ludden, & Eggen, 2020) that contributed to a total of 47 design recommendations (see Table 2). In this section we describe the insights that resulted from our analyses of the recommendations.

3.1 Varying specificity

The recommendations in the related work varied a lot in specificity, ranging from broad topics, such as *Empowerment* and *Reliability*, to very specific design suggestions, such as *Low physical effort* and *Make actions reversible*. Some recommendations were very specific, and mainly applicable in the context of that paper. *Portable audio*, for example, is described as a recommendation for designing a music player for PwD. Other design principles (Table 2, #22-28) build on principles from related areas such as Universal Design (Outi & Päivi, 2009) or User Centered Design Principles (Table 2, #36-42) (Donaldson, 2018). Building on this current body of knowledge and reflecting on it in the context of dementia results in a valuable foundation of design principles that are grounded in related literature.

3.2 Conflicts with related literature

Two of the design recommendations we found conflicted with literature on PwD, mainly because of their strict definition. Number 46 (in Table 2), for example, states that PwD "are not able to learn to use new devices" (Donaldson, 2018). Although learning to use new devices becomes increasingly complex as the dementia progresses, it is still possible for PwD to learn new things. Errorless learning, for example, is a popular approach to teach PwD new information or skills (de Werd, Boelen, Rikkert, & Kessels, 2013). Designers should not be discouraged by this recommendation to design innovative products for PwD. This recommendation does, however, highlight the complexity in understanding and using new products for PwD.

Recommendation No. 45 should also be nuanced in our view: prompts might work better if they come from a person they know. This does, however, not mean that other prompts will not work.

3.3 Categories

In our analysis we identified three categories based on the underlying goals of the design recommendations. Most recommendations (33) aim to *improve the interaction design*. In addition, a number of recommendations (11) aim to *improve the emotional wellbeing* of PwD. Several (3) recommendations stress the importance of the context of the product to make designers aware of the complex social context the product will be used in and thereby aim to *improve successful implementation* of the design. One design recommendation, No. 41, was classified as *other* and was excluded because it was too general to be classified as a recommendation on design for dementia.

4. Merging & Defining Design Principles

4.1 Merging Recommendations into Design Principles

Through our inductive analysis of the design recommendations, we identified recurring, more generic, principles. For example, the principle *familiar* emerged from a handful of recommendations that discuss the advantage of using familiar elements in the design. This finally resulted in 10 design principles. Some recommendations from the literature can be linked to multiple principles. For example, the recommendation *physicality* (#21 in Table 2) can be classified as *tangible*, but when we read the author's description of that recommendation, we can also classify it as *easy to understand*, *easy to use* and *visible*.

Table 2.   Analysis of Design Recommendations and Principles.

Source	#	Recommendation	Category: Interaction Design	Category: Emotional Wellbeing	Category: Successful Implementation	1. Easy to understand	2. Easy to use	3. Familiar	4. Tangible	5. Visible	6. Flexible	7. Reliable	8. Equitable use	9. Autonomy	10. Context	Other
Wesselink et al. (2020)	1	Adapt to declining capabilities	X								X					
	2	Low cognitive load	X			X										
	3	Self-explaining	X			X										
	4	Tangible interface	X						X							
	5	Tangible music source	X						X							
	6	Music source shows its contents	X							X						
	7	Portable device	X													X
	8	Portable audio	X													X
	9	In line with mental model	X			X		X								
HV	10	Scheduling		X										X		

Author	#	Principle														
	11	Simplicity	X			X										
	12	Tailoring	X									X				
	13	Reliability		X								X				
	14	Support		X								X				
	15	Passive	X			X										
	16	Durability		X								X				
	17	Being like the rest		X									X			
Brankaert (2016)	18	Empowerment		X										X		
	19	Social context			X										X	
	20	Familiarity	X			X	X					X				
	21	Physicality	X			X	X		X	X						
Outi & Päivi (2009)	22	Equitable use		X								X				
	23	Flexibility	X									X				
	24	Simple and intuitive	X			X										
	25	Perceivable information	X			X			X							
	26	Tolerance for error	X			X						X				
	27	Low physical effort	X				X									
	28	Size and space for approach and use	X				X									
Mayer & Zach (2013)	29	Familiarity and Emotions	X	X				X								
	30	Minimize complexity and choice, and emphasize clarity and simplicity	X			X										
	31	First Impression and Acceptance		X								X	X			
	32	Positive and supportive feedback		X		X						X				
	33	Learnability and clear instructions				X										
	34	Involve Caretakers and Relatives	X												x	
	35	Visual Design			X	X										
Donaldson (2018)	36	Don't take away user control	X											X		
	37	Show the obvious purpose of controls	X			X			X							
	38	Make actions reversible	X									X				
	39	Assume all possible errors will occur	X									X				
	40	Embrace typical processes (instead of screens)	X			X										
	41	Leverage computers instead of serving them														X
	42	Adapt to individuals	X							X						
	43	Any new equipment should look (and operate) as something they are familiar with	X			X	X					X				
	44	They need to maintain a sense that they control their environment		X								X	X			
	45	Prompts and reminders may be responded to, but only from a carer they recognize			X	X		X								
	46	They are not able to learn to use new devices	X			X	X									
Blackler et al. (2020)	47	Build on previous knowledge or Technology Familiarity (TF) / Affordances	X			X		X	X							

4.2 Defining 10 principles of design for dementia

The 10 design principles cover the unique aspects of the 47 design recommendations we found. A description was created per design principle by merging the related recommendations. Next, we grouped these 10 design principles based on the previously mentioned categories. We will now briefly describe each category and the related design principles.

Design principles to improve interaction design: The principles in this category aim to make it easier for PwD to operate the product. These principles directly relate to the physical and cognitive capabilities of the user. They have an impact on whether the product *can* be used by PwD.

1. *Easy to understand*: It should be easy to understand or discover the function of the product and how to use it. Aim for simplicity and intuitive designs that minimize the cognitive load. Consider the mental model users may already have of related products.
2. *Easy to use*: It should be easy to physically use the product. Consider low physical effort for the interaction, size of the interaction elements, space for approach and impairments in motor skills.
3. *Familiar*: Familiar elements in the design and interaction elements will help understand the products purpose, its functions, and the usability.
4. *Tangible*: Using physical and graspable elements for interaction has several advantages. It provides direct control over the functions; it allows for, and often automatically embeds, multi-sensory feedback (e.g., tactile, auditory, visual); it can communicate the current state (volume position, selected radio channel, etc.); and it informs the user on how to manipulate the control (rotate, press, slide, flip).
5. *Visible*: Users should conceive relevant information for product use, such as the purpose of controls or the content that can be manipulated.
6. *Flexible*: Users should be able to personalize, optimize or tailor the product. This needs to be possible throughout the lifespan of the product, allowing it to adapt to the declining capacities of the user with dementia. Although it is not the focus of this paper, we argue that flexibility could and should be improved in smart solutions that automatically adapt to the continuously changing needs of PwD.

Design principles to improve emotional wellbeing: The principles in this category focus on the emotional aspects related to product use. This requires specific attention in the context of dementia, not only because dementia can make someone emotionally more vulnerable, but also because these aspects can strongly affect whether PwD *want to* use the product.

7. *Reliable*: Products (and even research prototypes) just need to work. It should be hard to make errors and easy to undo them. Any problem in product use, bug or hick-up, will make PwD uncertain and hesitant to use the product. They should feel confident to use the product and trust they will not break it. Therefore, a durable look and feel is important too.
8. *Equitable use* (non-stigmatizing): The design of the product should appeal to a broad public. A product that is clearly designed for people with impairments will be experienced as stigmatizing and will not be accepted by the intended user.

9. *Autonomy*: The product should empower the users, improve their autonomy by giving them more control and an increased self-reliance.

Design principles to improve successful implementation: Principles in this category aim to raise the designer's awareness of aspects that impact the success of implementation. At this point, we have one design principle in this category.

10. *Context*: a product designed for a person with dementia is likely to be used by spouses, informal caregivers, professional caregivers, and others (visitors) as well. Some functions may even depend on these secondary users. To increase the chance of successful implementation, it is important to consider their roles in the design process.

5. Reflecting on design principles

5.1 Interconnectedness

We identified 10 unique design principles (DP) that together provide a structured overview of current knowledge on how to design for PwD. When embedded in design, these principles, however, cannot be seen as separate, they will always be connected. Improving a design with the focus on one principle, will affect other principles. To map this interconnectivity, two design-researchers with experience in design for dementia, analysed the relations between the design principles by discussing the potential effect each principle could have on every other principle. The resulting relations were visualised in the *Wheel of Design Principles* (Figure 1), which shows how each design principle affects, and is affected by, the other principles.

We like to explicitly note that these relations can represent both a positive and a negative impact. For example, improving the tangibility (DP4) of an interface, could make the interaction more familiar (DP3), which in turn could make it easier to understand (DP1). An easier to understand interface can make the user more confident in using the product and increase the feeling of reliability (DP7). All these improvements could empower the user and increase his or her autonomy (DP9). Or, to give an example of a negative impact: making an interface very easy to use, might lead to a design that is experienced as stigmatizing (DP2 could negatively affect DP8).

In a systematic review of dementia-focussed assistive technology, Evans et al. discuss the low acceptance rate of assistive technology (Evans et al., 2015). They highlight the impact of stigma, how the product makes a user feel and confidence in use, on the acceptability of products. The 10 design principles address these issues and can therefore affect acceptability of the designed product.

Since an improvement on one aspect could negatively affect the acceptance of a product, it is important that designers are aware of the interconnectivity of the design principles.

Wheel of Design Principles
for designing in the context of dementia

Categories:
- Improve Interaction Design
- Improve Emotional Wellbeing
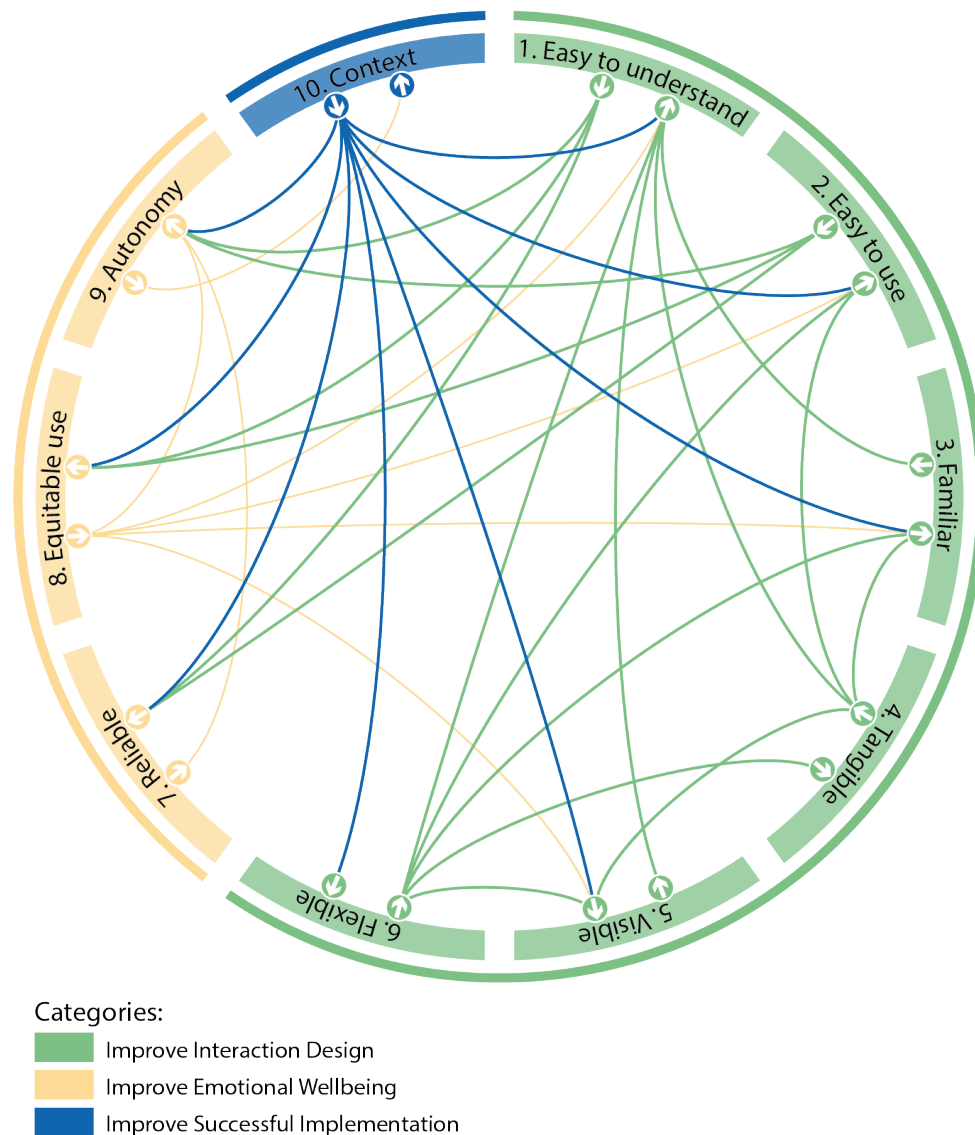- Improve Successful Implementation

Figure 1   The Wheel of Design Principles showing how the 10 principles affect each other. Each design principle has an input ("is affected by") and an output ("affects").

Visualising the relations in the *Wheel of Design Principles* (Figure 1), increases our understanding of the different roles the principles play in designing for PwD. By reflecting on Figure 1, we notice that:

1. *Autonomy* (DP9) could be considered an ultimate goal. If we reflect on the reason why we need these design principles, we see the problems in using everyday products increase the dependency of PwD. It is therefore not surprising that many routes, starting from any design principle, lead to *Autonomy* (DP9).

2. *Context* (DP10) strongly affects many other design principles. The product-context in designs for PwD can be quite complex due to the various users, situations, and sensitivities. For example, secondary users, such as informal caregivers, could play an important role in facilitating certain product functions. This can affect the visibility of these specific functions. A clear understanding of the complexity of this context (DP10) is, in our view, a prerequisite for the design process.

3. The main purpose of *Familiar* (DP3), *Tangible* (DP4), *Visible* (DP5) and *Flexible* (DP6) is to contribute to *Easy to understand* (DP1) and *Easy to use* (DP2). Their direct impact stays within their category *Improve Interaction Design*.

4. *Easy to understand* (DP1) and *Easy to use* (DP2) in turn strongly affect design principles from the other categories. They function as a gateway to the other categories.

5. *Equitable use* (DP8) functions as a guide, and provides boundaries, for most design principles in the category *Improve Interaction Design*. It can very well conflict with these principles, for example when improving the visibility of information leads to users feeling infantilized.

5.2 Pitfalls & priorities: Balancing the design principles

Through our reflection on the design principles, we realized that the design principles can both contribute and conflict with one another. In most cases, a positive effect is expected. For example, improving the tangibility of an interface is likely to lead to an interface that is easier to use. However, negative effects can occur as well. When a product is made very easy to use, for example by removing many functions, using large buttons, images, and colours, this could result in a stigmatizing design that is clearly intended for someone with an impairment. Increasing flexibility by allowing the user to personalize the product's appearance or interface, could increase familiarity, but at the same time it could make it more complex to use.

These examples address just a few of the complexities and potential pitfalls when applying the principles in a design case. Although the focus can differ from case to case, the design principles should never be applied in an isolated way. Designers will have to trade-off and prioritize these principles based on each specific design case.

5.3 Wheel of design principles: A tool for design and evaluation

We propose that the *Wheel of Design Principles* (Figure 1) can be used as a tool in the evaluation or products for PwD, or in the design process. In the evaluation, this wheel can guide the analysis of the product and its use. It can help understanding both the issues and the chances for improvement. For example, if users experience difficulties in understanding how the product works, you can first dive into *Easy to understand* (DP1) and discover issues with the cognitive load. Next, when you follow the lines that DP1 is affected by, you could gain insights related to issues with familiarity, or the visibility of important information.

In the design process, the principles can be used to inspire the ideation phase and to guide and promote reflection throughout the design process. For example, one could brainstorm for design solutions based on each design principle, explore their effect on the design direction and combine the most valuable ideas into a new design solution. Reflecting is an integral part of designing, and the *Wheel of Design Principles* can be used to support this activity throughout the design process.

6. Discussion and conclusion

In this paper we worked on creating a more structured overview of principles to design for dementia by exploring and analysing the literature. By reflecting on the resulting set of principles, we provide a more in-depth understanding of the interplay between the design principles, which we visualized in the *Wheel of Design Principles* (Figure 1). Before we conclude this paper, we briefly discuss how our work relates to design principles from other areas of design, and what the limitations are of this study.

6.1 Relation to other design principles

Our design principles have clear links to those from related areas such as Universal Design, Interface Design, User Centered Design and Ergonomics. All Universal Design Principles (NDA, 2020), for example, are integrated in our set of design for dementia principles. Some are a direct match, others are merged and combined (see Table 3).

Table 3. Integration of Universal Design Principles in our Design for Dementia Principles

Design for Dementia Principle	Universal Design Principle
Easy to understand	Simple and intuitive
Easy to use	Low physical effort; Size and space for approach and use
Familiar	
Tangible	
Visible	Perceivable information
Flexible	Flexibility
Reliable	Tolerance for error
Equitable use	Equitable use
Autonomy	
Context	

Other principles, such as *Tangible* and *Context* are topics that are promoted in design education. And although *Familiar* might seem specifically important in design for PwD, it can be argued that it is also covered by the 2nd and 6th usability heuristic as defined by Nielsen

(Nielsen, 1994). *Autonomy* seems to be the only principle that is not clearly covered by principles from other areas.

6.2 Limitations of this study

We do not claim this set of principles to be complete. Our aim was to create an overview of the work on design principles in the design for dementia domain. Although we performed a careful search, we do not claim to have included all related work on this topic. As we focused on product design, related work from areas such as interior design, was excluded. Reviewing a broader scope of related work might lead to valuable new insights. Moreover, new studies on this topic are published every year. New insights could lead to additional design principles, or updates of the current ones.

To give one example of what might be missing, Massimo et al. (2018) found that apathy is "one of the most common and pervasive of the behavioural and psychological symptoms of dementia" (Massimo, Kales, & Kolanowski, 2018). Apathy could be described as loss of initiative and motivation. If PwD do not take the initiative to use a product, even a well-designed easy to use product might still be left unused.

The 10 design principles we describe in this paper, and the insight into their interconnectedness, are a valuable foundation for future research. We propose future studies to focus on applying and evaluating these principles, as well as on broadening and refining them.

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About the Authors:

Rik Wesselink is researcher at the Interaction Design group of University of Twente and the IT-Innovations in Health Care group at Windesheim University of Applied Sciences. He is interested in smart technologies, interaction design, design for dementia and design for children.

Geke Ludden is professor of Interaction Design at the University of Twente. She studies design for behaviour change and motivation and the role of interactive devices and wearables in engaging people in therapy at home.

Marike Hettinga is head of the research group IT-Innovations in Health Care at Windesheim University of Applied Sciences. Her research focuses on multidisciplinary challenges in the design, development, embedding, financing, and up-scaling of digital health care.

Berry Eggen is Professor of Design for User Experience in Ambient Intelligent Systems, and head of the Future Everyday group at Eindhoven University of Technology. He has an interest in ubiquitous computing, multimodal interaction, and seamless interaction design for everyday life.