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Designing P4 - Predictive, Preventive, Personalised and Participative - Healthcare Interventions for Managing Cognitive Decline and Dementia: Where are we at?

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Published in:
Journal of Engineering Design

Link to article, DOI:
10.1080/09544828.2020.1763272

Publication date:
2020

Document Version
Peer reviewed version

Designing P4 Healthcare Interventions For Managing Cognitive Decline And Dementia: Where Are We At?

This paper presents a systematic literature review aimed at assessing how well current technology-based interventions that focus on dementia and other cognitive impairments align with the principles of the *P4* vision for healthcare: *Predictive, Preventive, Personalised and Participative*. A search of the SCOPUS database yielded 887 articles, of which 48 were ultimately selected for analysis. Looking at whether and how each intervention implements each "P"-principle, our results suggest a partial and non-systemic embrace of the P4 vision. Reasoning on possible explanations for this state-of-the-art, we propose that our findings represent an opportunity for the engineering design community to engage with P4-based healthcare delivery models through the development of design frameworks, new indicators for assessing the success of such healthcare delivery models, as well as tools and methods.

Keywords: Engineering Design, Healthcare Design, Healthcare Improvement, P4 Healthcare, Dementia

1. Introduction

Design for health is gaining attention. More specifically, design thinking and engineering methods generate growing enthusiasm as means to improve our healthcare services and systems (Clarkson et al. 2004; Craig and Chamberlain 2017; Doss 2014; Kim, Myers, and Allen 2017; Komashie and Clarkson 2018; Clarkson 2018; Ku and Rosen 2016; Lamé 2018; Patou and Maier 2017). This relatively recent realisation comes as process inefficiencies, budget limitations, increasing technology-adoption costs, rising prevalence of chronic diseases, and the scarcity- and work overload of care personnel continue to challenge the performance of our healthcare systems (Cutler, Rosen, and Vijan 2006; Spillman and Lubitz 2000). Only recently promoted by leading voices in healthcare organisational management and clinical practice, a call for design thinking and the adoption of engineering methods in healthcare have emerged from large systematic investigations of healthcare systems at both the national and international levels (Christensen, Hasman, and Hunter 2010; WHO 2009; Clarkson et al. 2017). These studies have revealed the potential of design thinking frameworks for improving value-effectiveness and cost-efficiency in healthcare, through interventions at various

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scales: from guiding national policy-making to prescribing recommendations for the structural remodelling of healthcare organisations, to the reengineering of more confined, context-specific care services. The successful application of such frameworks has confirmed the validity of a design- and systems approach to healthcare engineering. Although currently convincing when applied to the traditional healthcare delivery model, systems thinking and engineering design methods face a new challenge: the to-date unfamiliar emergence of new models of healthcare delivery and the novel types of products and services these models are inspired by and potentially call for.

The vision of a more *Predictive*, *Preventive*, *Personalised* and *Participatory* (P4) medicine is perhaps the most illustrative set of guiding principles both advocating and foreseeing the radical remodelling of medical practice (Flores et al. 2013). Although Hood et al. (2004) originally introduced his vision of a P4 *medicine* and did not elaborate on the implications of the transformation of medicine on the forms and objectives of our healthcare systems, we see in P4 a set of predictive and prescriptive principles with a transformative potential for the improvement of healthcare delivery *if and only if* these principles are operationalised through appropriate P4 healthcare delivery models. We therefore extend the semantic use of P4 and will refer from now on to *P4 healthcare* to relate to models of healthcare delivery founded on the P4 principles. We argued elsewhere that these models were essential for achieving value-effectiveness, i.e. cost-efficiency, clinical efficacy, equity of access to care, and economic sustainability our healthcare systems are desperately in need of (Patou and Maier 2017). The present paper builds on this perspective and seeks to highlight the need for specific engineering design frameworks, methods, tools, and metrics to foster successful P4 healthcare models, materialised through healthcare policies, organisational structures, services, and products.

In what follows, the fundamental principles at the core of P4 healthcare are drawn and a systematic review of the engineering design and relevant clinical research literature on complex medical interventions for the clinical management of Mild Cognitive Impairment (MCI) and dementia covering the past decade is presented. Mild Cognitive Impairment and dementia are chosen as the focus of this paper as they are of great concerns societally. More specifically, for each reviewed work, the contribution of the intervention at play to each ‘P’ of the P4 principles is assessed and reported in detail. Similarly, we identify and discuss, for the same set of complex interventions (Moore et al. 2015), the elements implementing principles antithetical to the P4 principles: those generally associated with the conventional care model, i.e. reactive, palliative, passive, and mostly population-based, which we refer to as generic. Findings are then discussed from an engineering design viewpoint. Following, we elaborate on the rationale that could explain why to-date, P4 remains largely unattained. Finally, opportunities for engineering design research and practice to support and lead developments towards *Predictive*, *Preventive*, *Personalised* and *Participatory* (P4) healthcare service delivery are highlighted.

2. Background

2.1 Predictive, Preventive, Personalised and Participatory (P4) Healthcare

Today, healthcare systems are still predominantly tailored around the reactive, curative or palliative, and population-based (i.e. generic) care delivery model of evidence-based medicine (Hood, Balling, and Auffray 2012). Their main objective is to react promptly to solicitations from symptomatic patients, i.e. to diagnose, treat and rapidly dismiss patients suffering an acute condition, or to provide episodic support for the chronically ill. The scientific and technological disruptions of the past two decades are driving a paradigm-shifting change in this model, with a trajectory set towards the advent of P4 medicine (Westont and Hood 2004; Hood, Balling, and Auffray 2012; Hood and Auffray 2013; Sagner et al. 2017). *Predictive*, *Preventive*, *Personalised* and *Participatory* (P4) medicine is deemed to emerge from the “confluence of a systems approach to medicine and from the digitalisation of medicine that creates the large data sets necessary to deal with the complexities of disease” (Hood, Balling, and Auffray 2012, p.992). In other words, P4 medicine promises proactive health and care delivery, more focused on wellness and on the implementation of anticipatory measures for predicting and preventing disease or adverse consequences. This vision contrasts with the main objectives and strongholds of our present healthcare systems: reactiveness and short-term efficiency of episodic care delivery. Conceptualised after the completion of the Human Genome Project and related breakthroughs in DNA sequencing technologies, the vision of a P4 medicine is as much relying on progress in the life sciences as it is dependent on the capabilities offered by novel Information and Communication Technologies (ICTs), including smartphones, wearables, virtual-reality, data science and artificial intelligence. The concept of digitisation that Hood et al. (2012) refer to is central in discussions on P4 medicine and the future of healthcare: it evokes the digital capture of health-related information and the algorithms and devices on which the vision of personalised medicine relies (Swan 2012; Topol 2014).

The emergence of this new paradigm has implications for the power of design- and systems methods for healthcare, especially for those aimed at guiding the design of healthcare products and services.

Let us consider the first of the four P's, namely *Prediction: Predictive* medicine aims to determine the odds in absolute or relative terms that an individual develops a disease, that her condition worsens, that she responds to specific medication or develops treatment side effects. Prediction means to anticipate diagnostic outcome or therapeutic efficacy most often to be able to prevent or to prepare in cases where prevention is not possible. Prediction is made possible by the identification, collection, fusion and analysis of personal data acquired from various and multimodal sources. Importantly, prediction is tightly coupled with *personalisation,* given that accurate and precise predictions require the availability of data of people's unique biology, behaviour and environment. This digital phenotyping of the individual is at the core of the future of healthcare and we can therefore anticipate that good healthcare service design will require relying on theories adapted to this reality (e.g. data-driven design (Parraguez and Maier 2017)). As *predictive* healthcare strategies better inform us on both the general and individual mechanisms of health and disease, the design of targeted *preventive* strategies will become feasible. Targeted preventive medicine requires a knowledge base of all the factors and causal mechanisms linking the genome, the environment and behaviour to the onset and development of disease and to treatment response. If predictive medicine grants us that knowledge, policy-makers and healthcare service providers should have the capacity to plan and implement *preventive* strategies focused on eliminating disease factors, or on diminishing their effects. Whether they involve pre-emptive exogenous care delivery measures or not, these strategies will certainly aim at changing endogenous behaviours among individuals presenting an unacceptable risk of health deterioration. P4's preventive medicine is, as its name indicates, particularly suited to the anticipation of preventable diseases, a significant number of which are chronic. The initial development and further progression of chronic diseases are often influenced by behaviour and lifestyle, suggesting that preventive healthcare strategies should be heavily based on cognitive and behavioural theories. Successful implementation of such strategies will thus depend on our ability to harness cognitive and behavioural insights; in particular those that are related to motivation, ownership, and engagement, so that we can design and actuate interventions reducing or limiting self-damaging behaviours in individuals most at risk. This brings us to the fourth P of P4 medicine. Future medicine is hoped to be *participatory* or collaborative: it is also expected that patients become much more involved and self-empowered in their own health management. The rationale behind this proposition, as has been argued e.g. in Topol (2015) is that our traditional healthcare delivery model is characterised by a large asymmetry in information availability and capability to take action between patients and clinicians, which has been said to be patriarchal, inefficient and unjustified. While the ill and weak have historically been largely dependent on their care providers, healthy citizens and patients alike are today empowered with tools to become prominent contributors of their own health management. Mobile health, personal health records and on-demand genetic testing are examples of the large spectrum of technology-derived empowerment tools that appear to make the vision of a *participatory* care model possible today. As mentioned earlier, participation is particularly relevant when it comes to preventable diseases, when asymptomatic citizens hold the key to remaining

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healthy in their behaviour and lifestyle. Moreover, *participatory* care also applies to scenarios beyond the point of prevention, in cases where treatment and day-to-day clinical management of disease are required. *Participatory* care could then take many forms, involving shared decision making between patient and clinicians, e.g. on objectives and strategies for treatment.

2.2 P4 healthcare for cognitive impairment and dementia care

Dementia care and management of other forms of cognitive impairment represent a challenging yet relevant use case for our investigation. Cognitive impairment in its milder forms often appears as an abnormal, faster-than-normal, symptomatology of ageing. Although some individuals diagnosed with a mild form of cognitive impairment remain stable, a significant number of them will see their condition evolve towards dementia. The milder forms and slow progression from Mild Cognitive Impairment (MCI) to dementia gives an opportunity for healthcare professionals, informal carer and the person living with MCI to attempt and slow down or mitigate the apparition of symptoms, the loss of autonomy, and the distress of both the person living with MCI and their entourage. Often progressive, with adverse events (e.g. episodes of confusion, wandering, etc.) partly predictable and to some extent preventable, it is reasonable to argue that cognitive impairment and dementia care should be relevant to a P4-guided approach (Kivimäki and Batty 2016; Norton et al. 2014; Sabia et al. 2017). It is worth noting that prevention may go beyond forestalling of the disease onset and may also relate to strategies designed to delay further *progression* of the disease or to prevent some of its adverse events. Also, people with dementia vary broadly in their functional capacity and lifestyle, and pattern of symptoms and co-morbidities. A wide range of individual needs and preferences can therefore be exploited to maintain wellbeing and autonomy as much and as long as possible. Within the limits of prescribed “good-behaviours”, *personalisation* ought to enable the selection of the tailored health management measures that people suffering from cognitive impairment are in great need of.

The current and expected impact of dementia worldwide is one of the most preoccupying figures in society today. Worldwide, 50 million people were living with dementia in 2018 (Patterson 2018). This number is expected to rise to more than 152 million by 2050. Adding to an incommensurate social and moral burden, the cost of dementia weighs heavy on our healthcare systems, with more than 1 trillion USD spent worldwide in 2018 alone.

3. Methods

A systematic review of the literature addressing technology-based complex interventions for dementia care and for managing cognitive impairment (Moore et al. 2015) was carried out following the process depicted in **Figure 1**. For each reviewed paper, the objective was to assess whether elements of the intervention implemented any of the 4 P's (*predictive, preventive, personalised and participatory*), and to what extent. Interventions in this context would include products, systems, services or a combination thereof, targeting actors in the care network, including people with dementia or other form of cognitive impairment, their caregivers or healthcare professionals such as nurses, general practitioners, gerontologists. The review process was conducted by two researchers. Both reviewers carried out the search and filtered search results according to the selection criteria. Papers included or rejected by only one of the reviewers were discussed until a definite list of papers to review was agreed upon. Both researchers then separately read and analysed each paper and reported their findings. Discrepancies in the evaluation were then discussed in tandem and resolved. The table cells for which a disagreement was originally present are marked with an asterisk* character in **Table 2**.

3.1 Literature search

We systematically searched, selected and analysed relevant papers, as outlined in **Figure 1**. The SCOPUS scientific database was searched for papers with a title, keywords or abstract containing the terms "design" + either "technology", "intervention" or "system"; + either "dementia" or "mild cognitive impairment". Sources were limited to a collection of journals within the fields of engineering design, technology, healthcare, and the clinical sciences (see Appendix A). To avoid any anachronistic mismatch (interventions specified before the formulation of the P4 medicine vision), we limited the timeframe of our search to papers published from 2007 onwards (Hood 2008; Price et al. 2008). As a reference point, this also coincides with the release of the first iPhone in 2007. Finally, we excluded review papers to avoid double-counting.

Figure 1

3.2 Selection process

The literature search yielded 887 results from which 48 papers were ultimately included in the analysis. In the first phase, all titles and abstracts were screened to filter out irrelevant search results. Reasons for exclusion included no mention of a design process for the intervention (explicit or implicit), the altogether absence of an intervention (such as in purely observational studies), retrospective studies, interventions missing a technological element, or wrong target group. Interventions lacking an appropriate technological element typically included pharmacology-only, diet, physical activity, relaxation/stimulation activities, group therapy or other counselling approaches, or archaic technology, e.g. a line telephone. The screening process filtered most of the original search results, yielding 75 candidates for a detailed review.

In the second phase, full-text reviews were conducted to elicit the aim and implementation details of each intervention. A further 27 papers were excluded in this process, mostly when an insufficient level of detail prevented the confident delineation of modular aspects, i.e. elements of the intervention realizing any of the P4 principles.

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3.3 Review and analysis

A total of 48 peer-reviewed journal publications met our inclusion criteria for final review and analysis. The goal of the analysis was to identify and describe interventions translating explicitly or implicitly to one or more of the 4 P's of P4 healthcare (*predictive, preventive, personalised and participatory*) or, on the contrary, any antithetical principle to P4. We thus contrasted each of the P's with their respective conceptual counterpart: reactive vs *predictive*, palliative/curative vs *preventive*, generic vs *personalised,* passive vs *participatory*.

An overview of the characteristics we strived to identify and describe is provided in Table 1. For each paper, an intervention with a technological element at its core, was identified along with its primary purpose. The paper was then analysed to find evidence that the intervention included at least one element representative of any of the characteristics listed in Table 1. A given intervention could very well include several elements, each supporting conceptually contrasting, opposing characteristics, e.g. reactive vs *preventive*, and generic vs *personalised*. In such a case, each element would be detailed in the appropriate table cell.

Table 1. Summary of characteristics of conventional and P4 healthcare used to review literature

Healthcare delivery	Characteristic	Description
Conventional Healthcare	Reactive	Care/treatment/intervention plan is determined and provided only after an adverse event, such as a trauma, or the appearance of or worsening of symptoms has occurred.
	Curative/ Palliative	Care/treatment/intervention aims to restore health after symptoms are already affecting the patient. In cases where recovery is not achievable, the objective is to accompany the individual (e.g. avoid discomfort) as the condition progresses.
	Generic	Care/treatment/intervention follows a one-size-fits-all: it is applied in the same way for all patients of a population meeting given criteria.

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	Passive	Care/treatment/intervention is administered unidirectionally by the healthcare professional to the patient without requiring active participation of the latter.
P4 Healthcare	Predictive	Care/treatment/intervention incorporates elements predicting the absolute of relative odds of health-related event to occur, e.g. disease onset or progression, or treatment response.
	Preventive	Care/treatment/intervention includes elements meant to prevent the onset or progression of disease, thereby avoiding or reducing the need for therapeutic measures.
	Personalised	Care/treatment/intervention is systematically tailored to each care recipient's individual health needs/disease profile and individual preferences.
	Participatory	Care/treatment/intervention is realized bidirectionally: it strongly encourages that the care recipient plays an active role in specifying, planning and implementing their treatment/intervention in collaboration with healthcare professionals.

4. Results

The literature search yielded 887 candidate papers before screening, of which 75 matched the inclusion criteria for full text review. The in-depth full text-analysis of said 75 interventions targeting cognitive impairment or dementia led to the further exclusion of 27 studies, arriving at a final selection of 48 papers, with the synthesis of results presented in what follows. Detailed results of the review are available as supplementary material (Patou et al. 2020). An abridged version is provided in Table 2 where papers are presented in descending, chronological order. Markings in the cells indicate whether elements translating a given characteristic could be identified or not (black cell = yes, white cell = no). The cells for which the two reviewers were originally in disagreement are marked with an asterisk * in Table 2, which was the case for overall 33 out of the 384 cells (8.59%) of Table 2. Disagreements were resolved and reflected in the final colour of the cell.

Table 2. Abridged results relating articles to characteristics of conventional and P4 healthcare. Each black cell represents the fact that the study reports an intervention including one or more elements satisfying a given criterion of either conventional or P4 healthcare. Results are listed in descending, chronological order. Abbreviations: R = Reactive, C/P = Curative/Palliative, G = Generic, Pa = Passive, Pd = *Predictive*, Pv = *Preventive*, Ps = *Personalised*, Pt = *Participatory*.

#	Paper	R	C/P	G	P	Pd	Pv	Ps	Pt
1	(McCreedy et al. 2019)	■			■		■	■	
2	(Thorpe, Forchhammer, and Maier 2019)						■	■	■
3	(Law et al. 2019)			■				■	■
4	(Bekrater-Bodmann et al. 2019)			■		■	■		■
5	(Jeon et al. 2019)		■					■	■
6	(Helal and Bull 2019)	■	*	■	■	■		■	■
7	(Tang et al. 2019)		■	■			*		
8	(Gelonch et al. 2019)			■			■ *		■
9	(Moyle et al. 2019)			■			■		
10	(Gustafson et al. 2019)			■			■	■	■
11	(Oksnebjerg, Woods, and Waldemar 2019)		■				■	■ *	■
12	(Hooper et al. 2019)			■			■	■	*
13	(Enshaeifar et al. 2019)			*	*	■	■		■ *
14	(Wijma et al. 2018)			■			■		
15	(Moyle et al. 2018)			■	*		■		
16	(Killin et al. 2018)	■		■			■	*	*
17	(Soellner et al. 2015)		■				*	*	■
18	(Barbera et al. 2018)			*		*	■	■	
19	(Burton and O'Connell 2018)						■	■	■
20	(Lindauer et al. 2017)	■		■					
21	(Duggleby et al. 2017)			■				■	
22	(Elfrink et al. 2017)				■ *			■	■
23	(Bahar-Fuchs et al. 2017)					■		■	■
24	(Lazarou et al. 2016)							■	■
25	(Jekel et al. 2016)			■		■ *			
26	(van de Weijer et al. 2016)			■ *			■	■	
27	(Mirelman et al. 2016)	■ *					■	■	■
28	(van Knippenberg et al. 2016)	■		■				■	■
29	(Gaugler, Reese, and Tanler 2016)	■ *						■	■
30	(Matthews et al. 2015)	■		■					■
31	(Tak et al. 2015)							■	■
32	(Moreno, Elena Hernando, and Gomez 2015)	■						■	■
33	(Baker et al. 2015)			■					■
34	(Schaller et al. 2015)	■		■ *				■	■
35	(Cristancho-Lacroix et al. 2015)			■					■ *
36	(Boman et al. 2014)	■		■			■		■ *
37	(Grindrod et al. 2014)	■ *					■	■	■

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#	Paper	R	C/P	G	P	Pd	Pv	Ps	Pt
38	(McKechnie, Barker, and Stott 2014)	■		■					■
39	(Aloulou et al. 2013)	■			*			■	*
40	(Blom et al. 2013)			■			■		■
41	(García Vázquez et al. 2012)	*		*				■	
42	(Meiland et al. 2012)			■				■	■
43	(van Hoof et al. 2011)	■					*	■	
44	(Van Der Marck et al. 2011)	■		■			*		
45	(Van Der Roest et al. 2010)			■			*	■	
46	(Hilbe et al. 2010)			■			■		
47	(Mihailidis et al. 2008)						*	■	
48	(Shoval et al. 2008)			■		*			

Results of the analysis indicate that *none* of the interventions we reviewed presented all four characteristics of the P4 healthcare model simultaneously. Furthermore, we do not observe any clear trend reflecting either a moving-away or a moving-towards a generalisation of the P4 principles. Noticeably though, elements of *preventive* and *personalised* care are generally observable over the entire timespan covered by this study, whereas aspects of *participatory* care seem to have appeared more recently. *Predictive* care remains very scarce. As mentioned earlier, complex technology-based interventions are not monolithic blocks: they are generally composed of several elements aggregating in a product-service system. It is at the lower element level that the characteristics of conventional or P4 healthcare appear, and it is therefore not incompatible to see conceptually-opposite characteristics fulfilled simultaneously by any given intervention. Many of the works reviewed are based on interventions that do present characteristics of conventional care, mirroring the opposite trend of that observed for the 4 P's. Overall, however, analysis results do *not* suggest trends towards P4 healthcare or away from conventional care models.

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5. Discussion

5.1 P4 in managing cognitive impairment and dementia

Our results suggest that *predictive* care may be the weaker point among interventions targeting cognitive impairment or dementia. We conclude that only six out of the forty-nine papers reviewed presented tangible element representative of *predictive* care. Prediction is arguably one of the foundational building blocks of P4 healthcare, often an enabler of the other three P's. Yet, building predictive models for diagnosis, prognosis or therapy efficacy is generally difficult, especially for syndromes such as forms of cognitive impairment or forms of dementia where both complex multigenic influences and numerous environmental and behavioural factors are at play. Moreover, we need to also see this against the background of a population mostly consisting of elderly individuals among whom co-morbidities are common which may complicate the issue of predictability further. Yet, prediction is overall becoming more achievable, thanks to increasing affordability, portability, pervasiveness and connectedness of multimodal data acquisition modalities and thanks to the increasing efficacy and efficiency of computational techniques for identification and validation of predictive models (Andreu-Perez et al. 2015; Topol 2014). Several of the articles reviewed here describe the collection of data with potential predictive power, such as cognitive impairment evaluation scores (Lindauer et al. 2017), performance in cognitive training exercises or functional tasks (Bahar-Fuchs et al. 2017; Jekel et al. 2016; van de Weijer et al. 2016), and behaviour, including sleep and physical activity patterns (Lazarou et al. 2016).

Examples of *preventive* care are more represented in the result table. It may seem somewhat surprising to see prevention without prediction for a number of the studies reviewed, since the former to some degree often depends on the latter: probabilistic knowledge about a likely future can assist the design of *targeted* prevention. Without predictive models, *preventive* care can still be pursued, though following a more generalised rather than targeted approach. *Preventive* interventions here included the use of cognitive/motor training exercises to mitigate the risks of disease progression or falls (Mirelman et al. 2016; van de Weijer et al. 2016). Similarly, wandering

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could be prevented by detecting door-exits and confirming intent with the patient at each occasion (van Hoof et al. 2011), or by detecting and responding to every bed-exit to prevent falls (Hilbe et al. 2010).

Personalised care was slightly more prominent in the literature reviewed here. Yet, again, across all reviewed works, the elements of any intervention that offered personalised – that is individualised - features generally accounted for few of the elements composing the intervention. Furthermore, the elements that did offer options/variants required for the satisfaction of individual needs or preferences did not appear to result from an explicit and systematic design process including analysis, concept definition, implementation, and evaluation. Still, some of the works reviewed did rely on prior user input for the definition of one or a few of their functional blocks. Examples include a web portal offering caregiver support with sections in which users can upload background information and patient-specific characteristics (Duggleby et al. 2017); or an online "life story book" for users such as people with dementia and their caregivers to complete with personal files and anecdotes (Elfrink et al. 2017). The conversion of possible design variants to a patient-specific interface or interaction could in principle take various forms. For instance, some of the interventions investigated here offer end-users to choose, that is essentially turning on/off various software functionality. This is the case for the CogKnow Day Navigator in which users may opt for a combination of features such as calendar, reminders, activity assistance (Meiland et al. 2012); and a home safety system offering adjustable features and security levels (van Hoof et al. 2011). These "user-master" implementations are both powerful and risky as they theoretically offer combinatorial numbers of individualised solutions at the cost of requiring sustained user-engagement in utilising the solution over time. Some works averted this issue altogether by setting up and fixing a set of personalised features during the initialisation (design) or kick-start of an intervention, e.g. based on the definition of personal goals (Burton and O'Connell 2018), or demographics, illness-related, functional and psychosocial characteristics (Tak et al. 2015). Others circumvent the challenge of user-master personalisation strategies by leveraging automated, algorithmic personalisation using

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behavioural data gathered via a home sensor network as part of an assisted living environment (Lazarou et al. 2016). Others describe similar approaches whereby an intervention continuously adapts to changes in users' needs based on pervasive processing of behavioural data. Examples include adjusting the difficulty level of training exercises based on user performance (Bahar-Fuchs et al. 2017; van de Weijer et al. 2016), or adapting computer-based guidance for activities of daily living based on user performance, responsiveness and feedback (Mihailidis et al. 2008). Other strategies for *personalised*, adaptive care that responds to changes in users' needs do not require automation, or in some instance should or could not be automated, such as when personalisation targets a feature of critical nature for the end-user's well-being (e.g. pharmacology). An example of this latter scenario is given in the case of caregiver support adapted based on face-to-face user-feedback sessions (van Knippenberg et al. 2016). Van Knippenberg's intervention, however, still leverages digital data acquired continuously in between user-carer meetings, feeding each personalisation session with relevant clinical and behavioural data.

Finally, *Participatory* care seem to enter the scene more recently in our results (2013) and with a seemingly dense concentration of works thereafter. Again, the extent to which *participatory* care is achieved varies, opening critical questions about the objectives, strategies and concrete implementations. Collaboration is at the core of *participatory* care, relying on patient engagement and on clinicians' involvement of their patients for the assessment, planning and execution of strategies to prevent or manage disease or otherwise improve their health and wellbeing (Valentin-Hjorth et al. 2018). For dementia care, collaboration may extend to include primary caregivers (typically a spouse or other close relative). In its current format and based on the results of the literature review, participation is mostly limited to a subset of (or single) decisions and activities. Several works reviewed here implement variants of a common strategy where healthcare professionals and caregivers partner to assess the burden of disease and agree on care strategies (Gaugler, Reese, and Tanler 2016; Matthews et al. 2015; Schaller et al. 2015). Once again, data relative to patient's cognition, functional capacity, behaviour or other health-related information can be harnessed to better assess and adjust care delivery (Bahar-Fuchs et al. 2017; Mirelman et al. 2016). Allowing the patient to define how and when they employ an intervention instead of relying solely on instructions from the healthcare professional prescribing its use also constitutes an essential element of *participatory* care, namely shared-decision making (Griffioen et al. 2017). One single work reviewed here combined all aforementioned elements relevant to *participatory* care, wherein the user participated in defining the care strategy and intervention goals and was able to access her own data to follow her progress. Communication with a healthcare professional was encouraged and facilitated by a messaging function incorporated into the system (Lazarou et al. 2016).

5.2 Engineering P4 Healthcare

This systematic review of state-of-the-art in the implementation of P4 healthcare models to address the management of cognitive impairment and dementia sheds light both on a number of opportunities and shortcomings. Attempts at proposing P4 models of care for managing cognitive impairment seem to some extent already be founded on engineering design practices, as we have seen here in several explicit or implicit uses of, for example, participatory-design, co-design or inclusive design. These examples illustrate the relevance of research in engineering design to support exploration, refinement, adaptation and widespread implementation of healthcare delivery models based on the P4 principles (*predictive, preventive, personalised and participatory*). Conversely, one can expect that engineering design research itself may benefit from embracing an application domain that has until now been hesitant to look for solutions outside of the clinical science community. One aspect in which research in engineering design and clinical- and healthcare improvement research can especially benefit from one another is their common interests in human behaviour. Clinical researchers already harness behaviouromic insights and theories from psychology and the cognitive sciences to generate new hypotheses on and interventions for dealing with chronic diseases. Engineering designers interested in the healthcare domain could build on these disciplines to rationalise further design process research and, in turn, help generalise practices that would facilitate the design of interventions engaging patients more, harnessing multi-omics data throughout broader and more integrative product- and service systems, and thus supporting better clinical decision making.

5.2.1 Design frameworks

Although encouraging in that they show a partial embrace of the 4 P's (*predictive, preventive, personalised and participatory*) in the management of cognitive impairment, our results also suggest obvious improvement opportunities in the systematic practice of and research in engineering design applied to healthcare. First of all, as mentioned earlier, none of the studies we reviewed demonstrated the systematic implementation of a complex intervention addressing all 4 P's simultaneously. One can hardly think that this would be deliberate since the 4 P's are not mutually exclusive. On the contrary, they were formulated with complementarity in mind: the 4 P's should interact positively whenever implemented together. Perhaps more importantly, none of the studies reviewed explicitly *claimed* an attempt to shape their complex intervention following the P4 principles. This simple observation suggests paradigmatic limitations in how complex healthcare interventions are crafted and call for remedies this community is proficient in making: the elaboration of holistic engineering design *frameworks* and *methodologies* to systematically design comprehensive P4 interventions. One can anticipate some of the commonalities these frameworks will exhibit: the comprehensive and iterative consideration of each of the 4 P's, each P implementing specific features reflecting the particular scope and context of the challenge under consideration.

5.2.2 Success indicators

Importantly, engineering design frameworks and the design models these frameworks will support will also need to adopt new or borrow existing outcome measures and *indicators* to assess the success of a P4 intervention. These measures are likely to include – but may very well not be limited to – metrics of clinical efficacy and health economics, i.e. *distal* clinical and economic measures against which medical or cost benefits of an intervention should be evaluated. But indicators of a different nature will be required to evaluate the *proximal* effects of a design process and its supporting framework on achieving high subjective or objective degrees of *Prediction, Prevention, Personalisation* and *Participation*. These indicators should allow us to answer the questions such as: how might we measure *Personalisation*? The availability of these measures should, in turn, help engineering designers and clinicians understand better which design principles, mechanisms or methods foster the clinical or operational benefits observed distally. These measures may well distinctly represent any of the P's but not necessarily: other conceptualisations of healthcare systems, other novel models of care will become available pressuring us in deriving new intermediary indicators of their success, e.g. to evaluate the degree of connectivity, stratification, personalisation, pervasiveness or decentralisation (Patou and Maier 2017) of a complex healthcare intervention. Only then would one be capable of determining which combination of elements, and in which forms, ought to lead to better health outcomes, including cost-reductions, and patient satisfaction.

5.2.3 Tools and methods

Although necessary, the availability of frameworks and design processes for P4 healthcare will not guarantee the success of complex interventions. The benefit of engineering design for improving healthcare systems' outcomes, whether clinical, economic, operational, organisational, etc. will also depend on the availability of adequate tangible *tools* and *methods*. For instance, none of data-centric approaches to prediction or personalisation reviewed in this work addressed the need for scalability or interoperability that clinical systems often require, e.g. interfacing with Electronic Health Records, Hospital Information Systems. One may attribute this shortcoming to several reasons, the first being the deliberate setting aside of these issues, on the account they may not be "central" or essential for proof-of-concept of the intervention. A second reason could be alternate priorities of clinical researchers and emphasis lying elsewhere than proposing tools and methods for the investigation of system properties, an activity usually the forte of engineering designers. Some early attempts to systematise the considerations of data-centric interventions for managing cognitive impairment, for instance, are presented in Thorpe and Forchhammer (2016) and Thorpe, Forchhammer, and Maier (2019). The challenge of developing tools and methods for P4 or any other new conceptualisation of healthcare delivery also comes from the fact that the ontology of the *concepts* advocated in the clinical literature is often not consensual or is lacking precise definitions. This invites preliminary attempts to clarify terms used, such as a recent work revolving around the concept of *Collaborative Care* (Valentin-Hjorth et al. 2018).

6. Limitations

The systematic review was conducted using the SCOPUS database. Future work may cross-check results using other research platforms. The two researchers, although individually conducting the search, screening, reading, selection, and analysis of the selected papers, are from the same institution inducing potential selection bias. Moreover, evaluating each intervention found in the selected literature records based on the four P's – *predictive, preventive, personalised and participatory* – is to some extent open for interpretation and translation as the principles may be operationalised differently in different contexts. Finally, the scope of this paper's investigation is arguably vast and aggregation of interventions related to cognitive impairment and dementia without further clustering (e.g. depending on the clinical endpoints of the intervention, depending on the clinical diagnosis, to, for example, maintain cognition, promote autonomy or else) makes it impossible to judge whether some sub-group of references may have after all revealed a clear pattern of implementation of the P4 principles. Further, the absence of an obvious pattern or advancement towards an implementation of P4 principles in literature cannot be attributed with certainty to a gap in design practice: P4 may simply not be a straightforward or applicable

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framework for addressing cognitive impairment and dementia. Yet, as stated earlier, we believe P4 healthcare that embraces *predictive, preventive, personalised and participatory* principles to be an option to consider as cognitive impairment is in parts preventable, evolves over a long time span (prediction), and affects multiple stakeholders in the surroundings of those affected (participation).

7. Conclusions

This paper presents a systematic literature review aimed at assessing how well current technology-based interventions that focus on dementia and other cognitive impairments align with the P4 - *Predictive, Preventive, Personalised, Participative* - model of healthcare. We identified forty-nine relevant studies and found that none of them demonstrated the simultaneous and systematic application of all four principles. We argued that this presents an opportunity for the engineering design community to engage with future models of healthcare delivery through the development of design frameworks, new indicators for measuring the success of these models as well as tools and methods.

In sum, awareness for the potential of engineering design for healthcare improvement (Clarkson, 2018) has previously been raised Griffioen et al. (2017). This paper builds on such calls. It is the first paper to map extant design research on to the principles of P4 healthcare and, by extension, shows the potential of design research in improving the path specifically towards P4 healthcare: *predictive, preventive, personalised and participative*.

Acknowledgements

We would like to acknowledge the Videncenter for velfærdsteknologi (VihTek) and DTU Management for partially funding the work that led to this manuscript.

References

Aloulou, Hamdi, Mounir Mokhtari, Thibaut Tiberghien, Jit Biswas, Clifton Phua, Jin Hong Kenneth Lin, and Philip Yap. 2013. “Deployment of Assistive Living Technology in a Nursing Home Environment: Methods and Lessons Learned.” *BMC Medical Informatics and Decision Making* 13: 42. https://doi.org/10.1186/1472-6947-13-42.

Andreu-Perez, Javier, Carmen C Y Poon, Robert D. Merrifield, Stephen T C Wong, and Guang Zhong Yang. 2015. “Big Data for Health.” *IEEE Journal of Biomedical and Health Informatics* 19 (4): 1193–1208. https://doi.org/10.1109/JBHI.2015.2450362.

Bahar-Fuchs, Alex, Shannon Webb, Lauren Bartsch, Linda Clare, George Rebok, Nicolas Cherbuin, and Kaarin J. Anstey. 2017. “Tailored and Adaptive Computerized Cognitive Training in Older Adults at Risk for Dementia: A Randomized Controlled Trial.” *Journal of Alzheimer’s Disease* 60 (3): 889–911. https://doi.org/10.3233/JAD-170404.

Baker, Christine, Peter Huxley, Michael Dennis, Saiful Islam, and Ian Russell. 2015. “Alleviating Staff Stress in Care Homes for People with Dementia: Protocol for Stepped-Wedge Cluster Randomised Trial to Evaluate a Web-Based Mindfulness- Stress Reduction Course.” *BMC Psychiatry* 15 (1): 1–9. https://doi.org/10.1186/s12888-015-0703-7.

Barbera, Mariagnese, Francesca Mangialasche, Susan Jongstra, Juliette Guillemont, Tiia Ngandu, Cathrien Beishuizen, Nicola Coley, et al. 2018. “Designing an Internet-Based Multidomain Intervention for the Prevention of Cardiovascular Disease and Cognitive Impairment in Older Adults: The HATICE Trial.” *Journal of Alzheimer’s Disease*. https://doi.org/10.3233/JAD-170858.

Bekrater-Bodmann, Robin, Annette Löffler, Stefano Silvoni, Lutz Frölich, Lucrezia Hausner, Simon Desch, Dieter Kleinböhl, and Herta Flor. 2019. “Tablet-Based Sensorimotor Home-Training System for Amnestic Mild Cognitive Impairments in the Elderly: Design of a Randomised Clinical Trial.” *BMJ Open*. https://doi.org/10.1136/bmjopen-2018-028632.

Blom, Marco M, Judith E Bosmans, Pim Cuijpers, Steve H Zarit, and Anne Margriet Pot. 2013. “Effectiveness and Cost-Effectiveness of an Internet Intervention for Family Caregivers of People with Dementia : Design of a Randomized Controlled Trial.” *BMC Psychiatry* 13: 1–7.

Boman, Inga-Lill Lill, Stefan Lundberg, Sofia Starkhammar, and Louise Nygård. 2014. “Exploring the Usability of a Videophone Mock-up for Persons with Dementia and Their Significant Others.” *BMC Geriatrics* 14 (1). https://doi.org/10.1186/1471-2318-14-49.

Cite as: François Patou, Nicholas Ciccone, Julia Thorpe & Anja Maier (2020) Designing P4 healthcare interventions for managing cognitive decline and dementia: where are we at?, Journal of Engineering Design, DOI: 10.1080/09544828.2020.1763272

Burton, Rachel L, and Megan E O'Connell. 2018. "Telehealth Rehabilitation for Cognitive Impairment: Randomized Controlled Feasibility Trial." *JMIR Research Protocols* 7 (2): e43. https://doi.org/https://dx.doi.org/10.2196/resprot.9420.

Christensen, JP, A Hasman, and L Hunter. 2010. *Engineering the System of Healthcare Delivery*. Edited by W B Rouse and D A Cortese. IOS Press BV.

Clarkson, PJ, D. Bogle, Jeffrey Dean, Michael Tooley, John Trewby, Lee Vaughan, Edward Adams, Patricia Dudgeon, Nicola Platt and Paul Shelton. "Engineering better care: a systems approach to health and care design and continuous improvement." (2017). London : Royal Academy of Engineering.

Clarkson, John. 2018. "What Has Engineering Design to Say about Healthcare Improvement ?" *Design Science* 4 (17): 1–35. https://doi.org/10.1017/dsj.2018.13.

Clarkson, P John, P Buckle, R Coleman, D Stubbs, J Ward, J Jarrett, R Lane, and J Bound. 2004. "Design for Patient Safety: A Review of the Effectiveness of Design in the UK Health Service." *Journal of Engineering Design* 15 (2): 123–40. https://doi.org/10.1080/09544820310001617711.

Craig, Claire, and Paul Chamberlain. 2017. "Behaviours: Design and Behaviour Change in Health." In *Design for Health*, edited by Emmanuel Tsekleves and Rachel Cooper, 191–203. Design for Social Responsibility. Abingdon: Routledge. https://doi.org/10.4324/9781315576619.

Cristancho-Lacroix, Victoria, Jérémy Wrobel, Inge Cantegreil-Kallen, Timothée Dub, Alexandra Rouquette, Anne-sophie Rigaud, and Assistance Publique -Hôpitaux de Paris. 2015. "A Web-Based Psychoeducational Program for Informal Caregivers of Patients With Alzheimer's Disease: A Pilot Randomized Controlled Trial." *Journal of Medical Internet Research* 1717 (5): 117. https://doi.org/10.2196/jmir.3717.

Cutler, David M., Allison B. Rosen, and Sandeep Vijan. 2006. "The Value of Medical Spending in the United States, 1960–2000." *New England Journal of Medicine* 355 (9): 920–27. https://doi.org/10.1056/NEJMsa054744.

Doss, Henry. 2014. "Design Thinking In Healthcare: One Step At A Time." Forbes. 2014. https://www.forbes.com/sites/henrydoss/2014/05/23/design-thinking-in-healthcare-one-step-at-a-time/#3441f9f63f1a.

Duggleby, Wendy, Jenny Ploeg, Carrie McAiney, Kathryn Fisher, Jenny Swindle, Tracey Chambers, Sunita Ghosh, et al. 2017. "Study Protocol: Pragmatic Randomized Control Trial of an Internet-Based Intervention (My Tools 4 Care) for Family Carers." *BMC Geriatrics* 17 (1): 1–9. https://doi.org/10.1186/s12877-017-0581-6.

Elfrink, Teuntje R, Sytse U Zuidema, Miriam Kunz, and Gerben J Westerhof. 2017. "The Effectiveness of Creating an Online Life Story Book on Persons with Early Dementia and Their Informal Caregivers: A Protocol of a Randomized Controlled Trial." *BMC Geriatrics* 17 (1): 1–11. https://doi.org/10.1186/s12877-017-0471-y.

Enshaeifar, Shirin, Ahmed Zoha, Severin Skillman, Andreas Markides, Sahr Thomas Acton, Tarek Elsaleh, Mark Kenny, Helen Rostill, Ramin Nilforooshan, and Payam Barnaghi. 2019. "Machine Learning Methods for Detecting Urinary Tract Infection and Analysing Daily Living Activities in People with Dementia." *PLoS ONE*. https://doi.org/10.1371/journal.pone.0209909.

Flores, Mauricio, Gustavo Glusman, Kristin Brogaard, Nathan D Price, and Leroy Hood. 2013. "P4 Medicine: How Systems Medicine Will Transform the Healthcare Sector and Society." *Personalized Medicine* 10 (6): 565–76. https://doi.org/10.2217/pme.13.57.

García Vázquez, Carolina, Esther Moreno Martínez, Miguel Ángel Valero Duboy, and Ana Gómez Oliva. 2012. "Distributed System for Cognitive Stimulation over Interactive TV." *IEEE Transactions on Information Technology in Biomedicine* 16 (6): 1115–21. https://doi.org/10.1109/TITB.2012.2220782.

Gaugler, Joseph E, Mark Reese, and Richard Tanler. 2016. "Care to Plan: An Online Tool That Offers Tailored Support to Dementia Caregivers." *Gerontologist* 56 (6): 1161–74. https://doi.org/10.1093/geront/gnv150.

Gelonch, Olga, Mireia Ribera, Núria Codern-Bové, Sílvia Ramos, Maria Quintana, Gloria Chico, Noemí Cerulla, Paula Lafarga, Petia Radeva, and Maite Garolera. 2019. "Acceptability of a Lifelogging Wearable Camera in Older Adults with Mild Cognitive Impairment: A Mixed-Method Study." *BMC Geriatrics*. https://doi.org/10.1186/s12877-019-1132-0.

Griffioen, Ingeborg, Marijke Melles, Anne Stiggelbout, and Dirk Snelders. 2017. "The Potential of Service Design for Improving the Implementation of Shared Decision-Making." *Design for Health* 1 (2): 194–209. https://doi.org/10.1080/24735132.2017.1386944.

Grindrod, Kelly Anne, Allison Gates, Lisa Dolovich, Roderick Slavcev, Rob Drimmie, Behzad Aghaei, Calvin Poon, Shamrozé Khan, and Susan J Leat. 2014. "ClereMed: Lessons Learned from a Pilot Study of a Mobile Screening Tool to Identify and Support Adults Who Have Difficulty with Medication Labels." *Journal of Medical Internet Research* 16 (8): e35.

Cite as: François Patou, Nicholas Ciccone, Julia Thorpe & Anja Maier (2020) Designing P4 healthcare interventions for managing cognitive decline and dementia: where are we at?, Journal of Engineering Design, DOI: 10.1080/09544828.2020.1763272

https://doi.org/10.2196/mhealth.3250.

Gustafson, David H., David H. Gustafson, Olivia J. Cody, Ming Yuan Chih, Darcie C. Johnston, and Sanjay Asthana. 2019. “Pilot Test of a Computer-Based System to Help Family Caregivers of Dementia Patients.” *Journal of Alzheimer’s Disease*. https://doi.org/10.3233/JAD-190052.

Helal, Sumi, and Christopher N. Bull. 2019. “From Smart Homes to Smart-Ready Homes and Communities.” *Dementia and Geriatric Cognitive Disorders*. https://doi.org/10.1159/000497803.

Hilbe, J, E Schulc, B Linder, and C Them. 2010. “Development and Alarm Threshold Evaluation of a Side Rail Integrated Sensor Technology for the Prevention of Falls.” *International Journal of Medical Informatics* 79 (3): 173–80. https://doi.org/10.1016/j.ijmedinf.2009.12.004.

Hood, Leroy. 2008. “A Systems Approach to Medicine Will Transform Healthcare.” In *Physical Biology: From Atoms to Medicine*, 337–66. Imperial College Press. https://doi.org/10.1142/9781848162013_0014.

Hood, Leroy, and Charles Auffray. 2013. “Participatory Medicine: A Driving Force for Revolutionizing Healthcare.” *Genome Medicine* 5 (12): 110. https://doi.org/10.1186/gm514.

Hood, Leroy, Rudi Balling, and Charles Auffray. 2012. “Revolutionizing Medicine in the 21st Century through Systems Approaches.” *Biotechnology Journal* 7 (8): 992–1001. https://doi.org/10.1002/biot.201100306.

Hood, Leroy, James R. Heath, Michael E. Phelps, and Biaoyang Lin. 2004. “Systems Biology and New Technologies Enable Predictive and Preventative Medicine.” *Science* 306 (5696): 640–43. https://doi.org/10.1126/science.1104635.

Hoof, J. van, H. S.M. Kort, P. G.S. Rutten, and M. S.H. Duijnstee. 2011. “Ageing-in-Place with the Use of Ambient Intelligence Technology: Perspectives of Older Users.” *International Journal of Medical Informatics* 80 (5): 310–31. https://doi.org/10.1016/j.ijmedinf.2011.02.010.

Hooper, Emma, Zoe Simkin, Harvey Abrams, Elizabeth Camacho, Anna Pavlina Charalambous, Fideline Collin, Fofi Constantinidou, et al. 2019. “Feasibility of an Intervention to Support Hearing and Vision in Dementia: The SENSE-Cog Field Trial.” *Journal of the American Geriatrics Society*. https://doi.org/10.1111/jgs.15936.

Jekel, Katrin, Marinella Damian, Holger Storf, Lucrezia Hausner, and Lutz Frölich. 2016. “Development of a Proxy-Free Objective Assessment Tool of Instrumental Activities of Daily Living in Mild Cognitive Impairment Using Smart Home Technologies.” *Journal of*

Cite as: François Patou, Nicholas Ciccone, Julia Thorpe & Anja Maier (2020) Designing P4 healthcare interventions for managing cognitive decline and dementia: where are we at?, Journal of Engineering Design, DOI: 10.1080/09544828.2020.1763272

Alzheimer's Disease 52 (2): 509–17. https://doi.org/10.3233/JAD-151054.

Jeon, Yun-Hee, Judy M. Simpson, Lee-Fay Low, Robert Woods, Richard Norman, Loren Mowszowski, Lindy Clemson, et al. 2019. "A Pragmatic Randomised Controlled Trial (RCT) and Realist Evaluation of the Interdisciplinary Home-BAsed Reablement Program (I-HARP) for Improving Functional Independence of Community Dwelling Older People with Dementia: An Effectiveness-Implementation Hy." *BMC Geriatrics* 19 (1): 1–14. https://doi.org/10.1186/s12877-019-1216-x.

Killin, Lewis O.J., Tom C. Russ, Sushee Kaur Surdhar, Youngseo Yoon, Brian McKinstry, Grant Gibson, and Donald J. Macintyre. 2018. "Digital Support Platform: A Qualitative Research Study Investigating the Feasibility of an Internet-Based, Postdiagnostic Support Platform for Families Living with Dementia." *BMJ Open*. https://doi.org/10.1136/bmjopen-2017-020281.

Kim, Sharon H., Christopher G. Myers, and Lisa Allen. 2017. "Health Care Providers Can Use Design Thinking to Improve Patient Experiences." *Harvard Business Review*, 2017. https://hbr.org/2017/08/health-care-providers-can-use-design-thinking-to-improve-patient-experiences.

Kivimäki, Mika, and G. David Batty. 2016. "Evidence-Based Prevention and Treatment of Dementia." *The Lancet Neurology* 15 (10): 1005. https://doi.org/10.1016/S1474-4422(16)30075-8.

Knippenberg, Rosalia J M van, Marjolein E de Vugt, Rudolf W Ponds, Inez Myin-Germeys, and Frans R J Verhey. 2016. "Dealing with Daily Challenges in Dementia (Deal-Id Study): Effectiveness of the Experience Sampling Method Intervention'Partner in Sight'for Spousal Caregivers of People with Dementia: Design of a Randomized Controlled Trial." *BMC Psychiatry* 16 (1): 136. https://doi.org/10.1186/s12888-016-0834-5.

Komashie, A., and P. J. Clarkson. 2018. "Designing Mental Health Delivery Systems: Describing the Relationship between System Components." In: *DS 92: Proceedings of the 15th International Design Conference, DESIGN2018*. https://doi.org/10.21278/idc.2018.0413.

Ku, Bon, and Paul Rosen. 2016. "Making Design Thinking a Part of Medical Education." NEJM Catalyst. 2016. https://catalyst.nejm.org/making-design-thinking-part-medical-education/.

Lamé, G. 2018. "Position Paper: On Design Research Engaging with Healthcare Systems." In: *DS 92: Proceedings of the 15th International Design Conference, DESIGN2018*. https://doi.org/10.21278/idc.2018.0164.

Law, Mikaela, Craig Sutherland, Ho Seok Ahn, Bruce A. Macdonald, Kathy Peri, Deborah L. Johanson, Dina Sara Vajsakovic, Ngaire Kerse, and Elizabeth Broadbent. 2019. “Developing Assistive Robots for People with Mild Cognitive Impairment and Mild Dementia: A Qualitative Study with Older Adults and Experts in Aged Care.” *BMJ Open*. https://doi.org/10.1136/bmjopen-2019-031937.

Lazarou, Ioulietta, Anastasios Karakostas, Thanos G. Stavropoulos, Theodoros Tsompanidis, Georgios Meditskos, Ioannis Kompatsiaris, and Magda Tsolaki. 2016. “A Novel and Intelligent Home Monitoring System for Care Support of Elders with Cognitive Impairment.” *Journal of Alzheimer’s Disease* 54 (4): 1561–91. https://doi.org/10.3233/JAD-160348.

Lindauer, Allison, Adriana Seelye, Bayard Lyons, Hiroko H Dodge, Nora Mattek, Katherine Mincks, Jeffrey Kaye, and Deniz Erten-Lyons. 2017. “Dementia Care Comes Home: Patient and Caregiver Assessment via Telemedicine.” *Gerontologist* 57 (5): e85–93. https://doi.org/10.1093/geront/gnw206.

Marck, Marjolein A. Van Der, Sebastiaan Overeem, Philomène C.M. Klok, Bastiaan R. Bloem, and Marten Munneke. 2011. “Evaluation of the Falls Telephone: An Automated System for Enduring Assessment of Falls.” *Journal of the American Geriatrics Society* 59 (2): 340–44. https://doi.org/10.1111/j.1532-5415.2010.03263.x.

Matthews, Judith T, Jennifer H Lingler, Grace B Campbell, Amanda E Hunsaker, Lu Hu, Bernardo R Pires, Martial Hebert, and Richard Schulz. 2015. “Usability of a Wearable Camera System for Dementia Family Caregivers.” *Journal of Healthcare Engineering* 6 (2): 213–38. https://doi.org/10.1260/2040-2295.6.2.213.

McCreedy, Ellen M., Xiaofei Yang, Rosa R. Baier, James L. Rudolph, Kali S. Thomas, and Vincent Mor. 2019. “Measuring Effects of Nondrug Interventions on Behaviors: Music & Memory Pilot Study.” *Journal of the American Geriatrics Society*. https://doi.org/10.1111/jgs.16069.

McKechnie, Vicky, Chris Barker, and Josh Stott. 2014. “The Effectiveness of an Internet Support Forum for Carers of People with Dementia: A Pre-Post Cohort Study.” *Journal of Medical Internet Research* 16 (2): 1–14. https://doi.org/10.2196/jmir.3166.

Meiland, Franka J.M. M, Ans I.E. E Bouman, Stefan Sävenstedt, Sanne Bentvelzen, Richard J. Davies, Maurice D. Mulvenna, Chris D. Nugent, et al. 2012. “Usability of a New Electronic Assistive Device for Community-Dwelling Persons with Mild Dementia.” *Aging and Mental Health* 16 (5): 584–91. https://doi.org/10.1080/13607863.2011.651433.

Mihailidis, Alex, Jennifer N Boger, Tammy Craig, and Jesse Hoey. 2008. “The COACH Prompting

Cite as: François Patou, Nicholas Ciccone, Julia Thorpe & Anja Maier (2020) Designing P4 healthcare interventions for managing cognitive decline and dementia: where are we at?, Journal of Engineering Design, DOI: 10.1080/09544828.2020.1763272

System to Assist Older Adults with Dementia through Handwashing: An Efficacy Study." *BMC Geriatrics* 8: 28. https://doi.org/10.1186/1471-2318-8-28.

Mirelman, Anat, Lynn Rochester, Inbal Maidan, S Del Din, Lisa Alcock, and Freek Nieuwhof. 2016. "Addition of a Non-Immersive Virtual Reality Component to Treadmill Training to Reduce Fall Risk in Older Adults (V-TIME): A Randomized Control Trial." *Lancet* 388.

Moore, Graham F, Suzanne Audrey, Mary Barker, Lyndal Bond, Chris Bonell, Wendy Hardeman, Laurence Moore, et al. 2015. "Process Evaluation of Complex Interventions : Medical Research Council Guidance." *British Medical Journal* 350 (1258): 1–7. https://doi.org/10.1136/bmj.h1258.

Moreno, Pedro A, M. Elena Hernando, and Enrique J. Gomez. 2015. "Design and Technical Evaluation of an Enhanced Location-Awareness Service Enabler for Spatial Disorientation Management of Elderly with Mild Cognitive Impairment." *IEEE Journal of Biomedical and Health Informatics* 19 (1): 37–43. https://doi.org/10.1109/JBHI.2014.2327638.

Moyle, Wendy, Cindy Jones, Toni Dwan, and Tanya Petrovich. 2018. "Effectiveness of a Virtual Reality Forest on People With Dementia: A Mixed Methods Pilot Study." *Gerontologist*. https://doi.org/10.1093/geront/gnw270.

Moyle, Wendy, Cindy Jones, Jenny Murfield, Lukman Thalib, Elizabeth Beattie, David Shum, and Brian Draper. 2019. "Using a Therapeutic Companion Robot for Dementia Symptoms in Long-Term Care: Reflections from a Cluster-RCT." *Aging and Mental Health*. https://doi.org/10.1080/13607863.2017.1421617.

Norton, Sam, Fiona E. Matthews, Deborah E. Barnes, Kristine Yaffe, and Carol Brayne. 2014. "Potential for Primary Prevention of Alzheimer's Disease: An Analysis of Population-Based Data." *The Lancet Neurology* 13 (8): 788–94. https://doi.org/10.1016/S1474-4422(14)70136-X.

Oksnebjerg, Laila, Bob Woods, and Gunhild Waldemar. 2019. "Designing the ReACT App to Support Self-Management of People with Dementia: An Iterative User-Involving Process." *Gerontology*. https://doi.org/10.1159/000500445.

Parraguez Ruiz, Pedro, and Anja M Maier . (2017). "Data-driven engineering design research: Opportunities using open data". In *Proceedings of the 21st International Conference on Engineering Design, (ICED17), Vol. 7: Design Theory and Research Methodology, Vancouver, Canada, 21.-25.08.2017*.

Patou, François, Nicholas Ciccone, Julia R Thorpe, and Anja M Maier (2020): Designing P4 Healthcare Interventions For Managing Cognitive Decline And Dementia: Where Are We At? - Detailed Literature Review.pdf. figshare. Online resource. https://doi.org/10.6084/m9.figshare.12034857.v2

Patou, François, and Anja M. Maier. 2017. "Engineering Value-Effective Healthcare Solutions : A Systems Design Perspective." In: P*roceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 3: Product, Services and Systems Design, Vancouver, Canada, 21.-25.08.2017*.

Patterson, Christina. 2018. "World Alzheimer Report 2018." London.

Price, Nathan D, Greg Foltz, Anup Madan, Leroy Hood, and Qiang Tian. 2008. "Systems Biology and Cancer Stem Cells." *Journal of Cellular and Molecular Medicine* 12 (1): 97–110. https://doi.org/10.1111/j.1582-4934.2007.00151.x.

Richards, Kathy C., Nalaka Gooneratne, Barry Dicicco, Alexandra Hanlon, Stephen Moelter, Fannie Onen, Yanyan Wang, et al. 2019. "CPAP Adherence May Slow 1-Year Cognitive Decline in Older Adults with Mild Cognitive Impairment and Apnea." *Journal of the American Geriatrics Society*. https://doi.org/10.1111/jgs.15758.

Roest, Henriëtte G. Van Der, Franka J.M. Meiland, Cees Jonker, and Rose Marie Dröes. 2010. "User Evaluation of the DEMentia-Specific Digital Interactive Social Chart (DEM-DISC). A Pilot Study among Informal Carers on Its Impact, User Friendliness and, Usefulness." *Aging and Mental Health* 14 (4): 461–70. https://doi.org/10.1080/13607860903311741.

Sabia, Séverine, Aline Dugravot, Jean-François Dartigues, Jessica Abell, Alexis Elbaz, Mika Kivimäki, and Archana Singh-Manoux. 2017. "Physical Activity, Cognitive Decline, and Risk of Dementia: 28 Year Follow-up of Whitehall II Cohort Study." *Bmj* 2709 (June): j2709. https://doi.org/10.1136/bmj.j2709.

Sagner, Michael, Amy McNeil, Pekka Puska, Charles Auffray, Nathan D. Price, Leroy Hood, Carl J. Lavie, et al. 2017. "The P4 Health Spectrum – A Predictive, Preventive, Personalized and Participatory Continuum for Promoting Healthspan." *Progress in Cardiovascular Diseases* 59 (5): 506–21. https://doi.org/10.1016/j.pcad.2016.08.002.

Schaller, Sandra, Velislava Marinova-Schmidt, Jasmin Gobin, Manfred Criegee-Rieck, Lena Griebel, Sabine Engel, Veronika Stein, Elmar Graessel, and Peter L. Kolominsky-Rabas. 2015. "Tailored E-Health Services for the Dementia Care Setting: A Pilot Study of 'EHealthMonitor.'" *BMC Medical Informatics and Decision Making* 15 (1): 1–9.

https://doi.org/10.1186/s12911-015-0182-2.

Shoval, Noam, Gail K. Auslander, Tim Freytag, Ruth Landau, Frank Oswald, Ulrich Seidl, Hans-Werner Werner Wahl, Shirli Werner, and Jeremia Heinik. 2008. “The Use of Advanced Tracking Technologies for the Analysis of Mobility in Alzheimer’s Disease and Related Cognitive Diseases.” *BMC Geriatrics* 8: 7. https://doi.org/10.1186/1471-2318-8-7.

Soellner, Renate, Maren Reder, Anna Machmer, Rolf Holle, and Gabriele Wilz. 2015. “The Tele. TAnDem Intervention: Study Protocol for a Psychotherapeutic Intervention for Family Caregivers of People with Dementia.” *BMC Nursing*. https://doi.org/10.1186/s12912-015-0059-9.

Spillman, Brenda C., and James Lubitz. 2000. “The Effect of Longevity on Spending for Acute and Long-Term Care.” *New England Journal of Medicine* 342 (19): 1409–15. https://doi.org/10.1056/NEJM200005113421906.

Swan, Melanie. 2012. “Crowdsourced Health Research Studies: An Important Emerging Complement to Clinical Trials in the Public Health Research Ecosystem.” *Journal of Medical Internet Research* 14 (2): 186–98. https://doi.org/10.2196/jmir.1988.

Tak, Sunghee H, Hongmei Zhang, Hetal Patel, and Song Hee Hong. 2015. “Computer Activities for Persons with Dementia.” *Gerontologist* 55 (December): S140–49. https://doi.org/10.1093/geront/gnv003.

Tang, Yi, Yi Xing, Zude Zhu, Yong He, Fang Li, Jianwei Yang, Qing Liu, et al. 2019. “The Effects of 7-Week Cognitive Training in Patients with Vascular Cognitive Impairment, No Dementia (the Cog-VACCINE Study): A Randomized Controlled Trial.” *Alzheimer’s and Dementia*. https://doi.org/10.1016/j.jalz.2019.01.009.

Thorpe, Julia R, Birgitte H Forchhammer, and Anja M Maier. 2016. “Needs Elicitation for Novel Pervasive Healthcare Technology.” In : *DS 84: Proceedings of the 14th International Design Conference, DESIGN2016, pp.1947-1956*.

Thorpe, Julia R, Birgitte H Forchhammer, and Anja M Maier. 2019. “Development of a Sensor-Based Behavioral Monitoring Solution to Support Dementia Care.” *Journal of Medical Internet Research* 21 (6): 1–14. https://doi.org/10.2196/12013.

Topol, Eric. 2015. *The Patient Will See You Now: The Future of Medicine Is in Your Hands*. New York: Basic Books.

Topol, Eric. 2014. “Individualized Medicine from Prewomb to Tomb.” *Cell* 157 (1): 241–53.

https://doi.org/10.1016/j.cell.2014.02.012.

Valentin-Hjorth, J., François Patou, Nicholas Syhler, Helena Dominguez, and Anja M Maier. 2018. “Design for Health: Towards Collaborative Care". In: *DS92: Proceedings of the 15th International Design Conference, DESIGN2018*. https://doi.org/10.21278/idc.2018.0506

Weijer, Sjors C. F. van de, Annelien A Duits, Bastiaan R Bloem, Roy P Kessels, Jacobus F A Jansen, Sebastian Köhler, Gerrit Tissingh, and Mark L Kuijf. 2016. “The Parkin’Play Study: Protocol of a Phase II Randomized Controlled Trial to Assess the Effects of a Health Game on Cognition in Parkinson’s Disease.” *BMC Neurology* 16 (1): 209. https://doi.org/10.1186/s12883-016-0731-z.

Westont, Andrea D., and Leroy Hood. 2004. “Systems Biology, Proteomics, and the Future of Health Care: Toward Predictive, Preventative, and Personalized Medicine.” *Journal of Proteome Research* 3 (2): 179–96. https://doi.org/10.1021/pr0499693.

WHO. 2009. “Systems Thinking for Health Systems Strengthening.” Vol. 7.

Wijma, Eva M., Marjolein A. Veerbeek, Marleen Prins, Anne Margriet Pot, and Bernadette M. Willemse. 2018. “A Virtual Reality Intervention to Improve the Understanding and Empathy for People with Dementia in Informal Caregivers: Results of a Pilot Study.” *Aging and Mental Health*. https://doi.org/10.1080/13607863.2017.1348470.

Appendix A: Journals List

Engineering Design

- International Journal of Design
- Systems Engineering
- Journal of Engineering and Technology Management
- Design Studies
- Design Science
- Research in Engineering Design
- Journal of Engineering Design
- Journal of Mechanical Design

Biomedical, Healthcare and Clinical Sciences

- Advanced Engineering Informatics
- British Medical Journal (BMJ)
- IEEE journals: Transactions on Engineering Management, Journal of Biomedical and Health Informatics, Systems Journal, Transactions on Biomedical Engineering, Transactions on Systems, Man and Cybernetics, Transactions On Information Technology in Biomedicine
- International Journal of Medical Informatics
- Journal of Biomedical Informatics
- Journal of Medical Internet Research
- PLOS ONE

Cite as: François Patou, Nicholas Ciccone, Julia Thorpe & Anja Maier (2020) Designing P4 healthcare interventions for managing cognitive decline and dementia: where are we at?, Journal of Engineering Design, DOI: 10.1080/09544828.2020.1763272

- Age and Aging
- Aging and Mental Health
- Alzheimer’s and Dementia
- Archives of Gerontology and Geriatrics"
- BioMed Central (BMC) Journals
- BMC Geriatrics
- Dementia and Geriatric Cognitive Disorders
- Geriatrics and Gerontology International
- Gerontechnology
- Gerontology
- Journal of Aging and Health
- Journal of Aging and Physical Activity
- Journal of Alzheimer’s Disease
- Journal of Applied Gerontology
- Journal of healthcare engineering
- Journal of Healthcare Management
- Journal of the American Geriatrics Society
- Journal of the American Medical Association (JAMA)
- New England Journal of Medicine
- The Gerontologist
- The Journals of Gerontology
- The Lancet

Cite as: François Patou, Nicholas Ciccone, Julia Thorpe & Anja Maier (2020) Designing P4 healthcare interventions for managing cognitive decline and dementia: where are we at?, Journal of Engineering Design, DOI: 10.1080/09544828.2020.1763272