Dementia Care Frameworks and Assistive Technologies for Their Implementation: A Review

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(Methodological Review)

***Abstract*—In this review, we focus on the various integrated care models that have been applied for the management of dementia patients. We explore the different types of assistive technologies (mobile, wearable, and home-based systems) for dementia care, with a special emphasis on technologies that involve or target the informal caregiver as end user. In an attempt to reveal the needs for information sharing, communication, and collaboration between people with dementia and caregivers involved in the effective and integrated management of the disease, we analyze the trends in research and development to date, we seek to understand and reflect upon the state of the art in assistive technologies for dementia, and we highlight domains that appear underexplored, in order to guide future research. We also explore the cost effectiveness of such technologies and integrated care models for the management of dementia patients and comment on current limitations and future trends and directions. Findings indicate the urgent need and the current lack of a comprehensive and cost-effective solution that will incorporate information system technologies for the provision of integrated care services to dementia patients and their informal caregivers.**

***Index Terms*—Alzheimer, collaborative technologies, dementia, integrated care models, telecare.**

I. Introduction

DEMENTIA is a clinical syndrome characterized by persistent intellectual deterioration severe enough to interfere with social or occupational functioning in an alert person. Unfortunately, dementia disorders are chronic, long lasting, progressive and currently incurable, that require coordinated care in order to address the medical, behavioral, and social aspects of the disease [1]. Statistics indicate that a person develops dementia every 3 seconds [2]. In parallel, global estimates of dementia prevalence are up to 7% of individuals above the age of 65 years [3]. Dementia is the fourth most common cause of death in developed countries [4] in which most people with dementia die in long-term care institutions including nursing homes [5].

At the financial level, Hund and colleagues [6] report that dementia are among the most expensive diseases for western countries, with an estimated cost of around $160 bn annually. Long-term care at nursing homes and other appropriate healthcare institutions is a major component of this societal and economic burden. In addition to such institutional care, informal caregivers (usually family members) provide a large proportion of dementia care [7]. It is important to note that these informal caregivers often experience psychological burden themselves, with more than 40% of them reporting emotional stress and 74% reporting concern about maintaining their own health since becoming caregivers [7].

Under these circumstances, the care of dementia is multidimensional and constitutes a great challenge for care givers and society [8]. To meet these complex needs, knowledge, skills and appropriate technologies are required which span multiple disciplines in various sectors, ranging from home care, to primary care, long-term care and social care. In order to address these needs and to improve quality of care and quality of life, integrated care is often introduced as the appropriate service delivery paradigm [9]. Recently, the World Health Organisation (WHO) has reinforced the importance for integration of care for people-centred and integrated health services in its vision and global strategy for health services delivery [10]. Because of these developments, a proliferation of integrated care initiatives in many different countries and settings do currently exist [11], [12] in which teams from across the health and social care system are working collaboratively in delivering care that is coordinated around people's physical, psychological and healthcare needs [13].

Although a few models of dementia care are available in several countries, none are widely accessible [14] and their fundamental elements are not analysed in detail. In addition, although Information and Communication Technologies (ICT) are increasingly used as a key enabler of integrated care models for different patient groups [15] a concerted analysis of the empirical evidence on how such ICT systems are supporting the integration of care for dementia patients is lacking.

This review has the following objectives. Firstly, to document and analyse existing models for the delivery of integrated care that have been applied for the management of dementia

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TABLE I
STAGES OF DEMENTIA (ADAPTED FROM SOUTH AUSTRALIA'S DEMENTIA ACTION PLAN 2009–2012[1])

Impact	Early Onset	Mild	Moderate	Advanced
	Estimated % of people with dementia			
	55%		30%	15%
Memory	Slight forgetfulness that happens regularly e.g. gets lost on familiar route	Noticeable short term memory loss affecting everyday life e.g. has false person has false memories, forgets layout of home.	Substantial memory loss when old information can be recalled and new information is rapidly lost.	Severe memory loss when only parts of old memories remain.
Personal Care	Manages own self care	May need prompting	Requires assistance	Full assistance required

patients. In so doing, our key objective is to reveal their demands for technological support in supporting the needs for information sharing, communication and collaboration between all those, formal and informal caregivers, involved in the effective and integrated management of dementia patients. Secondly, to explore the different types of assistive technologies that have been developed and those currently being developed in relation to dementia care. By analysing the trends in research and development to date, we seek to understand and reflect upon the state of the art in this area, and to highlight domains that appear underexplored, in order to guide future research in this area. Our final objective is to provide evidence, if such evidence exists, on the cost effectiveness of such technology enabled integrated care models for the management of dementia patients.

The remaining of the structure is as follows. Section II provides an overview of dementia and risk factors related to the disease.[1] It is important to understand the various clinical manifestations of dementia, during the stages of dementia (Table I), in order to enable ourselves to critically assess the technologies that either have been developed or in development to address these manifestations. Section III summarizes existing integrated care methodologies for dementia and their respective care models. Section IV provides an analysis of existing assistive technologies in support of integrated dementia management. There are a number of possible ways to group and categorize interventions in dementia care, for example, by the type of treatment approach used, i.e., pharmacological vs non-pharmacological interventions [16]. The latter include both environmental and behavioral modification. In our presentation and analysis, the main grouping is along the key dimensions of the most prominent models for integrated dementia care management, as identified in Section III-A. Section IV also reports on current research and development efforts to respond to some of the unmet needs in the domain. Finally, Section V reports and discusses on the available evidence regarding the cost effectiveness of the innervations for dementia. Section VI provides a thorough discussion of key finding, while Section VII concludes.

II. MANIFESTATIONS AND IMPACT OF DEMENTIA

Prevalence of dementia estimated to be up to 7% globally for individuals above the age of 65 years with marginally higher prevalence in the developed world due to longer life expectancy [3]. Dementia is a huge burden for caregivers and families and it has significant physical, psychological, social and economic impacts.

[1]https://www.flinders.edu.au/shadomx/apps/fms/fmsdownload.cfm?file_uuid=1B2817CF-C0E8-8642-0FA8-45BBDFF6CD62&sitename=sabs

In the lack of a cure for dementia, new approaches in the management of the disease are constantly sought, involving the early diagnosis, postponing its onset, and slowing down its evolution [17]. Ultimately, early detection of the disease is of great significance due to the increased possibilities for early initiation of treatment, and other forms of disease management interventions [18]. In that direction, signs of Mild Cognitive Impairment should not be disregarded, since it is characterized as an early indicator of cognitive impairment capable of further advancement to Alzheimer's disease (AD) or into another dementia [19] with 10–15% progression yearly [20]. A systematic scoping review from 1937 to 2016 on the signs and symptoms preceding the diagnosis of AD revealed that depression and cognitive impairment were the first symptoms to appear in 98.5% and 99.1% of individuals in a study with late-onset AD and 9% and 80%, respectively, in early-onset AD [21].

In addition to the early diagnosis of dementia, of crucial importance is also its differential diagnosis [22]. The majority of dementias in elder population have a neurodegenerative path. Some of them are AD, dementia with Lewy bodies, vascular dementia, frontotemporal lobar degeneration and Parkinson's disease [23].

Aging is the most common risk factor for AD and other dementias [24]. Other crucial risk factors are family history [7] and genetic predisposition [25]. Except from individual risk factors, some risk factors that are implicated in the appearance of dementia are diabetes [26], mid-life obesity and smoking [27]. There is strong evidence that traumatic brain injury is an elevated risk factor for some forms of dementia [28]. Lastly, there is weak evidence that psychiatric conditions, such as depression, elevate the risk of dementia [29].

A. Cognitive Symptoms of Dementia

Dementia is a disorder characterized by multiple cognitive deficits that differ depending on the disease causing dementia. The most common cognitive symptom is memory loss. At the early onset and mild stage of the disease, short-term memory dysfunction is the first complaint of the patients who face difficulties in learning new information. At later stages of the disease, substantial memory recalling problems emerge [30].

Dementia is typically diagnosed at the time that cognitive impairments begin to affect the social and occupational functioning of the person [23]. As the illness progresses impairments in visuoconstructional perceptual- motor functions, language functions, and social cognition occur [31]. In vascular dementia or vascular neurocognitive disorder, the second most common cause of dementia, cognitive deficits are mainly found in the fields of complex attention and executive functions. In Parkinson's disease, cognitive symptoms appear when the disease is

already established while deficits may vary with most common the executive, memory, and visuospatial domains [31]. Lastly, fronto-temporal dementia appeared with language difficulties such as perseverative speech, echolalia, mutism [30].

Table I shows the four stages of dementia (early onset, mild, moderate and advanced dementia) and their impact in terms of memory and personal care.

B. Non-Cognitive Symptoms of Dementia

Cognitive symptoms of Dementia have received significant attention. Nevertheless non-cognitive symptoms are considered to be an equally crucial factor that lead to low quality of life and poor health outcomes such as morbidity, mortality, frequent stays in the hospital, and early placement in a nursing home [32]. Behavioral and psychological symptoms are characterized by complexity, excessive stress and depression not only for the patients but also for the caregivers since they are the most burdened as far as patients' home care concerns [33]. These categories of symptoms are also known as neuropsychiatric symptoms and although they are common in dementia, some types of dementia are associated with different neuropsychiatric manifestations [34]. For instance, a common neuropsychiatric symptom of vascular dementia is depression while hallucinations occur more frequently in Lewy body dementia. Patients who suffer from frontotemporal dementia exhibit symptoms characterized by executive control loss. These symptoms are disinhibition, wandering, social inappropriateness, and apathy [35]. As the disease progresses different symptoms are emerged. At early stages, affective symptoms such as low mood, anxiety and agitation, are met more often. At later stages, psychotic-like symptoms and aggression are more common [36]. Other neuropsychiatric symptoms are motor disturbance, sleep disturbances, appetite and eating disorders [37]. Due to the episodic nature of these symptoms their prevention and management become more complex than cognitive and functional deficits [34].

C. Impact of Dementia on Caregivers and Patient's Life

Dementia as a chronic disease has an enormous impact on society and the quality of life of patients [38]. Whilst the impact of dementia on patient's life is evident and thoroughly studied, the corresponding impact on the caregivers life is not always as obvious [39].

Caregivers can be either formal, referring mainly to medical and nursing staff, or informal, where in most cases are family members or life partners. In the majority of cases caregivers tend to be informal and mainly family members who are untrained for the demanding task that they have been assigned [40].

Dementia caregivers face psychological burden in the alarmingly high proportions of 36% for depression and until 60% for frustration [41]. Patients' behavioral and psychological symptoms of dementia such as delusions, depression, anxiety, apathy, irritability, agitation, are strongly associated with caregiver burden [42]. Other studies revealed the concerns of family caregivers for (i) the lack of safety in the home, (ii) lacking quality time for themselves, (iii) the absence of meaningful activities for people with dementia, and (iv) difficulties experienced with time orientation [43].

The strong relationship along with the different demands between people with dementia and their informal caregivers emphasize the importance of taking their needs into consideration in order to help both of them with their daily life.

III. Integrated Care Models

A variety of terms have been used for defining the different approaches to chronic care management, including the terms "*disease management*" and "*integrated care*". The difference between these two terms was defined as being that integrated care concerns both the health and social care sectors whilst disease management programmes are usually restricted with respect to their focus on the healthcare sector. Integrated care is used synonymously to terms like coordinated care and seamless care, among others. However, there is no unifying definition or common conceptual understanding of integrated care [44]–[46].

Due to the multidimensional and multidisciplinary nature of integrated care [47], it is hard to be described with a standard definition. Nevertheless, in this manuscript we adopt the definition of integrated care as developed by Armitage *et al.* [48] since this definition encapsulates the various definitions found in their systematic review of the literature. According to this definition, integrated care focuses on continuity and coordination of care, management of the disease, efficient communication between the various caregivers and seamless transfer of information. We further define integrated care to include the collaborative interaction of health system stakeholders in order to achieve person-centered medical and behavioral care across a person's lifespan. Integrated care also includes patient-oriented services to support patient empowerment, self-care, adherence to care plans and treatment at the point of need, personalisation of care management programmes to specific characteristics of patients' profiles, and new organisational models to improve the coordination of care services as well as the skills of and the collaboration of health professionals and informal care givers. Thus, in integrated care models, patients become both the object of care and part of the care team [49].

Several integrated care models have been developed in the course of time. WHO, in a recent study, has documented the models of integrated care based on the scale of population at which integration applies [50]; the specific integrated care models are: individual models of integrated care, group- and disease-specific models and population-based models. Amongst those models, the Chronic Care Model (CCM) [51] is the most well-known and widely accepted for integrated care. According to CCM an effective model for chronic care must incorporate the interaction of the patient with the community, the health care system and the organization. CCM consists of six key elements [50], [51]: (i) Community resources and policies, (ii) Health system, (iii) Self-management support, (iv) Delivery system design, (v) Decision support, and (vi) Clinical information systems. An expanded version of the CCM was proposed by Barr *et al.* [52], aiming to reduce the burden of chronic disease and to support patients and communities to follow practices of good health. Another modification of the CCM is the WHO's Innovative Care for Chronic Conditions framework (ICCC), which has been developed with the following principles in mind: evidence-based decision making, integration, flexibility, adaptability, population, prevention and quality focus [53].

A. Models and Frameworks for Dementia Management

Dementias are chronic diseases that require longitudinal care, ongoing counseling, and psychosocial support for patients and families by dedicated care teams [23]. With a focus to neurological conditions, Jaglal *et al.* [54] proposed a care model for neurological conditions (NC), including dementia, based on the expanded version of the CCM. At approximately the same time,

the Champlain Dementia Network in 2013 [41] developed a set of pillars that are important for the construction of an integrated model of dementia care. These, amongst others, include the need for the a) early detection, diagnosis and proper assessment of the disease; b) self-management and caregiver support for improving the living conditions of patients; c) coordinated pathways and d) extensive systems integration.

Wiener *et al.* [55] in 2016, through a review process of a number of models, existing guidelines and practice recommendations for dementia care, identified a set of high-level principles of normative care that should be elaborated in any dementia care framework, as described below:

- **Detection, diagnosis & assessment,** including comprehensive assessment of cognitive status, functional abilities, behavioral and psychological symptoms of dementia, medical status and safety.
- **Management, assistance & support** including care plan, management, information, education and decision making, acknowledgement and emotional support, assistance with daily functioning and activities, involvement, emotional support, and assistance for caregivers.
- **Interventions** including prevention and mitigation of behavioral and psychological symptoms, ensuring safety, therapeutic environments, modifications to the physical and social environment.
- **Transition and coordination** including care transitions, referral and coordination of care and services.

The above principles form the needed dimensions of any comprehensive dementia management framework. These dimensions will provide the lens through which we will evaluate the current state of the art with respect to technologies that are available or in development to support the needs of people with dementia and their informal caregiver(s) and the effective collaboration among all dementia management stakeholders.

B. The Role and Needs of Caregivers in the Context of Integrated Dementia Care Models

It is evident from the previously defined high-level principles and dimensions of the popular models for the delivery of integrated care to dementia patients (Section III) that caregivers have a central role in these models of care. The importance of caregivers involvement has been identified in the Wiener's set of principles [53]. Their involvement also leads to positive disease outcomes [54]. There are different types of caregivers for people with dementia, including informal caregivers such as family members who are not paid for their services. There is evidence that approximately 70 percent of people with dementia are cared for by informal caregivers [56].

Caregivers face psychological burden, mainly depression and frustration, in a high proportion. In case of informal caregivers the consequences include physical, social and economic effects [57]. Caregiver burnout is also a significant problem of all types of caregivers, but especially for informal caregivers as documented in [58].

It is therefore most important, in the context of integrated care models for dementia management, to identify and understand better the areas that caregivers, especially informal caregivers, find challenging and to evaluate the availability of technological innovations targeting their needs and thus improving their wellbeing and capability to support the person in their care effectively.

IV. Assistive Technologies for Integrated Dementia Management

Significant research and development efforts have recently taken place for the design and development of assistive technologies for the elderly in general and the management of dementia patients in specific. In this section, we focus on the main developments in the domain and seek evidence as to whether assistive technologies have a positive impact on the well-being of patients and their informal caregivers as well as broader socioeconomic benefits. We initially separate technologies in two general categories, i.e., mobile and internet based platforms and services and technologies supporting home-based settings. We subsequently employ the dimensions of the Wiener's dementia care framework (Section III A) for our assessment and critical review.

A. mHealth Applications for Dementia Management

Mobile assistive technologies allow individuals to benefit from ubiquitous devices that repurpose smartphones and other relevant hardware platforms to electronic assistive devices supporting people in accomplishing everyday tasks more easily. An indicative example is the use of Global Positioning System (GPS) devices to reduce wandering among dementia patients. Devices for assistive technology improve also well-being by promoting independence to patients.

Several studies have assessed mobile and internet based resources for patients with dementia aiming on maintaining cognitive or functional skills and learning new things. Most of the tools for people with dementia lie in the category of robotic based assistive technologies, while other categories include health and patient monitoring, reminders and communication [59].

The presentation of applications that monitor the activities of daily living for people with dementia is out of the scope of this review, since a plethora of such reviews exist in the literature such as the D' Onofrio *et al.* [60].

1) Applications for the Detection, Diagnosis and Assessment: Dementia, as already discussed, can affect multiple areas of cognitive functioning, including memory, thinking, comprehension, learning capacity, orientation, judgment, and language, and many people also experience an impact on motivation, social behavior and emotion [30]. A variety of approaches have been published using those cognitive functions as biomarkers for the implementation and design of a test battery that is applicable on mobile devices (i.e., tablet computers, mobile phones, etc.). Zorluoglu and colleagues [61], provide a recent report on the development of such a mobile application. Their publication includes an excellent record of the commonly used cognitive assessment tests in the literature. Other efforts report on smartphone applications that encompass automatic speech recognition for the measurement and analysis of linguistic abilities [62] or the monitoring of patients with cognitive impairment based on speech analysis [63].

Several recent developments in this domain include Cognetivity[2] which is an integrated cognitive assessment tool, employing artificial intelligence algorithms that are used to cluster test performance in terms of accuracy, speed and image properties and Memrica,[3] a platform in its early development stage

[2]https://www.cognetivity.com/
[3]http://memricaprompt.com/

that aims to detect changes in physical and social behaviour as an early indicator for dementia.

For the assessment of disease evolution an app based on the widely-used Addenbrooke's Cognitive Examination III (ACE-III) test, called ACEmobile,[4] has been developed to provide the means for clinicians to support the reliability, accuracy and efficiency of ACE-based assessments in dementia clinics. Also, Niemann *et al.* [64] report on a framework for assessing disease evolution which incorporates the digitizing of existing, validated cognitive tests, the analysis of the handwriting input in parallel with the capture of participants electrodermal activity. Electrodermal activity was measured as an indication of stress/difficulty which in combination with cognitive load could lead to assumptions of cognitive impairments.

2) Applications for Disease Management and Patient Support: A multimodal training approach for the care, rehabilitation and diagnosis of dementia patients was proposed by Paletta *et al.* [65]. The authors developed a serious game framework that includes cognitive, physical, and sensorimotor oriented stimulation for the daily monitoring of a person's dementia profiles using eye-tracking technologies. Navarro *et al.* [66] also introduced a system for cognitive stimulation therapy in the form of a game, for patients with Alzheimer. The system is able to adapt the treatment plans over time, in accordance to patient's level of cognitive impairment and performance of interactions with the application. The fields of cognitive stimulation include attention, memory, language, gnosis, executive functions and orientation. Many Apps targeting this domain are available on both Google Play and Apple App Store.

Patient support includes supporting them through reminders. While a lot of general purpose systems provide reminders such as CybreMinder [67], Forget-me-not [68] or the Doro smartphones,[5] we will focus on applications dedicated to dementia. Applications for reminders in most of the cases act as memory aid tools. Indicative such applications include the Technology Adoption and Usage Tool (TAUT) [69] which collects and analyses data from the smartphone and is able to provide assistive functions that can improve the activities of daily living of a person with dementia. Reminder functions for specific activities of daily living can be set by the patient or by a proxy, such as the informal or formal caregiver.

HyCare [70] is another reminding platform intended to help people with mild dementia and improve their level of independence along with the quality of life. The platform provides a scheduling mechanism with synchronous time-based and asynchronous event-based reminding services. The interaction between the system and caregivers is based on a dedicated application providing functionalities for the design of rule-based reminders and their execution.

AP@LZ [71] is an electronic organizer mobile application specifically designed for persons with Alzheimer's disease. The system provides functionality for memory aid, scheduling, reminders and communication with caregivers and has been tested by persons suffering from Alzheimer.

3) Applications Supporting Non-Pharmacological Interventions: Intervention-based technologies that have been published mainly focus on the safety/monitoring of dementia patients using wearable sensors and on developing, so-called, smart home environments supporting independent living [72].

A number of real-time location tracking systems for dementia patients have been reported. Examples include a shoe-based tracking and rescue system for people with dementia [73]. The functions of the system include real time location tracking, emergency warning when detecting an abnormality, and proactive rescue. Another real-time location tracking system for dementia patients is reported in [74], in which the patient must carry the device allowing caregivers to receive messages through an android application.

iWander, [75] takes advantage of the social network of the user/patient and provides a location tracking service to the caregiver. Such a functionality can partially alleviate stress and offer easier remote monitoring of a person with dementia. iWander, also accepts user voice commands, can provide recommendations and directions to the user to navigate to a known/safe location while notifies the caregivers, and can also provide the GPS location and call the emergency number.

The Rosetta system [76] focuses on supporting people with dementia in different stages of the disease in their daily functioning, to monitor patterns of their daily behaviour and to automatically detect emergency situations. Additionally, the Elderly Day Navigator [77] application offers activity support, reminders, a visual dialling system, warnings and a GPS service to help them find their way home, whereas ehcoBUTLER [78] provides a psychosocial (mobile) platform with three main directions/versions. The effectiveness of the platform is currently under evaluation using a randomized controlled trial study protocol [79].

4) Applications Supporting the Communication With and Collaboration of the Care Delivery Actors: The interaction of the patient with the community and the health care system is central in the Chronic Care Model. As a result, the need to effectively support care transitions, referrals and the coordination of care and services amongst the various care delivery actors represents a key dimension for integrated care. It is of no surprise that one of the most common concerns and requests of people with dementia and their caregivers, is the need to develop appropriate collaborative technologies that will help patients when [80].

An online platform for the support of communication and collaboration of formal and informal caregivers was developed by Boessen *et al.* [81]. The platform includes standard, care related and entertainment focused applications, namely: Contacts, Messaging, Calendar, a Dementia care record, Share Care tools, Medication plan/reminder, Video Call, and My Games. The use of the platform has been tested during a ten-week period by seven family members and thirty-two formal caregivers of dementia patients. Although the results obtained showed value of use, the ultimate recommendation of the study is that the platform should be tested on a larger scale.

A social platform, enhanced with gamification elements and interactive interventions, has been presented by Tzallas *et al.* [82] for dementia patients and their caregivers. The platform included functionalities to support screening, treatment adherence, clinical reporting, social networking features, therapeutic education, and interactive interventions. Also, other efforts [83] report on using a video based communication channel to persons with dementia. Such a tool is found improve the social abilities and quality of communication of the patient and provide the sense of safety and independent living.

Additionally, several efforts to develop applications on mobile platforms to support the communication amongst care delivery

[4]http://www.acemobile.org/
[5]https://www.doro.co.uk/

actors include SMART4MD[6] [84], which provides a built-in planner that helps patients organize their day and sends reminders to take medications, attend appointments and perform day-to-day tasks in order to keep them independent for longer. Healthcare professionals can easily track the status of their patients' health through SMART4MD's secure data sharing capabilities. Finally, HyCare [70] is another platform intended to help people with mild dementia to improve their level of independence and quality of life. The platform provides a scheduling mechanism with synchronous time-based and asynchronous event-based reminding services. The interaction between the caregivers and the system is based on a dedicated application for caregivers with the functionality to design reminders or patterns of rule-based reminders.

5) Applications Supporting Informal Caregivers: As already discussed, taking care of a person with dementia is a difficult and lifelong task that informal caregivers have to handle. In addressing the needs of informal caregivers, several dedicated tools and systems for caregivers have been developed [85]. An indicative example in this category is reported in [86], where the authors present a web based e-learning platform for formal and informal caregivers of dementia patients. The platform was evaluated for a period of 2 to 4 months, by both formal and informal caregivers as well as volunteers. The evaluation results in terms of usefulness and friendliness were positive by all types of users. In addition evidence is provided in the literature that the guidance by a coach or therapist for informal dementia caregivers increases their commitment to the intervention and boost their confidence to design and execute learned strategies [87].

Tan *et al.* [1] developed a dementia care program that elaborates the collaboration of a nurse practitioner with primary care physicians in order to provide training and support to caregivers, to manage care transitions, and facilitate access to community-based services. Similarly, Galvin *et al.* [88] proposed a patient-centered care achieved by collaboration of nurse practitioners, physicians and caregivers for the decision making process of care plan. Nevertheless, in both cases ICTs do not play a central role in the deployment of the models.

Interventions focused on the targeted education is reported in [89] as a baseline intervention for caregivers. Another aim for caregiver training is for managing distressing behaviors in a nonpharmacological manner, as reported in [90].

Although, training is important for accurate care action, other types of interventions to manage the consequences of their role should be taken into account for caregivers. The authors in [57] report on the psychosocial interventions applied on informal caregivers of people with dementia living in home or non-institutional environment. The meta-analysis revealed that interventions reduce the degree of psychological morbidity and burden of informal caregivers while they support dementia patients to stay longer at home environment. Similarly, Mittelman *et al.* [91] reported that supportive intervention, counselling and treatment support, have positive results in reducing the depressive symptoms of informal caregivers (spouses) of AD patients.

The effectiveness of cognitive behavioral therapy for caregivers of people with dementia is reported in [92]. In their review for dementia patients caregivers' burden, Etters *et al.* [93] highlight the importance of developing multi-component interventions for caregivers. Multi-component interventions have been included in the work of Parker *et al.* [94]. Analysis of the reported evidence indicates that that well-designed psycho-educational or multi-component interventions could play an important assistive role for caregivers of people with dementia who live in the community.

B. Assistive Technology in Home-Based Settings

It is generally accepted that assistive technologies can promote the wellbeing of people with dementia, preventing any loss of autonomy for patients, whilst at the same time they are giving their caregiver's periods of relief to lessen the burden on their shoulders. The literature for assistive technologies for people with dementia depicts the great potential in these technologies to help these people to live independently [95]. In what follows, we will synthesize available evidence from studies related to home-based assistive technologies for dementia management.

1) Applications for Detection, Diagnosis and Assessment: A range of initiatives have been reported, mainly focusing on the monitoring and analysis of people's behavioral patterns with the objective to support the identification of the disease on set as early as possible.

An indicative such smart technology system that incorporates the requirements of dementia care was introduced by Amiribesheli and Bouchachia [96]. The available evaluation results are positive regarding the suitability of the proposed smart home system design.

A monitoring system based on Internet of Things (IoT) for the early detection of mild cognitive impairment was introduced in [97], using a variety of sensors. By combining the outcomes of the sensors three main features have been created that explain the behavioral patterns of the resident, namely, forgetfulness incidents of personal items, forgetfulness incidents of medication intake, and medication intake timings. The system is currently under evaluation regarding its ability to early detect signs of MCI. Also, an early detection system for dementia based on home behavioral patterns and lifestyle backgrounds was introduced by Kimino *et al.* [98], which uses different types of sensors such as magnetic field, light, tilt and motion applied in key places in home (door, bedroom and kitchen) for monitor behaviour and knowledge based data analysis methods for inferencing.

Another study on technology assisted monitoring system that uses Internet of Things on home-based setting for monitoring people with dementia, was presented in [99]. The system's design required the installation of nine sensors in the home of the patient and the acquisition of a range of physiological data with the use of Bluetooth-enabled medical devices. Machine learning algorithms combined environmental and physiological data for the analysis of patients' behavioral patterns and wellbeing. Using real life data, authors supported the efficiency of their proposed algorithms by conducting classification and prediction-based evaluations.

2) Applications for Disease Management and Patient Support: In recent years many projects [100] are exploiting the use of assistive robots to support the aging of older people. Assistive social robots are autonomous robots that communicate with the users for a well-defined care purpose. These robots are used as assistive devices supporting independent living and mobility or as companion type robots that are aimed at providing social support (improving social skills), increasing health and physiological well-being. They have been extensively used in the context of dementia management.

The ROBADOM project [101] designed a "robot-butler" for providing verbal and non-verbal interactions and feedback for

[6]http://www.smart4md.eu/

assisting the daily living of older people with mild dementia. The robot provides verbal and non-verbal help along with support and coaching during various tasks such as cognitive stimulation exercises.

Nursebot, is a robotic system that help the elderly with daily tasks, provide companionship and help them to remotely communicate with physicians and caregivers [102]. Another assistive robot is described in [103] that aims to address critical areas and gaps in care by automating supervision, coaching, motivation, and companionship aspects of one-on-one interactions with individuals.

Telepresence robotic technologies have also employed in supporting better communication between patients with dementia and their caregivers, with positive effects [104].

A large number of studies report on technologies for health monitoring in the context of smart homes. The majority of these technologies are used for activity monitoring, detection of abnormal activities and cognitive help. Indicatively, this category contains LightPaths targeting detecting falls among elderly people living at their own homes and care home facilities [105], a monitoring system for remote monitoring at night in dementia care [106] and the Rosetta system [76]. The latter is a product of the Rosetta project that aimed to integrate three separate, previously developed, ICT systems to one modular system for people with mild cognitive impairment and dementia in different stages of the disease in order to support them in daily functioning, identify deviations in behavior and detect emergency situations. Finally, a medication reminder system in the context of a smart home environment is proposed by Ramljak [107]. According to that, when a new medication is prescribed to a patient through the electronic health system a QR code is generated and delivered with the prescription, which hold info for the medication treatment, the duration, and next visit. The notifications appear to the user as smartphone notifications home voice and video notifications.

3) Applications Supporting Non-Pharmacological Interventions: A large and diverse set of literature reports on home based technologies that focus on interventions to maintain the cognitive capacities and their efficacy for people with cognitive disorders like dementia. Evidence exists that memory support technologies do enable people with dementia to live more independently and their caregivers to experience less burden [108]. Such support may be offered by the companion type robots. An indicative example is the robot Kompai, developed in the context of the EU funded MARIO project, which focused on developing smart solutions for the challenges of loneliness, isolation and dementia in older persons [109]. It is a companion robot designed to provide an interactive, low cost and extensible service robotic platform for older people and people with dementia. A considerable amount of literature is also available that documents the positive effects of interventions targeting the cognitive functioning of patients. Paletta *et al.* [110] incorporated a multisensory robot coach, developed in the basis of the social robot Pepper. The functionalities of the robot include motivation for personalized daily exercises, support of cognitive processes, reminder of tasks/events, dialogue involvement and entertainment for patient with dementia.

Broekens *et al.* [111] investigated the effectiveness of such robots in the health care of the elderly and concluded that companion type robots could have positive effects with respect to at least mood, loneliness and social connections with others. Other studies [112] showed that by using such a robotic system some patients improve their cognitive attention, their feelings and their ability to defeat stress.

Another type of technology that is employed for maintaining the cognitive capacities of people with cognitive disorders are the virtual reality training systems. In [113] the authors described a novel virtual reality cognitive training system for people with mild cognitive impairment, with the aim of preserving their mnesic and logical-praxic faculties for as long as possible through exercise and cognitive stimulation. The system is characterized by a high degree of realism and interactivity, to provide the patient with an adequate sense of presence within the virtual environment. Moreover, it is able to monitor the patient's biomedical signals and collect quantitative data on the training sessions, so allowing the therapist to analyze and adapt the training strategies to the patient.

Various serious games focusing on improving cognitive capabilities, e.g., Serious games [114], SOCIABLE project [115] have also been reported. Available evidence indicates that serious games can improve the user's cognition (e.g., memory), concentration and reasoning [116], help the person's ability to function in real-life everyday situations, in reducing user's distress and moon disturbances.

4) Applications Supporting the Communication With and Collaboration of the Care Delivery Actors: Giraff [117] is a human-height, mobile, telepresence robot and is equipped with a videoconferencing system that includes a video camera, LCD screen, speaker and microphone. It is used to connect a relative and a person with dementia as a means to improve communication between these two parties. With this robot, families can virtually visit the patients, participating in two-way conversations with their faces appearing on life-size video screen.

C. Current Trends in Research for Dementia

In the present section we focus on the analysis of key current research and development efforts, in an attempt to i) assess which of the dimensions for integrated dementia care management will be better supported in the near future and ii) identify areas that remain underserved and thus require additional research and development efforts.

Following the Group of Eight (G8) dementia summit in 2013, the G8 leaders set out an ambitious plan to '*find a cure or disease modifying treatment by 2025*'.[7] In Europe, the Council of Ministers adopted Council Conclusions on "*Supporting people living with dementia: improving care policies and practices*" in 2015 which, led to a joint action on dementia called "Act on Dementia,[8]" an action to improve care policies and practices to support people living with dementia. Since then many research and development projects that focus on dementia treatment and management have been funded. We will focus on those targeting technological developments in support of integrated care management.

Indicative such efforts include the PredictND[9] project, which develops diagnostic tools for neurodegenerative diseases, including AD, vascular dementia and fronto-temporal dementia. The tools, which have been thoroughly evaluated with 800 patients in four hospitals in Finland, Germany, Holland and

[7]https://www.alzheimersresearchuk.org/wp-content/uploads/2015/03/Alzheimers-Manifesto_2015_lores.pdf#page=6

[8]http://www.actondementia.eu/

[9]https://www.predictnd.eu/

Italy, focus at earlier diagnosis using a data-driven model. Also, SMART4MD[10] developed an mHealth application specifically targeted to patients with mild dementia, with the objective to support medication and treatment adherence, to sustain the progression of their illness and to improve the communication with their informal and formal carers. MinD[11] provides tools and mechanism for people with dementia to improve their social skills and psychosocial wellbeing.

MARIO[12] focuses on the challenges of loneliness, isolation and dementia. MARIO is built on top of the Kompai platform and an innovative robot application development platform. On the other hand, OurPuppet[13] is a robotic system able to interact with a person with dementia using emotional patterns. Its key objective is to contribute to the reduction of the stress of the patient, improve the activity of the patient and enhance the communication of the patient with his/her caregivers and family. Another objective of the OurPuppet project is to help and empower informal caregivers by providing the communication and information channels with the patient.

The ehcoBUTLER[14] project aims to improve the health and social care of elderly people, especially those with mild cognitive impairment, through technology enabled self-learning. The platform contains both leisure and care educational apps for the elderly population, promotes self-learning and offers a module of cognitive training.

The IN LIFE[15] project develops and integrates a range of ICT solutions for people with dementia and their caregivers that span across applications to empower informal and formal caregivers, tools to support patients in their everyday activities and travel assistance. Home4Dem[16] addresses the challenge of dementia through a home based ICT platform promoting the independent living at home for people with dementia and maintaining an active social life, thus improving their quality of life and that of their caregivers.

ROADMAP[17] is the only Innovative Medicines Initiative (IMI) project in our list since it is the only IMI in the field of dementia that involve metrics for the patient communication and does not focus explicitly to drug development. The project involved diverse stakeholders (carers, patients, researchers, regulators, health technology assessment bodies and industry) to prioritize data from various clinical trial outcomes and designed an integrated data environment and framework for real-world evidence in Alzheimer's disease.

DEEP[18] is a UK national project aiming to improve the communication between persons with dementia across UK. The Cygnus project conducted a feasibility study in UK, which has a longitudinal cohort design with yearly follow-ups. The patients and close friends or family members are also involved. The study is using a web/mobile app to collect patient and carer reported outcomes (PRO) on a regular basis from home and a wearable device that looks like a watch to collect information on activity and sleep. GameChanger[19] is a UK research project led by University of Oxford and supported by Alzheimer's Society that provides an app for non-patients aiming to understand more about how the brain works and support research that could prevent, slow down, or even stop the progression of dementia in future.

The Conversation Project[20] focuses to help families and informal caregivers of people with dementia diseases for their end of life care. Finally, it was recently announced that the National Institute on Aging awarded a $4.5 million grant to the University of California Berkeley and People Power,[21] an IoT software provider, to support research on smart home solutions for caregivers of dementia patients. They are to create customized systems through behavioral research on targeting everyday stressors for caregivers and dementia patients. The new technology is expected to give caregivers proactive alerts that identify abnormal qualities in patient activities, thus increasing the safety and quality of life for people living with dementia.

Table II summarizes the latest research projects focusing on dementia management with the aid of eHealth and mHealth tools for patients and their caregivers.

While the majority of the funded projects for dementia still focus on pharmacological interventions and drug development, there is a shift observed during the last decade to fund projects focused on supporting patients and their caregivers using ICT technology.

With a reference to our conceptual framework of analysis, it can be identified that *PredictND*, *PACE* and *GameChanger* focus mainly on the first dimension of our conceptual framework, i.e., developing solutions for the detection, diagnosis and assessment of the disease. From these only *PredictND* and *PACE* also focus on developing solutions to efficiently support care transitions and the coordination of care services, i.e., dimension four of our framework. Most of the projects analysed focus on developing services for the management, assistance and support (second dimension of our framework for analysis) including *SMART4MD*, *MinD*, *MARIO*, *echoBUTLER*, *IN LIFE*, *ROADMAP*, *Cygnus,* Our Puppet and Conversation Project. Only *IN LIFE* and *ROADMAP* out of the eight in the latter category also provide non-pharmacological interventions (dimension three) while *DEEP* focuses solely on delivering applications supporting the communication with and collaboration of the care delivery actors (dimension four).

V. Evaluating the Cost Effectiveness of Dementia Focused Interventions

The management of dementia represents a significant financial burden on society, which is comparable to the financial burden of heart disease and cancer [6]. As reported in [118] the worldwide costs of dementia were estimated at United States (US) $818 billion in 2015, an increase of 35% since 2010; 86% of the costs occur in high-income countries. The costs of home-based long-term care rather than the costs of medical services are major components of the costs attributed to dementia [6].

Costs of informal care and especially management of behavioral symptoms is considered one of the most costly elements in care to individuals with dementia [119]. This may be due to the fact that behavioral symptoms occur during all stages of the disease, affect the family and increase the need for caregiver time

[10] http://www.smart4md.eu/
[11] https://designingfordementia.eu/
[12] http://www.mario-project.eu/portal/
[13] https://www.ourpuppet.de/
[14] http://www.ehcobutler.eu
[15] http://www.inlife-project.eu/
[16] http://home4dem.eu/
[17] https://roadmap-alzheimer.org/
[18] http://dementiavoices.org.uk/
[19] https://www.alzheimers.org.uk/research/play-your-part/gamechanger
[20] https://theconversationproject.org/
[21] https://www.healthcareitnews.com/news/iot-firm-uc-berkeley-awarded-45-million-research-grant-dementia-caregivers

TABLE II
EU RESEARCH PROJECTS RELATED TO DEMENTIA

Project Name	Project Type	Budget (in 1K euros)	Duration	ICT for patient	ICT for informal caregiver	ICT for healthcare professional	Bioinformatics/Drug development	Pilot/Clinical Trial
PredictND	FP7	4200	2014-18	No	No	CDS, Clinical protocol for early diagnosis	No	Pilot
SMART4MD	H2020	4000	2017-19	Adhere treatment, health tracking	monitor patients	Share data with from patients	No	Pilot
MinD	H2020	530	2016-20	Social interaction	No	Mindful care	No	Pilot
MARIO	H2020	4000	2015-18	Assisted living environment, robotics	No	No	No	Pilot
ehcoBUTLER	H2020	3650	2015-18	Assisted living environment, self-learning, cognitive app	Yes	Yes	No	Pilot
IN LIFE	AAL	3800	2015-18	Independent living, social well-being, traveling	Telecommunication, scheduling, reminding	Telecommunication	No	Pilot
HOME4DEM	AAL	3350	2015-18	Assisted living environment	Monitor and connect	Access to data. React on Adverse Events	No	Pilot
ROADMAP	IMI	8210	2016-19	Communication	No	Effect of interventions	Yes	Pilot
DEEP	UK		2012-15	No	No	Services and policies	No	Pilot
Cygnus	UK		2016-18	Yes	Yes	No	No	Pilot
GameChanger	UK		2018	No	App to understand how brain works	No	No	Public engagement initiative
Our Puppet	DE		2016-19	Interact using emotional patterns, communicate	Connect with patient	No	No	Pilot
Conversation Project	USA		2010-	Communicate with family, friend, or other loved one	Communicate with patient	No	No	Public engagement initiative
People Power	USA	4500	2018-	increasing the safety and quality of life	caregivers proactive alerts	No	No	Pilot

in oversight [120]. Murman, *et al.* [121] identified that there is incremental direct costs associated with the management of al symptoms even when only one variable of the Neuropsychiatric Inventory [121], a behavioral symptom scale, is worsening.

A recent study [122] performed a systematic review of the available literature on economic evaluations of screening interventions for early diagnosis of dementia disorders including methods and empirical evidence, such as costs, and incremental cost-effectiveness ratio. The authors performed an assessment regarding the degree in which conclusions in terms of cost-effectiveness were actually supported by the reported evidence. They were able to identify and analyze fourteen studies, which satisfied their inclusion criteria. They fell into two main groups: screening without biomarkers and screening using biomarkers. They report that the cost-effectiveness of non-biomarker based interventions cannot be judged due to lack of information. On the other hand screening based on biomarkers has the potential to be cost-effective but their effectiveness has to be established first. The key finding of the study is that additional economic evaluations studies as well as good quality effectiveness studies are required.

There are several additional efforts focused on assessing the economic impact of interventions targeting the prevention or cure of dementia [79], [123]. The office of the assistant secretary for planning and evaluation of the U.S. department of health and human services conducted visits to five sites that support dementia care models and evaluated them based on 14 high-level principles of care. These principles span across diagnosis, care planning, medical management, safety, assistance for the patients and the family [124]. The report provides also an extensive list of fifty-five dementia models for intervention (Appendix B of report). Unfortunately, most of them did not use ICT technology for the intervention or are designed for the primary care setting. Only five out of the fifty-five interventions take advantage of ICT technology, namely the ACCESS [125], the Assisted Living Care Transitions, the Caregiver's Friend, Dealing with Dementia, the Creative Caregiving Training Modules and the ECHO-AGE. The reported outcome regarding these interventions provides positive evidence with respect to their cost effectiveness.

The authors of [126] performed a systematic literature review focusing mainly on the British National Health Service Economic Evaluation Database in order to evaluate the full and partial economic implications of dementia [127] taking into account cost-effectiveness. The authors identified fourteen interventions with cost effectiveness figures, while only one study [128] used an ICT tool (ComputerLink) for the caregivers in order to improve their confidence in decision-making.

Table III summarizes the identified dementia intervention models supported by ICT technology, their expected outcome, the role during the intervention of the person with dementia, the informal caregiver and the healthcare professionals.

Additionally, Nickel *et al.* [133] performed a systematic review whose key objective was to review and analyze all

TABLE III
DEMENTIA INTERVENTION MODELS WITH ICT SUPPORT (COMPILED FROM [124] – APPENDIX B AND [126])

Dementia intervention model	Reference	ICT for patient	ICT for informal caregiver	ICT for healthcare professional	Expected outcome of the intervention
ACCESS	[125]			web based communication and decision support system	To provide coordinated medical care and community support.
Assisted Living Care Transitions	[129]	medical, cognitive, functional, nutrition and psychosocial adjustment		Monitoring of medical, cognitive and functional status of the patient	To minimize transitions out of assisted living for people with dementia
Caregiver's Friend, Dealing with Dementia	[130]		Online training to create positive caregiving strategies. included multiple components of knowledge, cognitive, and behavioral skills and affective learning		To evaluate the efficacy of an online multimedia support program for informal caregivers and create positive caregiving strategies
Creative Caregiving Training Modules	[131]		Online guide for research-based caregiving exercises using creative arts. self-care for the caregiver	Online guide also available for professional caregivers	Enhanced quality of life and decreased depression and anxiety for persons with dementia and caregivers
ECHO-AGE	[132]	Case-based remote consultation	Participation of the family in the video sessions	remote case-based video consultation program with specialists (geriatrician, hospitalist, psychiatrist, behavioral neurologist)	Cope with challenging cases related to the behaviour of person with dementia or delirium to specialists via video-conferencing
ComputerLink	[128]		Standalone program for reducing caregiver's social isolation and increasing decision-making confidence		To enhance caregivers' confidence and improve their decision-making skills

available evidence on trial-based economic evaluations of non-pharmacological interventions directly targeted at persons with dementia as well as persons with mild cognitive impairment and their respective caregivers. It is of interest that only sixteen publications in total were identified. This finding reaffirms available evidence from previous systematic reviews which highlight the scarcity of economic evidence regarding non-pharmacological interventions for people with dementia and their supporting informal caregivers [134].

During the last decade non-pharmacological, multicomponent psychosocial interventions for people with dementia as well as their caregivers became more important, leading to a considerable growth in the evidence base [135]. The available evidence indicates that multicomponent psychosocial interventions are effective with respect to the maintenance of caregivers' psychological health and the delayed institutionalization of people with dementia [136]. Furthermore, a recent study by Straubmeier *et al.* [137] shows a highly promising effect of a structured multicomponent intervention targeted at persons with mild to moderate dementia on their cognitive abilities and activities of daily living. The cost-effectiveness, though, is not reported in none of these studies.

A recent study, specifically focused on patient's agitation, examined whether an optimized intervention is a more cost-effective option than treatment as usual for improving agitation and quality of life in nursing home residents with clinically significant agitation and dementia [138]. The study reports that improvements in agitation and quality of life were evident. Nevertheless, the study does not report any conclusive evidence on its cost-effectiveness.

Regarding collaborative care, Callahom *et al.* [139] tested the effectiveness of a collaborative care model with respect to its ability to contribute to the improvement of the quality of care for patients with Alzheimer disease in a controlled clinical trial of 153 older adults with Alzheimer disease and their caregivers. The team used standard protocols to initiate treatment and identify, monitor, and treat behavioral and psychological symptoms of dementia, stressing nonpharmacological management. Collaborative care for the treatment of Alzheimer disease resulted in significant improvement in the quality of care and in behavioral and psychological symptoms of dementia among primary care patients and their caregivers. These improvements were achieved without significantly increasing in costs.

Finally, regarding interventions targeting informal caregivers, Gibson *et al.* [140] report that informal caregivers receive greatest benefit from assistive living technology mainly by reducing stress and anxiety through maintaining the person with dementia's safety. Also, Curry and Ham [141], reported that in cases where ICT had successfully applied, the impact of use was positive and empahsize that reported problems in the evaluation of the outcome of deployment and cost-effectiveness relates to technology acceptance.

VI. DISCUSSION

Dementias are chronic diseases that require longitudinal care, ongoing counseling, and psychosocial support for patients and families by dedicated and often distributed care teams [23]. Effective dementia care, thus, demands appropriate models for integrated care. Information and communication technologies are key enablers of patient-centered integrated care for dementia patients, since many of the integrated care processes can only happen with the support of state-of-the art information and communication technologies (ICTs).

To date, a large number of assistive technologies utilising mobile devices, on body networks as wells as hospital, residential and community based solutions have been developed that address specific dimensions of the prevailing integrated care model for dementia, as described in Section IV.

In Table IV we summarize the reviewed assistive technologies for dementia detection, assessment and management, which include mobile and internet based applications, smart solutions

TABLE IV
SUMMARY OF THE CURRENT TECHNOLOGIES (MOBILE APPLICATIONS, HOME BASED SETTING AND RESEARCH PROJECTS) FOR PEOPLE WITH DEMENTIA AND THEIR CAREGIVERS MAPPED TO THE WIENER'S (HIGH-LEVEL PRINCIPLES) OF DEMENTIA CARE FRAMEWORK

Reference of Project name	Detection, diagnosis & assessment	Management assistance & support	Interventions	
Cognetivity[22], ACEmobile[23], [61], [62], [63], [64], [97], [99], [105], [106] GameChanger, PredictND	√			**Deep, PredictND and [1]** support also **Transition and coordination**
[69], [70], [71], [77], [81], [83], [86], [101], [110], [113], [114], [115], [117], MinD, MARIO, echoBUTLER, Cygnus, Our Puppet, Conversation Project		√		
[89], [90], [94]			√	
[65], [76], [96]	√	√		
[98]	√		√	
[73], [74], [75], [82], [102], [104], [107], IN LIFE, ROADMAP, People Power		√	√	
[1], [66], [88], SMART4MD	√	√	√	

for home settings, as well as the most prominent existing research and development efforts. All these are clustered along the four dimensions of our conceptual framework of analysis, i.e., mapped to the Wiener's high-level dimensions of an integrated dementia care model.

Analysis of the picture depicted in Table IV and the evidence from the reviewed literature relates to the following.

There are currently no specific treatments to prevent the progression of cognitive decline in dementia patients. Still, early and specific diagnosis is considered important as it can help to guide therapy and to allow for patients and families to properly prepare for the consequences of the disease. Early diagnosis is considered to enable an improved overall course of the disease and delay the conversion from early/mild to more severe disease stages [142].

The potential gains from treating dementia diminish as dementia progresses, and measuring individuals' outcomes becomes increasingly difficult as symptoms worsen. As a result, focus on prevention strategies is required [143]. A large number of efforts are reported that focus on the development of applications that implement one or more of the many cognitive assessment tests reported in the literature [61]. The evidence, nevertheless, regarding the effectiveness of all these efforts is not conclusive. Laske *et al.* [144] report on the need for additional noninvasive and/or cost-effective tools, allowing identification of subjects in early clinical stages of AD who could be suitable for further cognitive evaluation and dementia diagnostics.

Assistive technologies used for the management of dementia are limited due to the symptoms of the disease (movement, cognition etc). Thus, most of the tools for people with dementia are assistive technologies in the home setting and mainly assistive robotics, while other categories[22] include activity monitoring[23] and support, lifestyle monitoring, reminders and communication.

As reported in Section IV, in recent years various IT platforms have been developed focused on cognitive rehabilitation, which is a highly individualised, non-pharmacological intervention for people with dementia. We were unable to identify published efforts to assess the cost effectiveness of cognitive rehabilitation. Only recently an effort is reported focused on evaluating the effectiveness of the cognitive rehabilitation software GRADIOR in a multi-centre, single-blinded randomised controlled trial with people with MCI and mild dementia [79].

Regarding current research efforts related to dementia, one can easily identify one main pattern/trend from Table II with respect to ICT technologies. Two projects focus on clinical decision support and on the development of clinical protocols for early detection. The most recent research efforts focus on the implementation of ICT technologies that assist and empower the patient (e.g., mHealth and home robotics).

Despite the promising benefits stemming out from the adoption of such technologies, there are several issues that need to be clarified and resolved in order to really make a difference in dementia care. For example, the lack of high-quality studies with respect to their cost-effectiveness of assistive technologies in dementia care is often reported [145], [146].

Although, the integrated care frameworks with the respective principles for dementia has reached a satisfying degree of maturity at a theoretical level, it still lacks effective support in practical application. Practically, integrated care focuses on continuity and coordination of care, efficient communication between the various caregivers and seamless transfer of information for the management of the disease. Furthermore, integrated care includes collaborative interaction of health system stakeholders in order to achieve person-centered medical and behavioral care across a person's lifespan. We failed to identify such type of technologies. An explanation to this could be the fact that patients and caregivers are always seen as a dyad when applying a technology, and thus the patients get prioritized while the caregivers receive a secondary attention.

In parallel, informal caregivers are increasingly playing a pivotal role in looking after people with dementia. Informal caregivers endure tremendous physical, emotional, and financial burdens while caring for people with dementia. Consequently, informal caregivers themselves demand increasing support from health professionals, assisting them in managing the needs of the person with dementia but also in making sure that the needs of their own health are met.

A large number of efforts to develop technology enabled interventions targeting the needs of informal caregivers do exist. There is evidence that online social media interventions offer

[22]https://www.cognetivity.com
[23]http://www.acemobile.org

opportunities to enhance positive interactions and openness in dementia care networks, although their cost-effectiveness has not been fully studied [147]. A recent study [14] examined the cost-effectiveness of a home-based intervention customized to patient capabilities and training caregivers. As reported by the authors in their study, "*. . . to our knowledge, the current study is the first cost-effectiveness analysis of an activity-based non pharmacologic approach to reduce behavioral symptoms in patients and objective burden of caregivers*".

The findings reported in [133] indicate that the cost-effectiveness of physical exercise interventions and occupational therapy is positive. There was also evidence that psychological and behavioral therapies are also cost-effective. On the other hand the available economic studies investigating psychosocial interventions which did mainly target informal caregivers showed inconsistent results. No economic evaluations on sensory and creative interventions could be identified. The key conclusion drawn is that the increasing number of dementia non-pharmacological interventions and their health economic impacts are of increasing importance for health care decision-makers and health technology assessment agencies.

To summarize, various benefits of assistive technologies for persons with dementia have been reported. However, the results described need to be interpreted with caution because the majority of the included studies were uncontrolled studies with relatively small sample sizes. Reviews on cost-effectiveness studies of assistive and health care technologies in dementia were not found [95].

VII. Conclusion

Although dementia is a leading cause of dependency and disability, it remains one of the few chronic conditions that are not supported by comprehensive chronic disease management strategies. At the same time a growing number of programs to help people with dementia and their family caregivers are being developed, tested, and implemented in the United States, Europe and globally. Such initiatives for developing models of care for people with dementia integrate best practices in chronic disease and dementia management with those of integrated continuing care.

It is evident that integrated care is seen as a future direction for the early detection, continuous assessment and effective management of dementia. In so doing emphasis has been given on the development of innovative ICT based applications and solutions. While the objective is promising, integrated care remains a complex phenomenon which takes place at multiple levels, with various interventions, stakeholders and contextual factors that can influence processes and results. Based on all available evidence, "*the transition to integrated care is a highly complex process in all aspects, i.e., the design, the implementation and the assessment of integrated and collaborative care*" [47].

In general concepts of collaborative care differ. Whilst some concepts refer to collaboration within certain teams or between different types of professionals, others employ a broader perspective that focuses on collaboration between organizations and across care settings [148]. Analysis of the number of reported efforts for developing technology-enabled solutions for the transition and coordination of care (see Table IV) reveals that there is a clear need for novel technologies and digital collaborative platforms to support the dynamic interaction between the patient and its formal or informal caregivers.

A significant challenge relates to the need for developing technology-enabled solutions that are more closely oriented to the needs of patients and their caregivers, i.e., multidisciplinary, well-coordinated, anchored in community and home care settings, and shifting from a reactive approach to proactive and patient-centered care.

In parallel, it is evident that family caregivers are increasingly playing a pivotal role in looking after people with dementia. Informal caregivers endure tremendous physical and emotional burdens while caring for people with dementia. The main themes reported in recent literature that represent the most important aspects of caregivers' health needs relate to mental health, emotional support and social relationships, healthy diet and exercise, and personal time [149].

Available results, although mixed, indicate that the use of both internet-based and other mHealth based interventions are positively accepted by caregivers. On the other hand, there are significant gaps in understanding the types of solutions and technologies that can reduce the negative effects of caregiving. As a result the range of effective technical solutions targeting the needs of caregivers is very limited.

Also, more high-quality studies are required in trying to identify the cost-effectiveness of internet interventions aimed at supporting family caregivers during the different stages of dementia [58].

Regarding cost-effectiveness of available solutions in general, we searched for evidence as to whether assistive technologies have a positive impact on the well-being of patients and their informal caregivers as well as broader socioeconomic benefits. To summarize the available evidence, various benefits of assistive technologies for persons with dementia have been reported. However, the results described need to be interpreted with caution because the majority of the included studies were uncontrolled studies with relatively small sample sizes. There is, in our view, a relative lack of studies investigating cost-effectiveness of specific intervention of assistive and health care technologies in dementia management [95].

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Authors' photographs and biographies not available at the time of publication.