Virtual Health Agents for Behavior Change: Research Perspectives and Directions

Willem-Paul Brinkman[1]

Delft University of Technology, The Netherlands,
w.p.brinkman@tudelft.nl,
WWW home page: http://ii.tudelft.nl/willem-paul/

Abstract. Research on virtual health agents that can support people to change their behavior is steadily increasing. However, to move this research forward the coming years, understanding of opportunities, and the underlying research challenges from a technological perspective is needed. This paper examines a number of relevant trends, the type of support these agents can offer, and technological challenges. The analysis shows an economic and demographic trend indicating an increasing care need, an interest in health related apps, and research in this area. The analysis also identifies four research challenges for virtual health agents: (1) interpreting the situation and people's intentions, (2) intervention reasoning, (3) generating informative, educative, persuasive computer behavior, and (4) engineering generic solutions. It is hoped that this examination helps researchers to position their work, and to give outsiders an overview of key motivations and challenges that are relevant to understand research on virtual health agents.

Keywords: virtual health agents, behavior change support systems, persuasive technology

1 Introduction

Virtual health agents are interactive characters that often have anthropomorphic elements to evoke responses that humans would exhibit when interacting with other humans. Set within the health domain, these agents can help both care providers and clients to manage people's physical and mental health. Virtual patients, virtual nurses and virtual health coaches are all existing applications that show the potential benefits this technology can bring, such as accessibility, i.e. any time any place when offered on a mobile platform; and personalization, i.e. adapting interaction and services to the needs and desires of the clients and their situation. When the goal is to support people in changing their behavior, these agents can be regarded as special instantiations of behavior change support systems. These systems use persuasive strategies to help people to alter or maintain their behavior, attitude, or cognition without using coercion or deception [35]. Whereas these systems are the object of study, the research field is often referred to as persuasive computing.

Virtual health agents have the potential to be used in several situations. Currently there are a number of key examples. For example, the Virtual Nurse which educates hospital patients about their condition and provides them post-discharge information. When asked about their preference between a virtual nurse or human nurse, only 25% of the patients had a preference for a human nurse while other patients had no preference or preferred the virtual nurse [50]. Another example of these agents, this time outside the hospital, is SimCoach [41], which is a virtual human support agent that guides (ex)military personal and family members to seek medical help. One step further are initiative where agents are directly involved in the health intervention. For example, the Memphis system [23] designed to provide social phobic patients with a virtual reality therapy at home. Besides exposing these patients to social scenario's in virtual reality, a virtual coach tries to motivate patients to continue with therapy, provide them psycho-education, analyze their data, and explain the progress they are making. Although in these three examples, the agents have a graphical appearance, this is not always the case. For example, the Sleepcare app [8] offers cognitive behavior insomnia therapy on a smartphone. Besides presenting visualizing sleep data, the agent engages users in natural language conversation in text chat style manner. Although this is just a snap shot of some research projects with these agents, they show future potential in supporting people in their health needs.

Giving this potential, there is a need for a research vision from a technological perspective for a viable virtual health agents community. When considering these agents, the obvious questions that spring to mind is, do they work? and, do people want them? These are health domain perspective questions. They focus on domain benefit and acceptance. Although they are valid research questions, they do not give a direction for the research on developing these agents. Therefore, for technology to move forward there is a clear need for research from a technology perspective. The strength of such a perspective is to look across the various applications, and identify common underlying issues and establish generic solutions that could push forward the quality of these agents.

The research vision this paper puts forward is shaped into four key research challenges that are seen as fundamental toward research on establishing virtual health agents. For this, the paper explores Dutch health care trends that justify research, but also trends in research itself. The discussion also addresses the type of behavior change support these agents can provide. This analysis provides the framework to describe research from a technological perspective and identify key research challenges.

2 Trends

2.1 Health Care

Like any western country, The Netherlands is seeing some significant changes in demographics and health expectations that are likely to affect the need for care in the future. Some key statistics are provided by Statistics Netherlands (CBS) [3].

For example, people are getting older. While males born in 1981 had an average life expectancy of 72.71 and women 79.32 years, in 2014 this had risen to 79.87 and 83.29 respectively. This seeming improvement is also coming with a down side whereas males born in 1981 had an average life expectancy without chronic illness of 54.5 years and women 53.9 years, in 2014 this had dropped to 46.9 and 40.7 years. These chronic illnesses include asthma, heart defect, stroke, high blood pressure, gastrointestinal disorders, diabetes, back problem, rheumatic / joint diseases, migraine, and cancer. This means that people will be confronted with the need for care at a younger age, and will need to adapt their lifestyle, and/or manage and monitor their health more intensely and do this for a longer time.

Another key statistics is the expected changes in age demographics. The prognoses are that between 2015 and 2060 the Dutch population will increase from 16.9 million to 18.1 million. However, as Figure 1 shows, the ratio between age groups will change over time. Whereas the age group of 65 and older is expected to increase from 17.8% to 26%, the working group aged between 20-65 is projected to drop from 59.6% to 52.8%. In other words, more people that need care, and less people economically active to provide the resources for this.

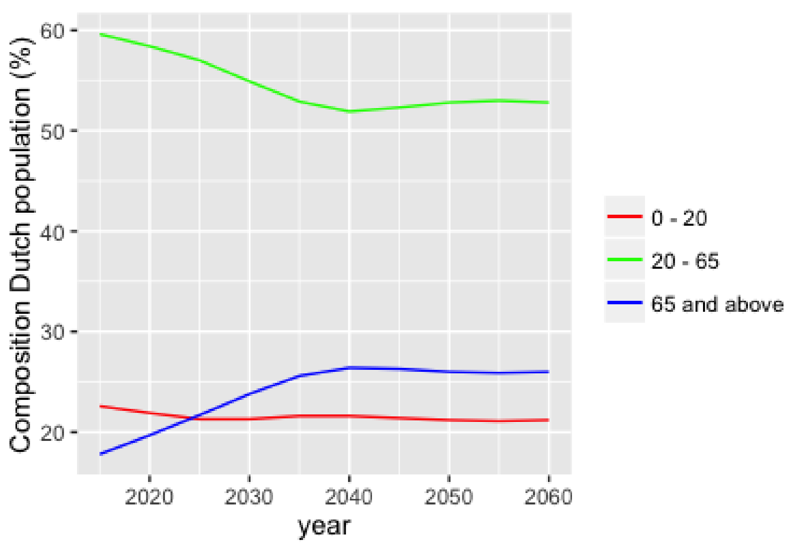

Fig. 1. Dutch demographic prognosis. Source: Statistic Netherlands (CBS) 2016.

The last decade Dutch spending on health care also shows dramatic increase [1]. Where in 2001 spending per capita was € 3241, in 2014 this had increased to € 5611. To put this even more in perspective in 1972 this was € 484 [47]. When considering age groups, the age group of 65 and above is responsible for the largest segment of the cost, and for 2003 to 2011 a steady increase is noticeable (Figure 2).

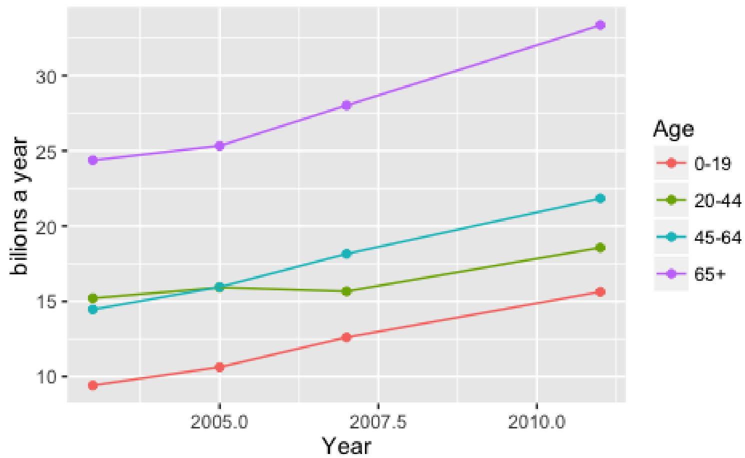

Fig. 2. Dutch health cost per age group. Source: Volksgezondheidenzorg.info 2016.

Consumer health applications is a growing market. An interesting indicator for virtual health agents is the use of mobile apps, as this involves only services and/or sales of software and not electronics or medicines. Statista [2] provides some relevant statistics in this area. For example, worldwide mobile app revenues in 2015 was $ 41.1 billion. Health related apps makes up a sizable segment (7.36%) of this market, as for example in March 2016 the fifth largest category of active iPhone app was the category health, fitness, medical and sport. The main apps in this category include apps such as: Fitbit, Period tracker, My Baby's Beat-Bay Hear Monitor, and Pill Identifier. When considering economic potential of mobile health apps in the next 5 years, a survey [4] among app developers, health managers, and project managers revealed the following top 4 : remote monitoring (53.2%), remote consultation (38.2%), diagnostics apps (31.7%), and reminders and alerts apps (26.8%).

2.2 Publications

Research on ehealth is growing. Figure 3 shows the results of a scopus database search on the intersection between technology (Internet, web, computer, system, technology, application, computing), the objective (persuasive, persuasion, persuasiveness, behavior change, behaviour change, behavioral change, behavioural change), and the domain (medical, health, wellness, wellbeing, illness, disorder) conducted at June 2016. It shows an accelerating rate that seems to have started somewhere in 2002. In 2014 it reached 1093 publications in that year alone. The top five venues for publications are: Journal of Medical Internet Research (158), Lecture Notes in Computer Science (including subseries Lecture notes in artificial intelligence and lecture notes in bioinformatics) (126), Plos One (101), BMC Public Health (89), and Patient Education and Counseling (80). Figure 3 also shows Scopus result if the search is limited to intelligent systems (agent, intelligent, intelligence). In 2014 the subsection reached 167 publications.

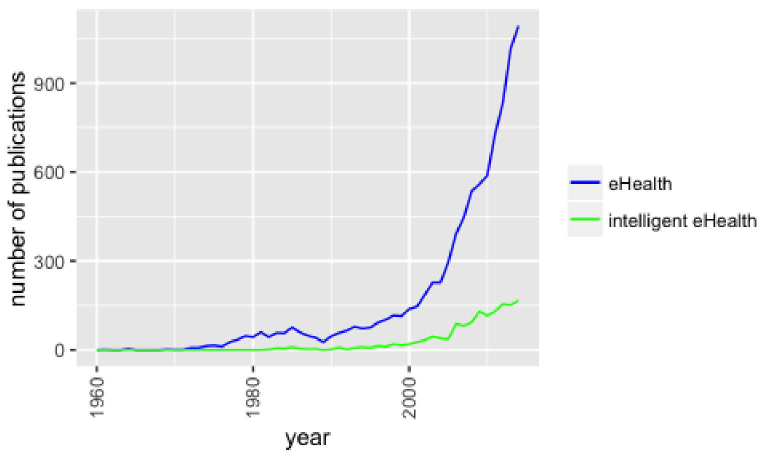

Fig. 3. Number of eHealth related publications . Source: Scopus 2016.

2.3 Paradigms

Research is often shaped by a dominant paradigm or a school of thought. They frame problems and challenges being researched. New paradigms emerge when existing ones are unable to grasp the central focus point of a real word challenge. Table 2.3 shows three paradigms. The first dominant paradigm that can be identified is the computer centered paradigm. Here the computer is the main focus. The paradigm was very popular at the begin of the computer era. Mainframes and mini computers were expensive, and operated by a limited number of experts. Besides programmers that developed software and maintained systems, human interaction was limited to primarily entering data.

The second dominant paradigm that can be identified is the user centered paradigm. Here users and their task take the center stage. This paradigm became popular with the introduction of personal computers. As computer time was no longer a scarcity, intense training was no longer justified to maximize computer deployment. Instead system design focused on making it easy for humans to use the computer. The introduction of graphical user interfaces, but also the rise of human-computer interaction as a research field are results of this paradigm shift.

Table 1. Different paradigms

Paradigm	Computer	Human	Optimizing
Computer centered	Data processing	Data provider	Computer performance
User centered	Tool	User	User task performance
Behavior centered	Expert	Client	Adherence to target behavior

A new emerging paradigm can be labeled the behavior (change) centered paradigm. Here the focus is set on the human behavior. In the user centered paradigm the focus is on supporting users with conducting a task, with the assumption that they know what needs to be done. This assumption is less valid when considering people's health, their wellbeing, their relationship with their environment, etc. For these states of being, people expertise and skills are limited; limited into what to desire, what to do, and how to motivate themselves in doing this. The system is positioned to fill this vacuum. It can offer support or guidance. It can help exploring goals, and implement them by supporting the subsequent behavior change process. Designers might take their inspiration by looking at human experts, such as coaches, teachers, doctors, and therapists. Still the aim is not to emulate these experts. Instead, they should consider the full range of the computational capabilities such as 24/7 accessibility, data processing power, consistency, and persevering. The role of the human on the other hand is also changing. It is no longer that of a user or data provider. Instead, it is a client, who uses the professional services of an computerized expert to modify his or her behavior.

3 Type of Support

To facilitate change, virtual health agents can be used to enhance human competences related to monitoring, cognition, affect, and behavior. How health care professionals support these competencies can be taken as an inspirational first step. Identifying the professionals' limitations can help to consider how virtual agents might be able to overcome them, for example, by doing it in another way. Maybe less effective, but more economically viable, or even more effective or acceptable. Table 3 gives an overview of these competencies, the human needs and computer potential.

3.1 Perception, Monitoring and Awareness

A change process consciously initiated requires an individual to perceive the current situation as less desirable compared to a potential future situation. Psy-

Table 2. Different type of support

Competence	Human needs	Computer potential
Monitoring	Awareness	Data processing of sensory and stored data
Cognition	Understanding, decision making, and intervention formation	Intervention space analysis, situational adaptation, decision support
Affect & Attitude	Motivation, attitude alignment	Persuasiveness
Behavior	Execute target behavior	Persuasiveness, and adapting environment

chological theories such as Perception Control Theory [38] even takes the position that mainly all human behaviors are initiated by discrepancy between the perceived world, including the person itself, and the desired world, in an attempt to remove this discrepancy. When considering the transition stages in a change process [39], beginning stages are characterized by a lake of awareness of the consequences of the current behavior, and the pros and cons of behavior change. Protection Motivation Theory [43] and Health Belief Model [15] see this awareness raising as a determining factor to motivate people to act. Likewise, human professionals use techniques such as motivational interviewing [34] as a mean to break through a blockage of ambivalences for people to move forward towards change. These ideas have also led to research into computerized motivational interviewing interventions, for example, to stimulate physical activities [11, 13], or fruit and vegetable intake [18].

Besides the awareness of symptoms, daily activities, or thoughts; measuring and recording is a central component of self-monitoring [49]. After the realization that initiating a change process, monitoring the state of being, such as blood pressure, stress level, weight, or amount of physical activity could trigger or stimulate new or continued of healthy behavior. Because of the repetitive nature, people can benefit from computers to make this task easy to perform, or automate it completely by using sensors. Additional computers could also help to process low level data into high level data, for example identifying patterns of deterioration over time with chronic illness. Here the system can offer early warning signals so people can early on seek medical assistance, making early intervention possible. For this, computers could rely on theory-based models, or data-driven models. For the latter, having access to extensive population database, e.g. data collected from other diabetic patients, would allow benchmark analysis or classifying people based on existing patient profiles to infer potential health progress, adherence rate, or susceptibility for specific persuasive strategies [29].

Once individuals are committed to change, monitoring could also mean adherence or compliance monitoring. This is importance because of the correlation found between adherence and treatment effect (e.g. [26]). As the classic Hawthorne effect [36] shows, the notion of being monitored could cause people to improve their behavior. Furthermore, it also gives an insight into people's ability to adhere, providing an opportunity to discuss potential barriers, and strategies to overcome them.

3.2 Cognition

Although awareness of behavior and symptoms is a first step, the next step for change is to understand underlying causes or make a diagnosis. Traditionally this field has been dominated by medical expert systems [44]. Still these systems primarily focus on supporting health providers, and not directly patients as is the case for virtual health agents. Additionally, although in theory the focus of a virtual health agent could comprise a multitude of illnesses, in practice it is often specialized at specific health issues. Assessment in this case often considers establishing the degree, extent, or the likelihood that a specific cause led to the observed health symptoms.

Another important cognitive competence is understanding the health situation, illness, disorder itself. In other words, people should comprehend what is happening to them. Health education and psycho-education therefore aim at empowering individuals or family members to cope with health conditions or to promote, maintain or the restore health. It should help them to make decisions on their quality of life such as changing their behavior. Whereas health professional are often limited in their time, the unlimited time virtual health agents can provide in giving this information is a key strength of this technology. This support in cognitive competence can be see in several virtual health agent examples such as psycho-education for patients with social phobia [23], sleep hygiene education for people with insomnia [8].

Once the causes have been identified, an intervention needs to be formulated. Ideally this intervention is adapted to individuals situations and also updated based on data collected at the start and during the intervention. To increase adherence, intervention needs to fit with the daily life of the individual. As multiple interventions might be possible, people need to understand the positive and negative consequences of interventions to be able to make decisions. Different to traditional decision support systems that might focus on a single decision, e.g. buying a house, behavior change is a process, which stretches over time and includes multiple decision points.

3.3 Affect and Attitude

Human emotions can be enablers and disables of a change process, and could also be the target of the change process itself when considering mental health issues as stress, depression or anxiety. Additional, attitudinal change, for example, self-efficacy, or attitude towards healthy living, can be a key enabler that could lead up to change in people's behavior. As the Elaboration Likelihood Model of Persuasion [37] and also Social Judgment Theory [45] indicate, emotional state or attitude influence how people ignore, focus on, and process information. Also, adequate motivation level is necessary for people to perform desired behavior [20, 33]. A virtual health agent that aims to motivate women to breastfeed their babies [46] is an example of computerized support for this type of competence.

Self-confidence and coping with emotions is also part of this competence. Health care professionals showing empathy and empathy understanding, thereby acknowledging people's emotional state and difficulties can be a necessary condition to initial change [42]. Developing rapport and trust with a care provider is another supporting strategy. Developing rapport with embodied conversational agents therefore also has received some research attention (e.g. [21, 22]), as well as studying the therapeutic alliance with virtual health agents [9], and the possibility to establish long term relationship with agents [10]. The latter is important as the effect of agents might quickly wear off after the initial introduction of the intervention.

According to Social Cognitive Theory [6] and Goal Setting Theory [32], self-efficacy, i.e. people's belief in being able to accomplish a goal, determine whether people engage in the related behavior. This can be influenced by verbal persuasion, but also by bringing people in a more positive emotional state [5]. Both strategies could in principle be target virtual health agents.

3.4 Behavior

Performing the act is ultimately what it comes down to. The first element of this competence involve people's ability of actually being able to perform the behavior. Skill training supports this need. Virtual health agents can help people to explain a specific skill or technique such as teaching soldiers breathing relaxation techniques to cope with stress [40], or teaching fire-fighter appraisal techniques to cope with traumatic events. Virtual agents have also been used for social skill training, by allowing individuals to role play a social situation, for example, a job interview [24], coping with peer pressure for patients with substance use disorders [25], and public speaking [28].

Another support strategy is to enhance the likelihood that a person will exhibit desired behavior by creating the right environment for the behavior to occur. Here, instead of engaging in a dialog, the agent could directly control the environment of the individuals. For example, they could block email when a person needs to relax at dinner, switch off the TV to get her to bed in the evening, or slowly turn up light and back ground music to wake her up again in the morning. In this case agents rely on actuators such as heating and cooling units to control temperature, or light to create a certain ambiance in a room. When agents are physically embodied, e.g. robots, their ability to control physical environment increases even further.

Less invasive strategies are also possible by targeting the initiation of behavior to occur. Fogg [20] argues that with a sufficient level of motivation and ability, a trigger is needed to set of the behavior. Technological support in this case could involve sending people reminders, e.g. to take their medication, or do their exercises. Here an agent helps conscious processes by implementing prior established plans and to control diversion of this plan by unconscious processes, or in other words to enhance the person's self-control.

Key to lasting behavior change is the establishment of habits. An important technique of habit creation is the use of rewards. Virtual agents can offer these rewards for example by praising people for their behavior, giving them points to enhance their social status, or by giving or denying access to rewards, e.g. financial stimulus. With their 24/7 availability, virtual health agents can give instant rewards immediate after the behavior, which maximizes the impact of rewards. Agents can enhance positive reinforcement technique by varying the rewards and recording the effect of rewards to establish personalized reward profiles.

Making the behavior easy to perform also increases the chance a person will exhibit the behavior [19]. When planning for behavior change, an important step for designers is to establish a behavior plan. A good behavior plan is one where unnecessary steps are removed. One way of removing them is by letting a computer do them. For example, an agent can schedule when a group sports together, give health food suggestions when doing the groceries, or automatically contact a therapist when a bipolar disorder patient slips into a major depressive episode.

4 Research Challenges from a Technological Perspective

Examining the support of human competences as perception, cognition, affect, and behavior helps to identify general research challenges. Figure 4 gives an overview of the three main functionalities involved in virtual health agents for behavior change. They can be summarized as: (1) situations interpretation, (2) intervention reasoning, and (3) generation of informative, educative, and persuasive computer behaviors.

4.1 Situated Intelligent Actor Behavior and Intention Interpretation

Support for perception, monitoring, and awareness puts forward the challenge that a system is able to interpret the situation and the intention of an individual. For this two main sources of data collection can be distinguished: subjective and objective data. Subjective data involved asking individuals for information about themselves and their situations. This is the most direct way of data collection, which has a high level of face validity, but risks burdening the individuals. Natural language processing, automatic question formulation, and answer processing are techniques that can be deployed. Objective data collection, on the other hand, minimizes human effort, but it's validity is a main challenge. The use of sensors, e.g. for (psycho-)physical measurement (e.g. heart rate, breathing, blood pressure, weight), GPS location, pedometers, or glucometers, provide longitudinal insight into health indicators. But also tracking people social interaction (e.g. voice, email, text messages, online postings) can provide an insight into people mental state. For effective interpretation, the system also needs information of

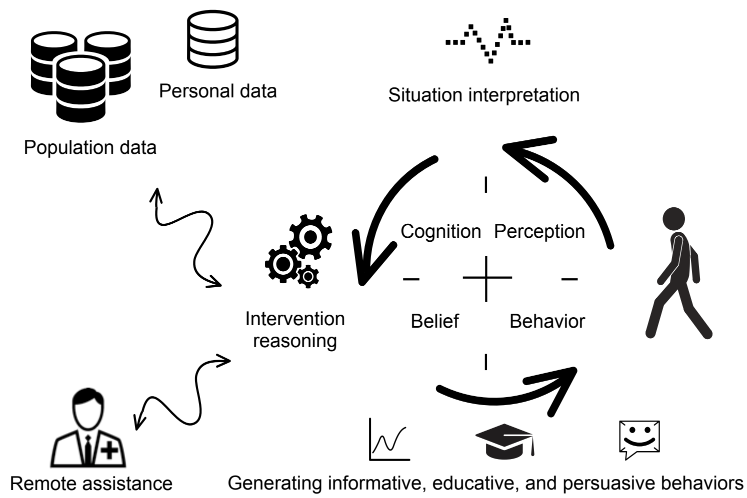

Fig. 4. Research framework for behavior change support systems

possible external factors, e.g. weather condition, work demands, financial situations. Effective interpretation requires the ability to combine different data sources, remove noise, and identify potential patterns using for example unsupervised machine learning techniques.

A related challenge is defining and interpreting change progress metrics. Once the situation has been charted out, it needs to be assessed. This requires change progress metrics and reasoning about the causes. These metrics can be theory-driven, e.g. prior medical knowledge, or data-driven, e.g. statistical analysis of historical population data. Theory-driven indicators might also require transformation or re-operationalization of existing indicators as they are often established under different measuring conditions and importantly measuring frequencies, for example, once every two weeks by a hospital laboratory compared to every day at home with a lower quality measuring device [31]. For data-driven indicators supervised machine learning classification techniques can be used. This requires the existence of a training set to establish a classification model. To interpreter progress, benchmark data is needed. This could derive from population data, or historical data from the individual self.

4.2 Intervention Reasoning

The next challenge is establishing computational models that determines an appropriate an intervention strategy which is continuously adapted to current situation. As the medical and health care domain provides validated treatment protocols, computer intelligence can contribute by tailoring it to individuals to make it more effective and acceptable. This opens the possibility of personalized behavioral medicine, or even more advanced adaptable intervention that is tuned to changing needs and demands over time. An advantaged system would be able to select the most effective and acceptable treatment for the individual and tailor the treatment protocol to optimize potential conflicting value a person holds, e.g. autonomy versus safety. Instead of independently determining the intervention strategy, the system should also engage in shared decision making, or negotiating with the individual. For this the system needs to inform about the consequences of specific interventions, ideally translated to individual health condition and environment. During the intervention, the system preferably should also be able to reason about the effectiveness and possible adherence barriers. This way, it can become self-learning, to improve the selection of future intervention strategies for this or other individuals. In addition, this process can also trigger re-evaluation user goals and consequently recalibration situation interpretation process. Fundamental to the reasoning process, in general, is the use of a series of models: theory model, user model, behavior model, protocol model, external data model, and task model [12]. Defining, initializing, updating, and reasoning with them comprises a core research activity on establishing intervention reasoning.

When using a data-driven approach, a derived challenge of dynamically tuning intervention strategy, is the initialization of this process when little is known about the individual. The use of population data offers an effective approach to address this challenge. For theory-driven approach the challenges often involves reasoning with and about incomplete and uncertain knowledge. Related to this is the challenge about the systems ability to reason about its limitations and also act on this. Systems are designed and tested within a set of constraints. When operating within these constraints, the consequences of the system support on the human should be reasonably predictable. When starting to use a computerized intervention these constraints might be checked, less attention is often, however, given on how the system copes with situations when these constraints are no longer met. Take for example patients that following a computerized post traumatic stress disorder self-therapy where substance abuse reemerges to a degree that normally would have led to exclusion for treatment enrollment. Similarly, a home-based anxiety therapy system that identifies the lack of progress or even deterioration of symptoms [23]. In a stepped care framework, this would be a vital step of reflection. Identifying when a more resource intense or invasive intervention is needed.

4.3 Generating Informative, Educative, and Persuasive Computer Behavior

For the outside world the most noticeable system capability is its behavior that targets change. The challenge is to generate this behavior. As the discussion on support for the human competence shows, the behavior could inform individuals about their health status to make informed health decisions, educate them to make them able to perform the healthy behavior, or persuade and motivate them to actually exhibit the behavior or change in their attitude. The objective of informing behavior is to present information in a understandable, usable way at the right moment, in a format suitable to the situation, the person, and current health situation. It also includes advising on possible actions the individual can take. Again defining, initializing, updating and reasoning with advise and presentation models are fundamental research activities.

Contrary to informative behavior, educative, and persuasive behavior ultimately aims at optimizing human adherence to target behavior. Educative behavior involves explaining procedures tailored to the situation and the person. In addition, it involves facilitating practicing and experiencing the new human behavior, for example, role play in the case of social behavior. The timing and format of feedback is an additional challenge to make it effective. As newly learned routines require maintenance, periodic assessment of person's ability is necessary. Ideally, this would mean using existing data sources for this assessment to avoid additional demands.

The challenge in generating persuasive behavior includes the strategy, the delivery, and identification of effective pressure points. Several persuasive strategies have been put forward: tunneling, conditioning, tailoring etc [19]. The use of population and personal data sets makes persuasive profiling [29] an interesting and potential effective strategy. Emulating social intelligence is another persuasive strategy to evoke social response using psychological persuasive principles such as reciprocity, social validation, liking, and authority [16]. Research into embodied conversational agents and natural dialog systems, in general, is in this context important. These agents can evoke social responses of compliance as they employ both verbal and nonverbal communication modes such as text, speech, graphics, and gestures. These systems are however complex. They are made up of a series of components, e.g. speech recognizer, syntactic and semantic parser, dialog manager, output generators, and renderer. This therefore motivates research into less complex persuasive solutions that do not rely on natural language conversations, but on principles such as gamification, framing, and nudging.

4.4 Engineering Generic Solutions

Although not visualized in Figure 4, the design and evaluation of these agents also provide a set of challenges. Design methodology specifically for virtual health agents has received little attention, with some exception, discussing the design of behavior change systems in general [48]. The core challenge is generalization of design solutions to other application domains. The current state of the art mainly looks at solutions that cater for a specific application domain. Without clear conceptualization and formalization of the design, claims and specification of underlying mechanisms it is unclear how, or if, these computerized behavioral interventions can be applied in other domains. One direction would be the use of ontologies for the software components and the data entities they operate on. This might facilitate the reusability of the software and data [12]. In attempt to find generic solutions it is vital also to consider the embedding of these systems within the already existing health care environment. As Figure 4 shows these agents can also interact with remote human assistance, i.e. health care professionals. Easy to use systems, with a clear benefit for the health care professionals are essential to the acceptance of patient oriented agents.

5 Final Remarks

A number of conclusions can be derived from the previous discussion. First, the current trends seems to justify research on health related agents. It shows an increase in health care demand because of demographic changes, and having people deal with a chronic illness earlier in their life. Next, mobile apps sales suggest a market for health related application. Also, number of publications on intelligent behavior change support systems is increasing. The last trend is an emerging paradigm that seems to center on behavior change. The second conclusion is the possibility to classify behavior change support into four categories of human competences: perception, cognition, affect, and behavior. The third and final conclusion is the identification of four research challenges on virtual health agents from a technological perspective: (1) situation interpretation, (2) intervention reasoning, (3) generating of informative, educative, and/or persuasive behaviors, and (4) engineering generic solutions.

The presented discussion also has a number of limitations, and issues that were not discussed, for example ethics, which is an important issue when considering behavior change. Especially, when it involves computerized programs that try to change a person. From a non technological perspective the questions often focus on conditions under which such intervention would be ethical. Conditions such as the existence of informed consent from the person on the goal, and also the means in which the system will try to accomplish this. In addition, people should always be able to withdraw their consent and disengage from the system. Also clinical justification for goal and intervention is needed.

The ethics discussion from a technological perspective, i.e. the designer perspective, however, is less about finding the right constraints or conditions. Instead, the question is about the design of solutions that do not cause or cope with these ethics concerns in the first place. In other words, what is an ethical design for behavior change? For example, how can designers create systems that are inherent transparent, empowers a person, is worthy to be trusted by users, and is courageous in its support. In a sense, this is the idea behind Values Centered Design [17] to consider human values, such as safety, privacy, and autonomy, when designing a solution, something that is very relevant for virtual health agents. Developing guideline, conducting stakeholder analysis, and involving users in the design process have been put forwards as approaches to consider ethics considerations in the design [30]. Working with health data also raises security issues, i.e. confidentiality, integrity and availability aspects and require compliance with standards for managing health information (e.g. ISO 27799:2016, [27]). Other fields could also be looked at for inspiration. Seeing these systems as an extension of health professionals, designers might look at principles of biomedical ethics for guidance such as (1) respect for autonomy, (2) non-maleficence, (3) beneficence, and (4) justice [7]. Another source for inspiration could be the discussion about robot ethics [14].

Another issue not addressed in the prior discussion is a vision of the ideal virtual health agent, a road map or strategy with milestones to establish this vision, or indicators that progress is being made towards this ideal. These are all valid issues that can help to organize and move research forwards. Still the discussion presented in this paper, is a first step in this direction. It identifies that the current trends and environment do justify research on virtual health agents. It identifies the type of support these agents can offer. And finally, it identifies four key research challenges that can help researchers to position their work.

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